Weld Australia

Welding Safety Council

AUSTRALIAN STEEL INSTITUTE

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Weld Australia
Technical Guidance Note

# Fume Minimisation Guidelines: Welding, Cutting, Brazing & Soldering

www.weldaustralia.com.au

## Foreword

This Technical Guidance Note provides weld fume control guidelines, originally produced as part of a research project of the Cooperative Research Centre for Materials Welding and Joining in 1997. 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 what is now the national *Code of practice – Managing the risks of hazardous chemicals*, and to provide advice on the control measures which could be introduced to achieve this.

This sixth edition of the *Fume Minimisation Guidelines* includes comment from the International Institute of Welding's Commission VIII *Health, Safety & Environment* on the 2017 ruling from IARC (an agency of the World Health Organisation) in relation to welding fume being reclassified from Group 2B *Possibly Carcinogenic to Humans* to Group 1 *Carcinogenic to Humans*. It also includes comment on minimising the welder's exposure to fume to:

(a) Minimise the risk to the welder developing serious acute and long-term health issues; and,

(b) Comply with statutory workplace exposure limits.


## Acknowledgement

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## Future Revisions

This Technical Guidance Note will be revised from time to time and comments aimed at improving its value to industry will be welcome. 

## Disclaimer

The use of these Guidelines cannot guarantee full compliance with the Codes of Practice. 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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# About Weld Australia

## Who We Are

Weld Australia represents the welding profession in Australia. Our members are made up of individual welding professionals and companies of all sizes. Weld Australia members are involved in almost every facet of Australian industry and make a significant contribution to the nation's economy.

Our primary goal is to ensure that the Australian welding industry remains both locally and globally competitive, both now and into the future.

A not-for-profit, membership-based organisation, Weld Australia is dedicated to providing our members with a competitive advantage through access to industry, research, education, certification, government, and the wider industrial community.

Weld Australia is the Australian representative member of the International Institute of Welding (IIW).

## Our Vision & Mission

Our vision is to facilitate the growth of a world class welding industry in Australia.

Our mission is to create opportunities for our members and advocate welding policies and practices which protect the Australian public.

## Our Value Proposition

Weld Australia generates revenue through its commercial activities which is then reinvested back into the welding community for the benefit of members.

Weld Australia brings individual and company members together to deliver:

- A forum for the exchange of ideas and the sharing of resources
- A voice to promote the interests of the welding community and shape the market for welding services
- Specialist technical problem solving and a conduit between industry and research organisations
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Our advice can help you substantially increase the operational life of your plant and equipment and thereby reduce your maintenance and repair overheads.

## Further Information

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# Welding and the Risk of Cancer

## Introduction

In March 2017, the International Agency for Research on Cancer (IARC) reclassified welding fume from Group 2B *Possibly Carcinogenic to Humans* to Group 1 *Carcinogenic to Humans*. Their assessment was subsequently published in IARC's Monograph 118 in July 2018.

The International Institute of Welding (IIW) through their Commission VIII experts, evaluated the findings published by IARC and a position statement was published as document *IIW-VIII-2290r2-21*.

Safe Work Australia has since revised its *Workplace exposure standards for airborne contaminants* reducing the permitted weld fume exposure limit from 5mg/m$^3$ to 1mg/m$^3$, effective from 18th January 2024 in all jurisdictions throughout Australia. They have also confirmed that workplace exposure limits (WELs) will replace these workplace exposure standards (WESs) commencing 1st December 2026.

Following discussions with Commission VIII, Weld Australia advises that the guidelines published within these *Fume minimisation guidelines* and Weld Australia's Technical Note 7 be followed.

## Recommendations

Conduct a risk assessment, and in compliance with National and State WHS Regulations, identify the hazards and controls required (see Guideline 1) to ensure that the welder and people working nearby, are protected from exposure to fume from welding and welding-related processes (including thermal cutting, gouging etc.). See Appendix A for an example self-audit form to assist in identifying the hazards associated with weld fume. Control measures are discussed in Guideline 2.

The following actions, based on the hierarchy of controls, should be considered:

1. **Elimination**: Where practicable, either remove the welder from the source of the fume by mechanising or automating the welding process, or utilise a lower fume emission process or weld procedure.
2. **Substitute** a lower fume process:
   (a) Optimise the weld procedure to maximise arc stability, minimise spatter and minimise weld fume production. Arc stability is enhanced through:
      (i) use of an inverter-based welding power source; and,
      (ii) use a copper-free wire consumable for the GMAW and FCAW processes.
   (b) For the GMAW process, waveform controls are highly effective (up to 80% fume reduction possible) at reducing weld fume.
   (c) For the GMAW and FCAW processes, reduce the $CO_2$ content of the shielding gas to minimise the amount of fume generated.
3. **Engineering controls**:
   (a) At-source fume control is recommended to maximise the level of fume captured as it is generated. Fume management equipment such as hooded fume extractors (e.g. fixed, downdraft extraction table, portable) and on-gun extraction systems can remove up to 90% of the fume generated. Captured fume should be filtered and exhausted to atmosphere, preferably outside of the workshop in a non-hazardous area.
   (b) A good overall ventilation system used throughout the workshop in conjunction with fume capture systems is essential for the protection of personnel working in the vicinity of welding. Accumulation of fumes in areas away from welding or welding related process in the workshop must also be prevented to ensure that co-workers are not exposed to the fume.
4. **Administration controls**: In conformance with these *Fume minimisation guidelines*, arrange the work piece so that the welder's head is not in the plume.

   **NOTES**:
   (i) When welding in flat (PA, 1G or 1F) or horizontal-vertical (PB or 2F) position, the welder's head is likely to be positioned within the plume, and fume management methods or personal protective equipment (PPE), or a combination of both, may be required.
   (ii) All welding processes generate fume. The plume may not be visible to the welder or with some processes, the observer.

5. **PPE**: To ensure conformance with the 1mg/m$^3$ exposure limit, the use of supplementary personal protective equipment is likely to be required (e.g. powered air purifying respirators or PAPR), especially if the welder's head is in the plume.

**A combination** of fume control methods that includes the use of fume capture systems, good general ventilation, and personal protective equipment such as powered air purifying respirators (PAPR) or air-fed helmets etc that minimises the welder's exposure to weld fume is recommended. Additional controls are required if welding stainless steels, hardfacing, or through coatings.

Where doubt exists on control effectiveness, WHS regulations requires that air monitoring be undertaken (see Guideline 2). In addition, if there is a lack of engineering controls in use, it is likely that a regulator will require air monitoring (fume assessment) to be performed by a hygienist. Portable real-time air monitors are available to assist fabricators to demonstrate compliance for those working near welding operations.

Specialist advice may be sought from an Occupational Hygienist e.g. www.aioh.org.au, particularly in the preparation and implementation of a risk assessment, and the verification of the application of the controls (i.e. air monitoring).

# IIW Announcing a New Statement on Lung Cancer and Welding

*(Extract from IIW Document IIW-VIII-2290r2-21 Press release - Lung Cancer Statement)*

## IIW and Commission VIII

IIW is recognised as the largest worldwide network and centre of reference for welding and allied joining technologies. It operates as the global body for the science and application of joining technologies, providing a forum for networking and knowledge exchange among scientists, researchers, industry and educators, and disseminating leading-edge information and best practices.

Through the work of the Technical Management Board and of its Commissions, the organisation's focus encompasses the joining, cutting and surface treatment of metallic and non-metallic materials by such processes as welding, brazing, soldering, thermal cutting, thermal spraying, adhesive bonding, micro joining and additive manufacturing. IIW's work also embraces allied fields including quality assurance, non destructive testing, standardisation, inspection, health and safety, education, training, qualification, certification, design and fabrication.

Commission VIII "Health, safety and environment" is devoted at studying of phenomena occurring during welding which potentially affect health, safety and the environment, and the development of technical guidance documents for correct management of the fabrication process in industry. Commission VIII acts as the global interdisciplinary forum for exchange of knowledge in the field, supported by the expertise of its members representing different scientific disciplines including Medicine, Chemistry, Occupational Hygiene and Welding Engineering.

## The International Agency for Research on Cancer (IARC) Monograph 118, 2018

In 2018, IARC published Monograph 118, in which welding fumes were evaluated, and has reclassified them as Group 1 (carcinogenic to humans). Based on this assessment, IARC revised its evaluation from 1990, when it classified welding fumes as "possibly carcinogenic" to humans (group 2B).

This assessment was based on an epidemiological excess risk for lung cancer and was supported by publications on local and systemic inflammatory processes and a suppressive effect on the immune system caused by welding fumes.

## The IIW statement on Lung Cancer and Welding

In 2003, IIW Commission VIII issued a statement on the excess risk of lung cancer in electric arc welders. In 2011, this statement was reconfirmed (Ref. Welding in the World, 55, 12-20, 2011).

IIW recommended that to eliminate the excess risk of lung cancer, welders and their managers must ensure that:
- Exposure to welding fumes is minimised, at least to national guidelines,
- There is no further exposure of welders to asbestos, and
- Welders are encouraged and assisted not to smoke tobacco.

On the balance of evidence, the grade of risk excess has been confirmed. This assessment has been corroborated also in a meta-analysis published subsequently after the IARC monograph 118 (Honoryar et al. 2019). Again, the excess risk has been shown irrespective of the type of steel (mild steel or stainless steel) welded.

In addition to lung cancer, IARC stated that there is also an excess risk for kidney cell cancer, as shown in several epidemiological studies. The evidence was rated "limited" due to the fact that any confounding effect of solvents could not be ruled out.

IARC also classified ultraviolet radiation from arc welding as carcinogenic (sufficient evidence, group 1), based on an excess risk of uveal melanoma of welders found in some epidemiological studies.

Therefore, based on the current state of knowledge, IIW confirms its statement from 2011 and encourages all those responsible to reduce the exposure to welding fume to a minimum.

**IIW recommends that to eliminate the excess risk of lung cancer, welders and their managers must ensure that exposure to welding fume is minimized, at least to national guidelines.**

## Minimisation of Weld Fume

Aside from the use of a process that generates less fume, fume generation rates can be minimised by careful selection of welding parameters, and in particular, through the use of waveform-control technologies in conjunction with inverter-based power sources to minimise arc instability, excessive arc energy and fume generation (see Guideline 2).

Waveform-control technologies commonly utilised in both pulsed spray mode and controlled short circuiting (dip) mode for the gas metal arc welding (GMAW) process for example, permit welding at lower average amperages and voltages than would be otherwise possible whilst maintaining good control and stability of the process, including productivity and arc penetration characteristics.

In contrast, the use of the globular transfer modes using the GMAW process can be problematic and result in higher fume generation rates due to process instability[1].

Welding consumable manufacturers have also enhanced the composition of their consumables so as to reduce fume generation. Further reduction in fume emissions are possible by reducing the $CO_2$ content of shielding gas in gas-shielded welding processes (see Guideline 2).

Even when utilising these options, fume cannot be eliminated, and it is essential that the welder keep their head out of the plume at all times so as to minimise their exposure to weld fume. Note that the plume may not be visible to the welder, nor in some cases, the observer.

**Unventilated welding helmets are ineffective at preventing weld fume exposure exceeding the Workplace Exposure standards in the welder's breathing zone without the application of additional control measures.**

Where this cannot be done, control measures such as those included within Guideline 2 in this Technical Guidance Note are generally required to ensure that the welder is not exposed to fume levels in excess of the Workplace Exposure Standards (see Guideline 3).

With IARC declaring in 2017 that weld fume is carcinogenic to humans, it is now essential to minimise the welder's exposure to weld fume to minimise the risk to the welder developing serious acute and long-term health issues. Additional control measures are often required to be used in combination with extraction systems or fans.

Egeland et al in IIW Doc VIII-2344-22[1] confirmed that the provision of personal respiratory protection using ventilated helmets such as powered air purifying respirators (PAPR) are highly effective in reducing operator fume exposure particularly when used in conjunction with local exhaust ventilation. This also confirmed findings by other researchers.

[1] **Reference**: Egeland S, Wiesinger M, Sharma R, Ebert B, *Experimental study of measures preventing welders from fume exposure*, International Institute of Welding, Doc VIII-2344-22, July 2022.

## GUIDELINE 1: Hazardous Chemicals and Regulations

### 1.1 Objective

The objective of the national *Code of practice – Managing the risks of hazardous chemicals* published by Safe Work Australia, is to reduce the risk of adverse health effects for employees exposed to hazardous chemicals (formerly referred to as "hazardous substances") in their day to day workplace activities. This Code of practice, which is referenced in the national code of practice entitled *Welding processes* (also published by Safe Work Australia), was originally based on the Hazardous Substances Regulations introduced by the States and Territories of Australia in 1994.

> ***NOTE**: Whilst most states and territories now refer to hazardous chemicals in their regulations, Victoria refers to hazardous substances.*

### 1.2 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 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.

In 2012, the national model regulations and accompanying codes of practice were published by Safe Work Australia replacing the hazardous substance regulations. The code of practice entitled *Welding Processes* is an approved code of practice under section 274 of the *Work Health and Safety Act* (the WHS Act). Approved codes of practice are a practical guide to achieving the standards of health, safety and welfare required under the WHS Act and the Work Health and Safety Regulations (the WHS Regulations).

The *Foreword* of the code of practice *Welding Processes* states:

*"… A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the WHS Act, in relation to the subject matter of the code. Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks that may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist."*

These codes of practice and the model regulations have since been substantially adopted by most States and Territories of Australia.

### 1.3 What is a Hazardous Chemical?

In general, a hazardous chemical (or hazardous substance) is a substance that has the potential to adversely affect human health. Hazardous chemicals may:

(a) Be included in the *Workplace exposure standards for airborne contaminants* [Safe Work Australia (January 2024)] or on a list produced by a particular State or Territory, or,

(b) Fit the criteria for a hazardous chemical set out in Workplace Australia's *Classifying Hazardous Chemicals* — National Guide.

However, employers need only refer to Safety Data Sheets (SDS – previously referred to as Material Safety Data Sheets or MSDS) for a hazardous chemical identification. The SDS should be updated every five years and be accessible to all personnel.

> ***NOTE**: The SDS should refer to chemicals using the Global Harmonised System (GHS) of chemical hazard classification.*

### 1.4 Application to Welding and Allied Processes

Fume is a hazardous chemical according to (b) above. Certain fume components may also be on the list of hazardous chemicals in (a). Individuals should not be exposed to levels above those given in the *Workplace standards for airborne contaminants*.

## 1.5 Responsibilities

Federal and state regulations set out the responsibilities of manufacturers, importers, employers and employees. With respect to welding and allied processes the following requirements apply.

Suppliers must:

- Provide updated / current Safety Data Sheets (SDS) for substances being supplied for the first time to a particular buyer for use in the workplace.
- Label substances that are hazardous chemicals, or can be when used. Refer to Safe Work Australia's Code of Practice *Workplace labelling of hazardous chemicals*.

Persons conducting business or undertakings (i.e. employers) must:

- Develop and subsequently maintain a register of all hazardous chemicals used or produced in the workplace. This may include consumables, welding fume or any other hazardous chemical in the workplace.
- Maintain a collection of SDS as part of the register. This register must be available for reference by all employees.
- Identify the risks and hazards to health. For example, ensure that a suitable and sufficient assessment is made of the risk to health created by welding fume or other hazardous chemicals. In most circumstances use of these Fume Minimisation Guidelines will assist in the assessment.
- Eliminate all risks to health and safety, and if they cannot be eliminated, they must be eliminated as far as is reasonably practicable.
- 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 monitoring 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 chemicals 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.

Workers are required to:

- Cooperate with the employer to ensure that activities within the workplace comply with the statutory requirements.
- Report promptly to supervisors/managers any matter that might diminish the employer's ability to achieve compliance.

## 1.6 Hazard Assessments for Fume

The purpose of a workplace hazard assessment is to enable decisions to be made about potential health risks, control measures, training requirements, monitoring and health monitoring. An employer has a duty of care to ensure a suitable and sufficient assessment is made where there is potential for exposure to hazardous chemicals. 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 chemicals 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 hazard in terms of degree of exposure and potential health effects.

The possible assessment methods include the following:

(a) Simple and obvious assessments: These are straightforward assessments where, after reviewing the Safety Data Sheets (or equivalent information such as the composition of the metal or alloy to be welded) for hazardous chemicals 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.

(b) 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 chemicals primarily from SDS 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 hazardous chemicals.

(c) Generic assessments: Where a particular hazardous chemical(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 Safe Work publication "Managing risks of hazardous chemicals in the workplace, Code of practice June 2023". An example self-audit form to assist in identifying the hazards associated with weld fume is provided in Appendix A of these Guidelines. Control measures are discussed in Guideline 2.

> ***NOTE:*** *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.*

## 1.7 Actions Following Assessment

Where assessment indicates a significant health risk, decisions must be made on:

(a) Appropriate control measures: Where prevention of exposure to hazardous material is not practicable, the degree of exposure must be controlled to minimise risk to health. If required for welding and allied processes, the controls are listed in these Guidelines;

(b) Instituting periodic airborne contaminant monitoring;

(c) The need for health monitoring: Includes biological monitoring which can assist in assessing the effectiveness workplace controls;

(d) Training: Training shall be provided by the employer to all employees with potential exposure to hazardous chemicals on the health impacts and control measures and should be commensurate with the identified risk.

## 1.8 Compliance Actions

The WHS Act and Regulations permit evidence of compliance with codes of practice to be admitted in court proceedings should this be required. Code of practices are usually seen as evidence of what is known about a hazard, risk or control and the court may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

When considering what is reasonably practicable, regard is given to:

(a) The **likelihood** of the hazard or **risk** concerned **eventuating**;

(b) The **degree of harm** that would result if the hazard or risk eventuated;

(c) What the person concerned **knows**, or **ought reasonably to know**, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;

(d) The **availability and suitability** of ways to eliminate or reduce the hazard or risk;

(e) The cost of eliminating or reducing the hazard or risk.

This objective test considers the standard of behaviour expected of a reasonable person in the duty-holder's position who is:

(i) Committed to providing the highest level of protection for people against risks to their health and safety; and,

(ii) Proactive in taking measures to protect the health and safety of people.

The WHS Act and Regulations also permits the use of alternative compliance methods, such as a technical or industry standards if it provides an equivalent or higher standard of work health and safety than the code. Examples of these documents include Weld Australia's Technical Note 7 (which is specifically referenced within the *Welding Processes* code of practice and these fume minimisation guidelines).

> ***NOTE:*** *Regulatory inspectors may refer to approved codes of practice when issuing provisional improvement notices, or prohibition notices.*

## GUIDELINE 2: Fume Control Options

### 2.1 Introduction

Some form of fume control is generally required in welding, cutting, brazing and soldering operations, usually in addition to existing general workshop ventilation to ensure that the welder is not exposed to fume levels in excess of the Workplace Exposure Standards (see Guideline 3).

It is known that unventilated welding helmets are ineffective at preventing weld fume exposure exceeding the Workplace Exposure limits in the welder's breathing zone without the application of additional control measures. Egeland et al in IIW Doc VIII-2344-221 confirmed that the provision of personal respiratory protection using ventilated helmets such as powered air purifying respirators (PAPR) are highly effective in reducing operator fume exposure particularly when used in conjunction with local exhaust ventilation. This also confirmed findings by other researchers.

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.

A risk-based approach is recommended (see Guideline 1), and the choice of control must be carefully considered. Expert advice should be sought if an effective control approach is not obvious.

### 2.2 Workplace Environment

#### 2.2.1 General

In general, the more enclosed the working area, the more likely weld fume levels will exceed exposure standards. 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.

For welding operations, with the reduction in fume exposure to $1 mg/m^3$, the hierarchy of controls should be considered.

There are shielding gases, arc welding consumables and welding power sources with waveform controls available that can substantially reduce the quantity of weld fume generated (see clause 2.5 in this Guideline).

In many situations though, an engineered approach to fume control is required to manage the workforce's exposure to weld fume. Based on the hierarchy of controls, these include:

(a) Fume capture at source (e.g. fixed or portable fume extractors, on-gun extraction etc) is recommended to reduce the volume of fume in the work environment. This reduces the risk of excess fume exposure to the welder when they remove their welding helmet once the arc is extinguished, and personnel nearby.

(b) Good general ventilation is required throughout the workshop to prevent a build-up of fume.

(c) Where the welder cannot be removed from the proximity of the arc e.g. through mechanisation or automation, in many welding situations, it is likely that the welder will also require personal protective equipment to prevent excess fume exposure, particularly where the welder's head cannot be kept out of the fume plume. An air-fed helmet or powered air purifying respirator (PAPR) is recommended as these devices when maintained correctly, provide a steady supply of clean filtered air within the helmet (i.e. the welder's breathing zone). The positive air pressure within the helmet prevents the fume from entering the welder's breathing zone.

A definition of various working environments is given in the following.

#### 2.2.2 Outdoor/Natural Ventilation

When working outdoors, natural ventilation is often erroneously considered to be a satisfactory form of fume control, particularly where there is only a low rate of visible fume generation. This type of air movement is highly variable and must be considered as being unreliable. 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, in which case additional mechanically assisted ventilation measures may be required.

Whilst good outdoor airflow will limit workers' fume exposure, depending on the materials being welded, welding consumables and welding process in use, the welders may require additional protection to minimise their exposure to weld fume and comply with the exposure standards.

### 2.2.3 Open Workspace

An open workspace is defined as an area where all of the following apply:

- The average space per worker exceeds 300m$^3$ (minimum roof height 3m).
- Free cross-ventilation occurs and fume dispersion is not obstructed by the workpiece, partitions or screens.
- The workplace has good general ventilation.
- The operators are able to keep their heads out of the pollutant plume.

### 2.2.4 Enclosed Workspace

An enclosed workspace is one which does not comply with all the requirements of an open workspace, but is not a confined workspace.

### 2.2.5 Confined Workspace

A confined workspace is one which is not a normal work area, and which meets the criteria defined in WHS regulations. Additional criteria are listed in the code of practice *Confined spaces* (published by Safe Work Australia), and AS 2865 *Confined spaces*. Both documents include specific recommendations on hot work (e.g. welding) in confined spaces.

> **NOTE**: *Enclosed (or partially enclosed) workspaces where harmful airborne or flammable contaminants are present, or where the oxygen level is unsafe, or there is a risk of engulfment (e.g. from liquids or free-flowing solids where there is a risk of drowning or suffocation), are considered to be confined workspaces.*

## 2.3 Fume Generation

Particulate fume and gases are produced in the high temperature regions of the welding heat source i.e. arc, plasma, laser or flame.

The constituents of the welding fume are generated from one of three sources:

- The filler metal and flux;
- The parent plate, including its coating (e.g. zinc, chromium etc) and/or surface contaminants (e.g. greases, oils etc); or,
- 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 and from spatter particles. They are largely confined to the plume of heated gases which rises from the weld zone. This plume is usually (but not always) 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.

Due to the action of ultraviolet radiation on atmospheric oxygen, ozone is generated in a volume of the atmosphere beyond the arc zone, including near the welder's breathing 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 places the welder at some risk of exceeding the exposure standard unless controls are implemented.

Where the ozone exposure standard is likely to be exceeded, the use of either a powered air purifying respirator (PAPR) or air-fed helmet is likely to be required. Whilst respirators such as the disposable P2 respirator impregnated with activated charcoal provide protection from nuisance levels of ozone, they are quickly overloaded by the ozone generated during open arc welding processes and are ineffective.

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.

## 2.4 General Ventilation

It is essential that the general ventilation of the workplace is adequate to prevent the accumulation of hazardous chemicals or airborne contaminants in the atmosphere. This protects both operators and other workers from exposure to excessive (general fume) levels. It is also essential to remove fume directly from the source where it is generated, using a ventilated booth or local exhaust ventilation or on gun extraction where feasible. Fume extraction and ventilation 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.

## 2.5 Control Measures

Given IARC's ruling on cancer and weld fume exposure, welding fumes pose known environmental and health risks to the operator, capable of causing serious acute and long-term diseases. Control measures should not only comply with the exposure limits, they should minimise worker exposure to weld fume and other hazardous chemicals, and 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 federal and/or state regulations, the control method chosen should follow the hierarchy given in *Managing risks of hazardous chemicals in the workplace, Code of practice June 2020*, viz.

- Change to a process which produces less fume.
- Modify the process to produce less fume.

  **NOTE**: *Welding consumables, shielding gases and welding power sources with waveform controls are available that can assist to reduce the quantity of weld fume generated.*
- 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:
  - Capturing the fume locally, before it enters the breathing zone.
  - Preventing the fume entering the breathing zone by use of a cross draft.
  - Using personal protective equipment (PPE).

Many welding situations will require a combination of these methods to comply with the weld fume exposure limits, and minimise the risk of fume exposure, particularly to welders. It has been confirmed that the provision of personal respiratory protection using ventilated helmets such as powered air purifying respirators (PAPR) are highly effective in reducing and minimising operator fume exposure particularly when used in conjunction with local exhaust ventilation or on-gun extraction systems.

Likewise, it has been confirmed that co workers will be exposed to weld fume levels in excess of the 1mg/m$^3$ statutory limit if the control methods applied (including general ventilation), are inadequate.

### 2.5.1 Processes Producing Less Fume

Guidelines 4 to 17 in this Technical Guidance Note indicate the potential of each process to produce fume. The lower fume processes must be further evaluated to determine the need for further controls.

### 2.5.2 Modification of Processes for Less Fume

The modification of shielding gas by reducing oxidising components, can be used to reduce fume (see Figure 2.1).

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;
- Stabilisation of the arc; and,
- The use of waveform control technologies.

GMAW (MIG) spray mode | GMAW (MIG) pulsed mode

Shielding gas M21 ( Ar + 18% $CO_2$)

Shielding gas M20 ( Ar + 10% $CO_2$)

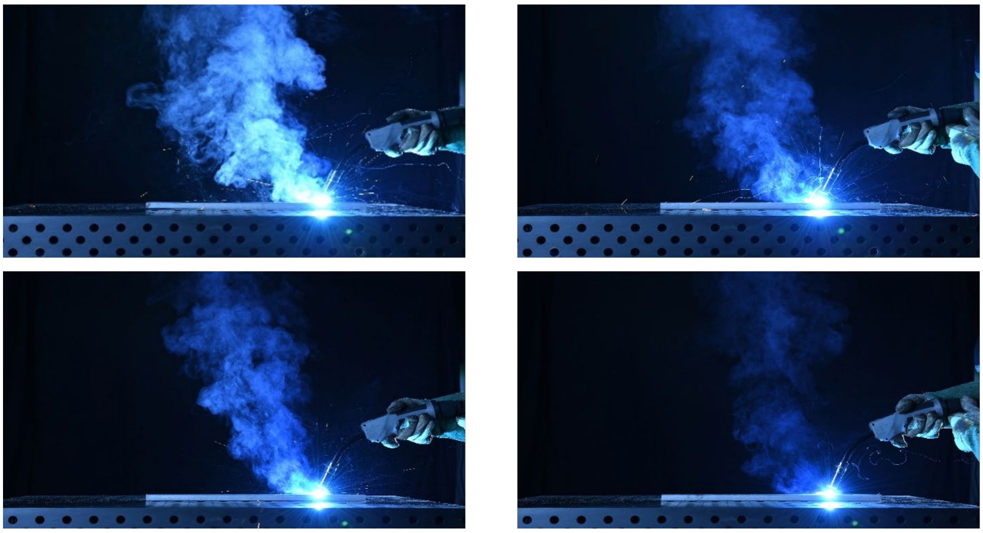


**Figure 2.1.** Effect of waveform controls and $CO_2$ content of shielding gas on weld fume generation

Maximising the stability of the welding arc is essential to minimising weld fume. Excess weld spatter is indicative of arc instability and higher levels of weld fume, and the minimisation of spatter is known to reduce weld fume. This can be achieved by optimisation of weld procedures, and ensuring that the welding torch, cables and electrical connections are well maintained. The use of modern inverter-based welding power sources, especially synergic pulse power sources, is also known to enhance arc stability compared with the use of older transformer-based power sources.

For waveform control technologies, Figure 2.1 illustrates the effectiveness of using these controls where the power source has this capability.

Waveform controls for the GMAW process includes pulsed welding and the various controlled-dip mode process variants marketed as CMT, LSC, RMD, STT etc, and their use can reduce the fume generated by up to 80%.

Furthermore, it has been established that the level of carbon dioxide in the shielding gas has a significant impact on the amount of fume produced (see Figure 2.1). Reducing the $CO_2$ content from 18% to 10% can nearly halve the level of fume generated. In some cases, reducing the $CO_2$ content of the shielding gas may not be feasible from a technical perspective as it can adversely affect weld-metal properties and classification of the welding consumable.

These fume control methods can be highly effective but should be supported by measurements of workers fume exposure.

### 2.5.3 Isolate Workers from the Hazardous Fume

Automation and mechanisation 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.

### 2.5.4 Engineering Control Methods

There are two types of control methods (see also Table 2.1):

- Breathing zone ventilation where hazardous chemicals are prevented from entering the operators breathing zone by a cross draft of air.
- Local exhaust ventilation, where some or most of the hazardous chemicals are captured at source.

#### 2.5.4.1 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 may be 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.

#### 2.5.4.2 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 well-positioned LEV can capture up to 90% emitted fume at the source and is primarily suited to locations where the welder is static e.g. welding in a booth or fixed location, or welding short weld runs. Its effectiveness is sensitive to the hood location and is therefore limited for long weld runs and/or if the welder is mobile i.e. the capture efficiency of LEV rapidly diminishes if it is too far from the fume source or incorrectly positioned. Manufacturer's guidelines should be followed to maximise fume capture.

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 led to greater efficiency of capture of fumes. Most gas shielded welding processes can tolerate air velocities around the weld zone of about 2m/s. Where adequate welds cannot be made due to disturbance of the gas shield by fume extraction, options available include:

- 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 must be followed, and be isolated from any air intake to the workplace. Ozone generated between the arc and the operators breathing zone may require additional control measures.

> **NOTE***: History shows that in-situ fixed extraction systems can often be ignored by welders if they are challenging to move with the work. Likewise, mobile hooded capture devices that require regular maintenance and cleaning also tend to fall into disuse. Self-cleaning systems are readily available which maximises their efficacy.*

#### 2.5.4.3 On-gun Extraction

On-gun fume extraction systems are available for the gas metal arc (GMAW or MIG), flux cored arc and gas tungsten arc (GTAW or TIG) processes. Whilst early on-gun extraction systems tended to bulky with capture efficiencies around 70%, newer systems are much lighter with capture rates reported to be around 90% on average when welding in the downhand positions (1G, 2F or PA, PB).

On-gun systems are available as stand-alone and multi-user systems. Some on-gun extraction systems can also be connected to existing fixed local exhaust capture systems.

As with all fume capture systems, efficacy of on-gun extraction systems is dependent on maintenance. If the equipment is self-cleaning, its efficacy can be maximised.

**Table 2.1.** Summary of extraction systems advantages and disadvantages

| Extraction Type | Advantages | Disadvantages |
|---|---|---|
| Standalone hoods<br><br>(e.g. articulated arms, or magnetic hose kits) | • Long capture distance so does not interfere with worker<br>• High flow design so will capture/extract high fume concentrations | • Has to be moved around in line with the work, and as a result may not always be used<br>• Not suitable for welders who require mobility when they weld<br>• Can interfere with the head position of the welder, or welder can put their head in the plume before it is captured<br>• Cross-breeze can impact effectiveness<br>• Generally, has a higher cost per worker |
| On-gun<br><br>(e.g. fume extraction welding torch, or on-tip soldering extraction) | • Automatically used whenever work is done, follows the welder<br>• High pressure/low flow design uses small diameter hoses, with easier design/installation requirements<br>• Generally has a lower cost per worker | • Adds weight to the tool / handpiece, and reduces flexibility<br>• Welder's technique can impact effectiveness<br>• Will not capture all fume (e.g. fume off sparks, residual fume when welding/ soldering finished)<br>• Limited effectiveness in vertical and overhead welding positions<br>• Requires careful set up to capture fume without stripping away shielding gases and regular service to maintain performance<br>• Cross draft can impact effectiveness |
| In-bench/fixed<br><br>(e.g. downdraft or slot benches, solder fume enclosure systems) | • Automatically used whenever work is done<br>• Combines work top/bench with extraction system<br>• Suitable for high velocity fume applications such as oxy-cutting | • Reduced flexibility<br>• Only suitable for work on smaller items<br>• Generally, has a higher cost per worker |
| Overhead canopy hoods | • Effective in heavy fume environments<br>• Low cost | • Does not follow the welder<br>• Positioning is critical to maximise extraction<br>• Rising fume generally travels straight through the workers breathing zone |

### 2.5.5 PPE Control Methods

Where welding fumes cannot be removed at the source of generation, additional respiratory protection will be required. Respiratory protection selected must filter both particulates and ozone e.g. a PAPR with A1 filter.

A number of factors need to be considered when determining the appropriate type and level of respiratory protection to be used. Such factors not only include the types and amounts of airborne contaminants being generated by the welding process, but also the presence of facial hair and the wearers face shape. Individuals working in and around welding activities may also require some level of respiratory protection.

Care must also be taken regarding hygiene, maintenance and correct facial fit. As such, individuals required to wear disposable or maintainable respiratory protection must:

a) Have undertaken respirator ‘fit testing’;
b) Be trained in the correct wearing and maintenance of such equipment; and,
c) When worn, be clean-shaven at all times.

Compliance with all of these requirements will ensure that the best respirator is selected that to ensures a good fit and maintains an effective seal (see AS/NZS 1715).

There are two basic types of respirators: air purifying or air supplied (see Table 2.2). Refer to AS/NZS 1715 *Selection, use and maintenance of respiratory protection devices* for more details.

**Table 2.2.** Respiratory protection equipment options

| Type | Style | Features/Applications |
|---|---|---|
| Air Purifying | Disposable | Lightweight, maintenance free. |
| | Maintainable | Suitable for more prolonged use, though with the same protection factor as disposables. Various replaceable filter cartridges available to suit particular pollutants. Uncomfortable to wear for long periods. |
| | Powered air purifying respirators (PAPR) | Battery powered units which draw air through replaceable filters. Higher protection factor. Can be worn for long periods as they have no breathing resistance, deliver a constant flow of filtered air to the wearer’s face, and do not require the wearer to be clean shaven. Incorporated in the actual welding helmet or visor. |
| Air Supplied | Air line | 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. |
| | Self-contained breathing apparatus (SCBA) | Air supplied from a backpack tank, for situations where air line systems are not possible. |

AS/NZS 1715 requires powered air purifying respirators (PAPRs) to have a required minimum protection factor (RMPF) of at least 50, meaning that the filtered air supplied into the wearer's breathing zone will be equal to or less than 1/50th of the outside fume concentration.

Some PAPRs can filter and remove up to 99.5% of fume particulates, and therefore are extremely effective at minimising the welder's exposure to fume, particularly if used in an area with good general ventilation, or in combination with local exhaust ventilation (refer to IIW Doc. VIII-2344-22). They may not be suited to environments with a high fume loading where the filters can quickly clog restricting the flow of clean air to the wearer, or in confined spaces where air-supplied systems are preferred.

A risk based approach should be taken (see Guideline 1) when considering the correct respiratory protection required for the job at hand. The type of respiratory protection required will be determined by both the frequency and duration of the welding activities being undertaken. For example, for a single welding activity of only ten minutes, a disposable P2 respirator with a thin layer of activated charcoal for nuisance levels of ozone, would be required. In contrast, for larger welding jobs, either a half face or full-face respirator with both a P2 and organic vapour cartridge, or a powered air purifying respirator (PAPR) may be required.

To determine the appropriate level of respiratory protection required, it is recommended that a workplace risk assessment be undertaken to determine the levels of fume and ozone that welders are being exposed to. Personal exposure monitoring of workers can be undertaken by an occupational hygienist, who, based on the levels of fume and ozone being generated, can identify the correct level of respiratory protection.

As noted previously, for respiratory protection to be effective (excluding PAPR) workers should be clean shaven and have undertaken respirator fit training.

> ***NOTE**: The P2/N95 mask is a particulate filter personal respiratory protection device, and is capable of filtering 0.3μm particles. They are used for protection against mechanically and thermally generated particulates or both, especially metal fume produced during welding, thermal cutting and allied processes. It conforms with the requirements of AS/NZS 1716:2012 Respiratory protective devices.*

### 2.5.6 PPE Alternatives

All alternatives to PPE 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 e.g. 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. Consideration should be given to ongoing maintenance and efficiency testing requirements.

## 2.6 Air Monitoring

Air monitoring for weld fume and other hazardous chemicals in the workplace by a suitably qualified and experienced person such as an Occupational Hygienist is required by the WHS regulations typically when:

(a) There is uncertainty as to whether the exposure standard is or may be exceeded; or,
(b) There is a need to determine whether there is a risk to health.

It is not required where it is obvious that there is very little exposure to weld fume e.g. welding in a robot cell, or where the fume is well captured at-source with good general ventilation. Low ambient levels of weld fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates. Where there is visible weld fume surrounding welders during welding, or it can be seen "hanging" in the atmosphere, or there is extensive welding occurring in the workplace (e.g. arc-on time >1 hour per 8 hour shift), air monitoring will most likely be required to validate the effectiveness of the controls in use. Alternatively, when new controls are implemented, it may be required to validate the effectiveness of these controls.

Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

When air monitoring is being conducted, rather than just monitoring for total fume, Weld Australia recommends that consideration be given to measuring fume constituents with lower exposure limits to be introduced from 1st December 2026.

By being pro-active in this regards, additional air monitoring is unlikely to be required once the lower limits become enforceable in December 2026.

## 2.7 Control Recommendations

Conduct a risk assessment, and in compliance with National and State WHS Regulations, identify the hazards and controls required (see Guideline1) to ensure that the welder and people working nearby, are protected from exposure to fume from welding and welding-related processes (including thermal cutting, gouging etc.). See Appendix A for an example self-audit form to assist in identifying the hazards associated with weld fume. The following actions, based on the hierarchy of controls, should be considered:

1. **Elimination**: Where practicable, either remove the welder from the source of the fume by mechanising or automating the welding process, or utilise a lower fume emission process or weld procedure.
2. **Substitute** a lower fume process:
   (a) Optimise the weld procedure to maximise arc stability, minimise spatter and minimise weld fume production. Arc stability is enhanced through:
      (i) use of an inverter-based welding power source; and,
      (ii) use a copper-free wire consumable for the GMAW and FCAW processes.
   (b) For the GMAW process, waveform controls are highly effective (up to 80% fume reduction possible) at reducing weld fume.
   (c) For the GMAW and FCAW processes, reduce the CO2 content of the shielding gas to minimise the amount of fume generated.
3. **Engineering controls**:
   (a) At-source fume control is recommended to maximise the level of fume captured as it is generated. Fume management equipment such as hooded fume extractors (e.g. fixed, downdraft extraction table, portable) and on-gun extraction systems can remove up to 90% of the fume generated. Captured fume should be filtered and exhausted to atmosphere, preferably outside of the workshop in a non-hazardous area.
   (b) A good overall ventilation system used throughout the workshop in conjunction with fume capture systems is essential for the protection of personnel working in the vicinity of welding. Accumulation of fumes in areas away from welding or welding related process in the workshop must also be prevented to ensure that co-workers are not exposed to the fume.
4. **Administration controls**: In conformance with these Fume minimisation guidelines, arrange the work piece so that the welder's head is not in the plume.
   **NOTES**:
   (i) When welding in flat (PA, 1G or 1F) or horizontal-vertical (PB or 2F) position, the welder's head is likely to be positioned within the plume, and fume management methods or personal protective equipment (PPE), or a combination of both, may be required.
   (ii) All welding processes generate fume. The plume may not be visible to the welder or with some processes, the observer.
5. **PPE**: To ensure conformance with the 1mg/m$^3$ weld fume exposure limit, the use of supplementary personal protective equipment is likely to be required (e.g. powered air purifying respirators or PAPR), especially if the welder's head is in the plume.

**A combination** of fume control methods that includes the use of fume capture systems, good general ventilation, and personal protective equipment such as powered air purifying respirators (PAPR) or air-fed helmets etc that minimises the welder's exposure to weld fume is recommended. Additional controls are required if welding stainless steels, hardfacing, or through coatings.

Where doubt exists on control effectiveness, WHS regulations requires that air monitoring be undertaken (see 2.6 of this Guidance Note). In addition, if there is a lack of engineering controls in use, it is likely that a regulator will require air monitoring (fume assessment) to be performed by a hygienist. Portable real-time air monitors are now available to assist fabricators to demonstrate compliance for those working near welding operations.

Specialist advice may be sought from an Occupational Hygienist e.g. www.aioh.org.au, particularly in the preparation and implementation of a risk assessment, and the verification of the application of the controls (i.e. air monitoring).

## GUIDELINE 3: Materials

### 3.1 Introduction

The potential hazards associated with base materials and consumables are detailed in safety data sheets (SDS) 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 SDS are not available, for example in the case of coatings.

### 3.2 Types of Fume

The materials found in fume consist of:

*Particulates*

- Metal and metal oxides, lead and zinc 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.

### 3.3 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 the fume.

### 3.4 Exposure Standards

The ratio of hazardous chemicals 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.

Safe Work Australia not only lists a specific exposure standard for welding fume, it also lists exposure standards for specific metals (e.g. chromium VI in stainless steel) that may also be present within the fume generated. These may have much lower exposure limits which must also be observed. In non-ventilated laboratory tests, most welding processes result in a breathing zone concentration greater than the exposure standard. Similarly for ozone and solder flux (pyrolyzed rosin as formaldehyde), the exposure standard can be exceeded in poorly or non-ventilated workshops.

Safe Work Australia has also announced that their Workplace exposure standards (see table below) will be replaced by Workplace exposure limits from 1st December 2026. Whilst some limits will remain unchanged from the exposure standards published on 18th January 2024, it is known that the exposure limits for materials such as manganese, molybdenum, nickel, cobalt, beryllium and cadmium will be significantly reduced. The limit for hexavalent chromium $Cr_{IV}$ has been removed with a requirement that it not be emitted.

> ***NOTE**: Weld Australia and the International Institute of Welding recommends that in addition to compliance with the national and state exposure standards, exposure to hazardous chemicals should be minimised at all times for all personnel.*

### 3.5 Consumables

- Consumables generally contain metals and also various elements, which assist the process and protect the weld from the atmosphere. Consumables that contain high levels of chromium such as stainless steel consumables can in some arc welding situations, form $Cr_{IV}$. When present in weld fume, because of its toxicity and carcinogenicity, additional precautions are necessary to minimise the welder's exposure to $Cr_{IV}$ and comply with its ultralow exposure limit. Hardfacing consumables can contain high levels of manganese, cobalt (irritant and sensitiser with an ultra-low exposure limit), and chromium for example. Refer to the SDS for additional information.

- 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 glycerine. 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.  As these fluxes are highly corrosive, significant risk is present from any skin/eye contact. 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 SDS, which is available from the consumable supplier.

## 3.6 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.

(a) *Metallic coatings*: galvanising (zinc), sprayed coatings (aluminium, zinc and others), electroplating (chromium with copper and nickel underlays, cadmium, zinc or tin) are common.

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

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

## 3.7 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.

## 3.8 Major Classes of Metals

*Mild steels usually contain:*

- Iron, carbon, manganese, silicon, aluminium.
- Occasionally nickel, chromium, molybdenum, niobium, vanadium, boron.

*High strength steels usually contain:*

- Iron, carbon, manganese, silicon, chromium, molybdenum, nickel
- Occasionally niobium, vanadium, boron.

*Stainless steels usually contain:*

- Iron, chromium and nickel.
- Occasionally molybdenum, manganese, titanium and other elements.

*Hardfacing steels may contain:*

- Iron, chromium, manganese and cobalt.
- Occasionally tungsten, molybdenum, niobium, vanadium, titanium, and other elements.

*Aluminium and its alloys usually contain:*

- Aluminium, silicon, iron, magnesium, manganese, chromium, zinc, titanium.
- Occasionally copper, gallium, vanadium, titanium, zinc and/or boron in wrought alloys.
- Occasionally tin and/or lead in cast alloys.

*Copper, bronze and brass alloys usually 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 below should be contacted for further information if required:

- Australian Aluminium Council
- Australian Stainless Steel Development Association
- Copper Development Association of Australia
- Nickel Development Institute

**Table 3.1.** List of Atmospheric Contaminants, Safe Work Australia's Workplace Exposure Standards, and the Medical Effects

| Chemical | Type | | TWA | | STEL mg/m³ | Carcinogen Category | Medical Effects |
|---|---|---|---|---|---|---|---|
| | | | ppm | mg/m³ | | | |
| Aluminium | Fume | Al | | 5 | | | Respiratory irritant |
| Barium | Sol. compounds | Ba | | 0.5 | | | Respiratory tract and skin irritant, benign pneumoconiosis with heavy exposure |
| Beryllium | & compounds | Be | | 0.002 | | 1A | Very toxic, damages respiratory tract, quick acting, carcinogenic |
| Boron oxide | | | | 10 | | | Eye and respiratory irritant |
| Cadmium | & compounds | Cd | | 0.01 | | 1A | Very toxic, lung and kidney damage. Quick acting, may be fatal, carcinogenic |
| Calcium Oxide | Fume | CaO | | 2 | | | Irritant of eyes, mucous membranes and skin |
| Chromium | Compounds | Cr (II)&(III)<br>Cr (VI) | | 0.5<br>0.05 | | 1A | Toxic, damages respiratory tract, corrosive to skin<br>Carcinogenic |
| Cobalt | Metal dust & fume | Co | | 0.05 | | 2 | Irritant, fibrosis of the lung, sensitizer, suspect carcinogenic |
| Copper | Fume | Cu | | 0.2 | | | Metal fume fever |
| Fluorides | | F | | 2.5 | | | Irritant of eyes, mucous membranes, skin and lungs |
| Iron Oxide | Fume | Fe2O3 | | 5 | | | Siderosis (no long term effects) |
| Lead | Fume | Pb | | 0.05 | | | Affects the nervous system, digestive system, and mental capacity |
| Magnesium Oxide | Fume | MgO | | 10 | | | Irritant, metal fume fever |
| Manganese | Fume | Mn | | 1 | 3 | | Toxic, tiredness, pneumonia, psychotic behaviour |
| Molybdenum | Sol. Compounds<br>Insol. Compounds | Mo | | 5<br>10 | | | Irritant |
| Nickel | Metal<br>Sol. compounds | Ni | | 1<br>0.1 | | 1A | Metal fume fever, carcinogenic<br>Respiratory and/or skin irritant |
| Nitrogen Dioxide | | $NO_2$ | 3 | 5.6 | 9.4 | | Irritant |
| Ozone | | $O_3$ | 0.1 Peak limitation | 0.2 Peak limitation | | | Irritant of the respiratory tract and lungs. |
| Phosphoric acid | | $H_3PO_4$ | | 1 | 3 | | Mild irritant of the eyes, upper respiratory tract and skin. |
| Potassium Hydroxide | | KOH | | 2 Peak limitation | | | Severe irritant of eyes, mucous membrane, and skin |

| Substance | Type | | TWA ppm | TWA mg/m³ | STEL mg/m³ | Carcinogen Category | Medical Effects |
|---|---|---|---|---|---|---|---|
| Pyrolysed rosin (colophony) | Fume | | | 0.1 | | 2 | Respiratory and/or skin irritant |
| Selenium | Compounds | Se | | 0.1 | | | Irritant of eyes, mucous membranes and skin. Central nervous system effects with chronic exposure. |
| Silica (fumed) | Respirable dust | $SiO_2$ | | 2 | | | Fever, similar to metal fume fever |
| Sodium Hydroxide | | NaOH | | 2 Peak limitation | | | Severe irritant of eyes, mucous membrane, and skin |
| Tin | Oxide & inorganic compounds | Sn | | 2 | | | Stannosis, a rare benign pneumoconiosis |
| Titanium Dioxide | | $TiO_2$ | | 10 | | | Mild respiratory irritant |
| Vanadium Pentoxide | Respirable dust & fume | $V_2O_5$ | | 0.05 | | | May cause tremor and depression of central nervous system |
| Zinc Oxide | Fume | ZnO | | 5 | 10 | | Metal fume fever, bronchitis |
| Weld Fume | | | | 1 | | See notes 3 & 5 | Carcinogen, see notes 3 & 5 |

***NOTES:***

1. *Safe Work Australia's Workplace exposure standards as of 18th January 2024. Table includes IARC carcinogen classifications where relevant. Copper and aluminium fume levels remain under review.*
2. *The Australian workplace exposure limits are similar in many instances to those published in the United Kingdom and Europe. In some instances, UK authorities differentiate between Inhalable fractions and Respirable (i.e. penetrate deep into the lungs) fractions with the latter having similar TLV's to those published in Australia. Notable exceptions are outlined in the table opposite.*
3. ***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.*
4. ***Other health effects*** *- Certain alloying elements may result in further health complications.*
5. ***Risk of Cancer*** *- See "Welding and the risk of cancer" section published in these Guidance Notes.*

| Chemical | | TWA (mg/m³) |
|---|---|---|
| Aluminium | Inhalable<br>Respirable | 10<br>4 |
| Calcium Oxide | Inhalable<br>Respirable | 2<br>1 |
| Magnesium Oxide | Inhalable<br>Respirable | 10<br>4 |
| Manganese | Inhalable<br>Respirable | 0.2<br>0.05 |
| Nitrogen Dioxide | | 0.96 |
| Pyrolyzed rosin (colophony) | | 0.05 |
| Selenium | | 0.1 |
| Titanium Dioxide | Inhalable<br>Respirable | 10<br>4 |

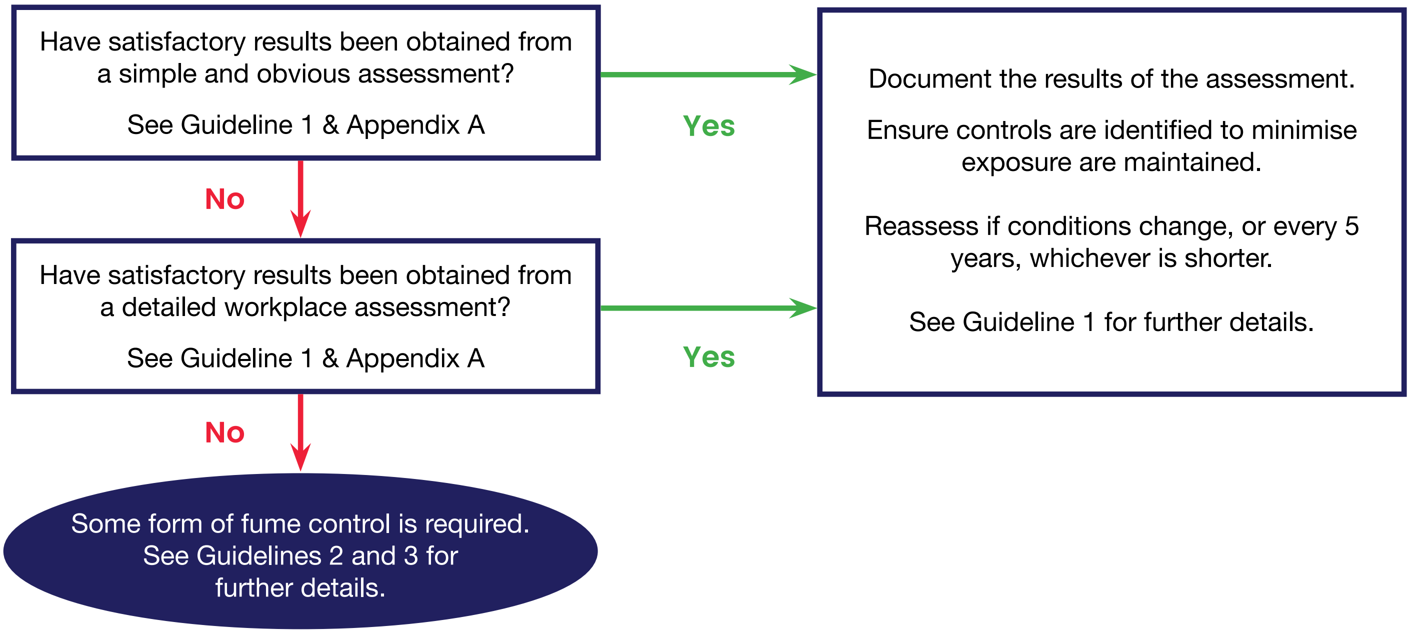
*Source: EH40/2005 Workplace exposure limits 2020 published by the Health & Safety Executive of the United Kingdom*

## 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 chemicals.

It should be noted that in tests conducted under still air conditions, breathing zone fume from MMAW usually exceeds the recommended levels (see Figure 4.1). For the welding of carbon and carbon-manganese steels, the use of fume capture devices may be necessary to protect the welder. Additional protection may not be required provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 4.2). Accumulation of fumes in the workshop must be prevented by general ventilation. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

When the welder's head is in the plume, or when welding materials such as stainless steels, the use of PPE such as a powered air purifying respirator (PAPR) may also be required.




### Steps to Reduce the Effect of Fumes and Gases

#### 1. Process Alternatives

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.

#### 2. Process Modifications

Use fume capture devices and arrange welding to reduce welder's exposure as shown in Figure 4.3. This also reduces fatigue and back problems.

#### 3. Exposure Minimisation

To minimise the welder's exposure to fume, the use of PPE will also be required, especially if the welder's head cannot be kept out of the plume. The use of PAPRs is particularly effective.

Additional protection and air monitoring will be required when welding materials with consumables that give rise to hazardous fume constituents and their associated low exposure limits e.g. stainless steels due to $Cr_{IV}$.

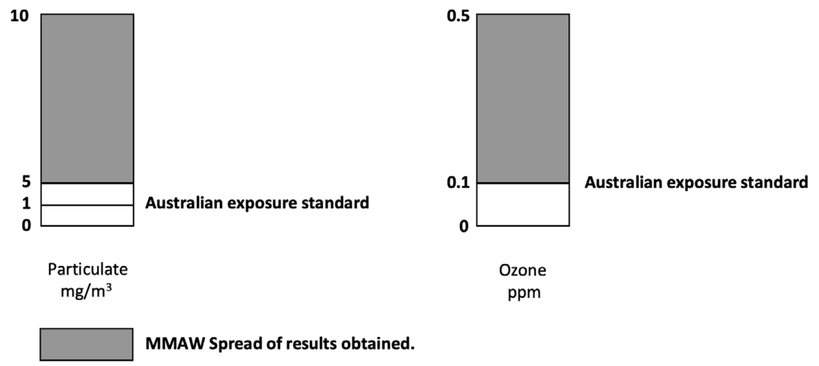



**Figure 4.1.** MMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

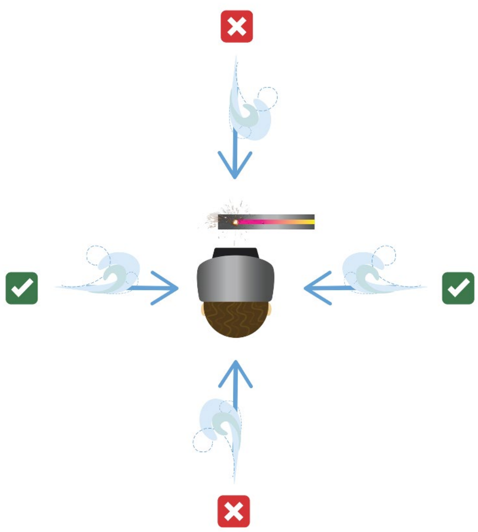


**Figure 4.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

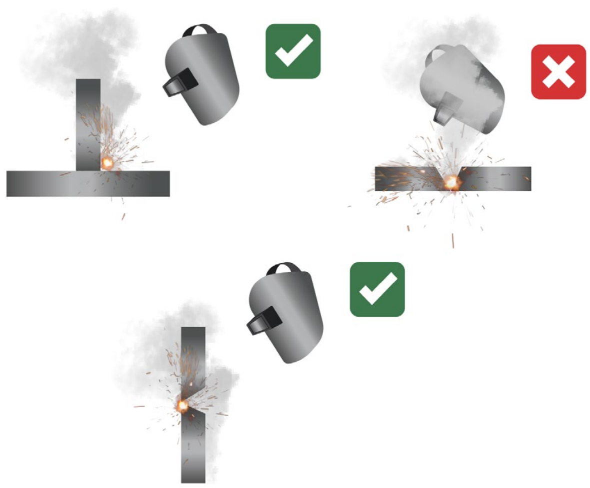


**Figure 4.3.** The welder's head should not enter the visible fume plume.

## 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 chemicals.

It should be noted that in tests conducted under still air conditions, breathing zone fume from GMAW (or *MIG*) processes usually exceeds the recommended levels (see Figure 5.1). The use of fume capture devices in combination with good general ventilation is recommended to protect the welder and co-workers. Additional protection may not be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 5.2). Accumulation of fumes in the workshop must be prevented by general ventilation. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

When the welder's head is in the plume, or when welding materials such as stainless steels, the use of PPE such as a powered air purifying respirator (PAPR) may also be required.

Have satisfactory results been obtained from a simple and obvious assessment?

See Guideline 1 & Appendix A

Yes

No

Have satisfactory results been obtained from a detailed workplace assessment?

See Guideline 1 & Appendix A

Yes

Document the results of the assessment.

Ensure controls are identified to minimise exposure are maintained.

Reassess if conditions change, or every 5 years, whichever is shorter.

See Guideline 1 for further details.

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

#### 1. Process Alternatives

Consider using cold or hot wire GTAW or SAW for flat position seams in heavier material. Higher capital costs are often offset by higher productivity.

#### 2. Process Modifications

(a) Mechanise the process using simple tractors, turntables or cobots/robots.

(b) Use waveform controlled processes (e.g. controlled dip, pulsed mode etc) to minimise weld fume.

(c) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone, and, for steel using a shielding gas with a lower $CO_2$ content.

#### 3. Exposure Minimisation

Use fume capture devices and arrange welding to reduce welder's exposure as shown in Figure 5.3. This also reduces fatigue and back problems.

To minimise the welder's exposure to fume, the use of PPE will also be required, especially if the welder's head cannot be kept out of the plume. The use of PAPRs is particularly effective.

Additional protection and air monitoring will be required when welding materials with consumables that give rise to hazardous fume constituents and their associated low exposure limits e.g. stainless steels due to $Cr_{IV}$.

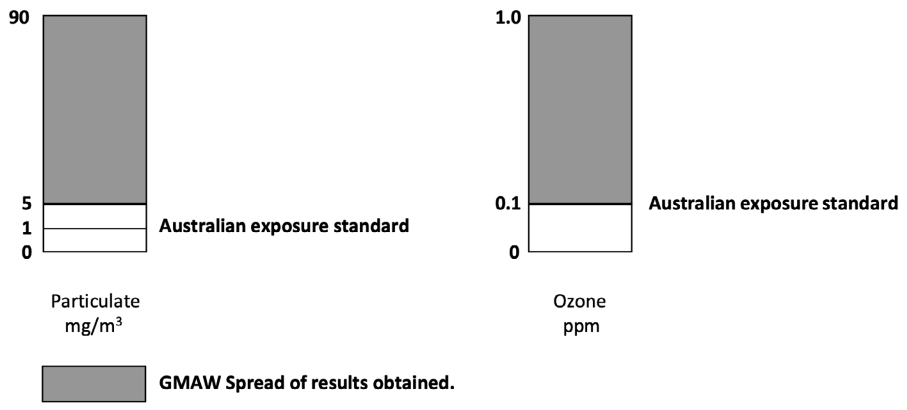



**Figure 5.1.** GMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

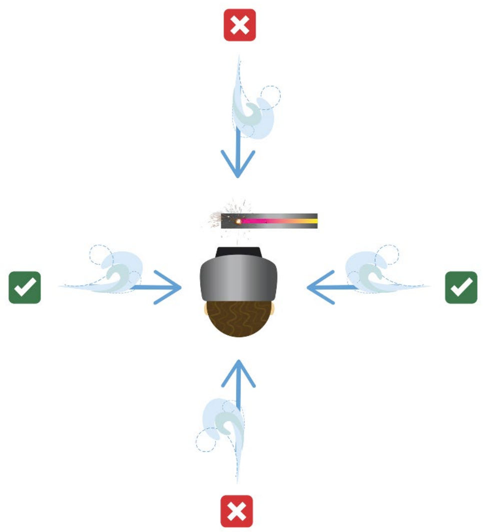


**Figure 5.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

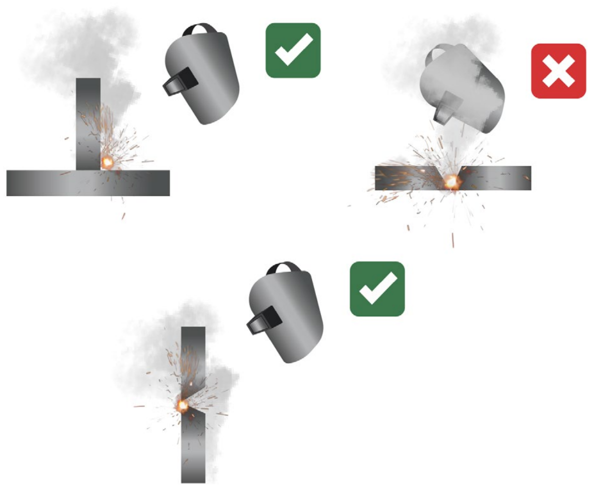


**Figure 5.3.** The welder's head should not enter the visible fume plume.

## 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 chemicals.

It should be noted that in tests conducted under still air conditions, breathing zone fume from GTAW (or TIG) usually exceeds the recommended levels (see Figure 6.1). 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 6.2). Accumulation of fumes in the workshop must be prevented by general ventilation. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

Where clean air movement across the welder's breathing zone cannot be guaranteed, the use of fume capture devices may be required.

When the welder's head is in the plume, or when welding materials such as stainless steels, the use of PPE such as a powered air purifying respirator (PAPR) may also be required.

Have satisfactory results been obtained from a simple and obvious assessment?

See Guideline 1 & Appendix A

Yes

No

Have satisfactory results been obtained from a detailed workplace assessment?

See Guideline 1 & Appendix A

Yes

No

Document the results of the assessment.

Ensure controls are identified to minimise exposure are maintained.

Reassess if conditions change, or every 5 years, whichever is shorter.

See Guideline 1 for further details.

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

### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

Consider using cold or hot wire GTAW which are capable of significantly reducing welding arc times. Laser and electron beam welding may be viable but higher capital costs must be offset by higher productivity.

#### 2. Process Modifications

(a) Use fume capture devices and arrange welding to reduce welder's exposure as shown in Figure 6.3. This also reduces fatigue and back problems.

(b) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone in aluminium and stainless steel welding and Argon/Hydrogen may be used to reduce ozone levels with austenitic stainless steel).

(c) Mechanise or automate the process.

#### 3. Exposure Minimisation

To minimise the welder's exposure to fume, the use of PPE may also be required, especially if the welder's head cannot be kept out of the plume. The use of PAPRs is particularly effective.

Additional protection and air monitoring will be required when welding materials with consumables that give rise to hazardous fume constituents and their associated low exposure limits e.g. stainless steels due to $Cr_{IV}$.

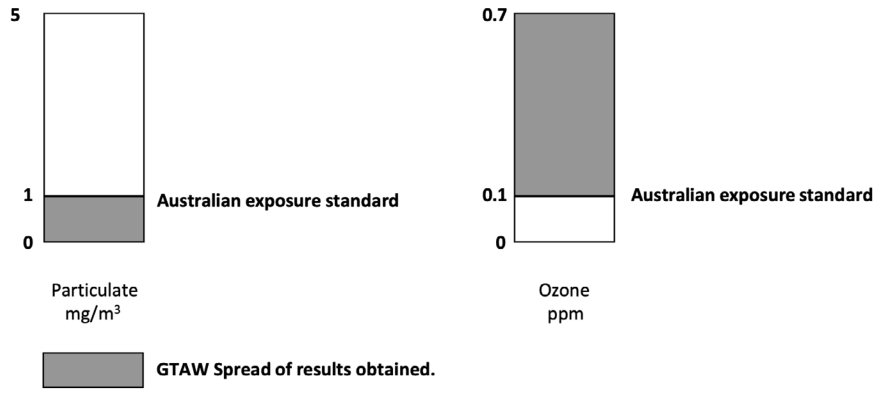



**Figure 6.1.** GTAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

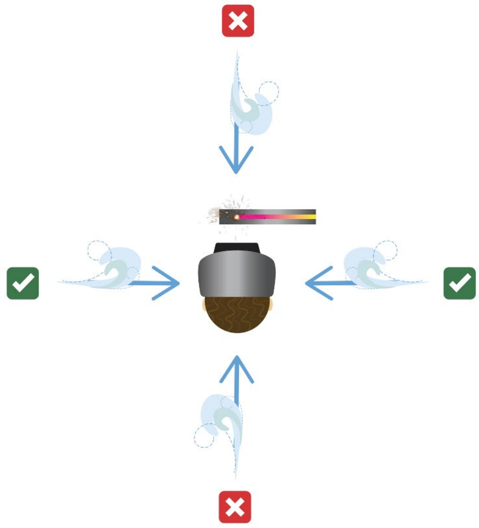


**Figure 6.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

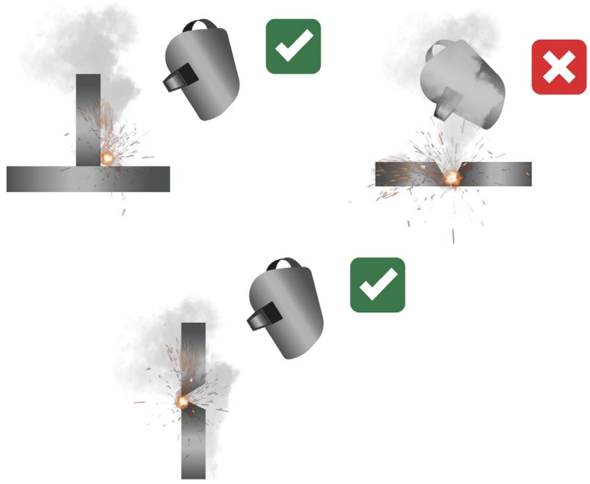


**Figure 6.3.** The welder's head should not enter the visible fume plume.

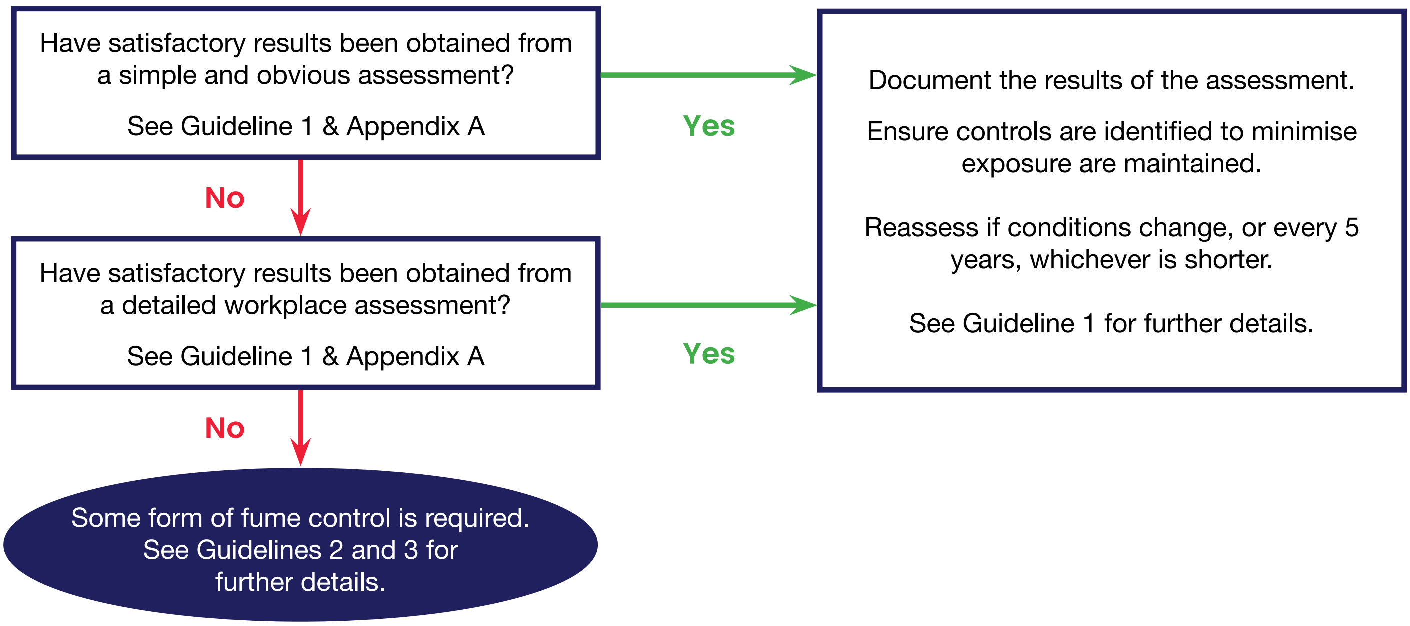
## GUIDELINE 7: Flux Cored Arc Welding (FCAW)

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

It should be noted that in tests conducted under still air conditions, breathing zone fume from FCAW usually exceeds the recommended levels (see Figure 7.1). Similarly, due to the high levels of fume generated, there is a greater likelihood of co workers exposure exceeding the relevant exposure standards. The use of fume capture devices may be necessary to protect both the welder and co-workers.

Where clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 7.2), a measure of additional protection will be provided to the welder. Good general ventilation is also required to prevent the accumulation of fumes in the workshop and to provide protection to co-workers. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

When the welder's head is in the plume, or when welding materials such as stainless steels, the use of PPE such as a powered air purifying respirator (PAPR) is generally required. Particular care should be taken with self shielded hardfacing wires which are normally expected to be used outdoors.




### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

Consider using SAW or GMAW for flat position seams in heavier material and for hardfacing. Alternatively, consider waveform controlled GMAW. Higher capital costs are often offset by higher productivity.

#### 2. Process Modifications

(a) Mechanise the process using simple tractors, turntables or cobots/robots.

(b) Consider using alternative shielding gases e.g. a shielding gas with a lower $CO_2$ content.

#### 3. Exposure Minimisation

Use fume capture devices and arrange welding to reduce welder's exposure as shown in Figure 7.3. This also reduces fatigue and back problems. To minimise the welder's exposure to fume, the use of PPE will also be required, especially if the welder's head cannot be kept out of the plume. The use of PAPRs is particularly effective.

Additional protection and air monitoring will be required when welding materials with consumables that give rise to hazardous fume constituents and their associated low exposure limits e.g. hardfacing consumables, stainless steels due to $Cr_{IV}$ etc.

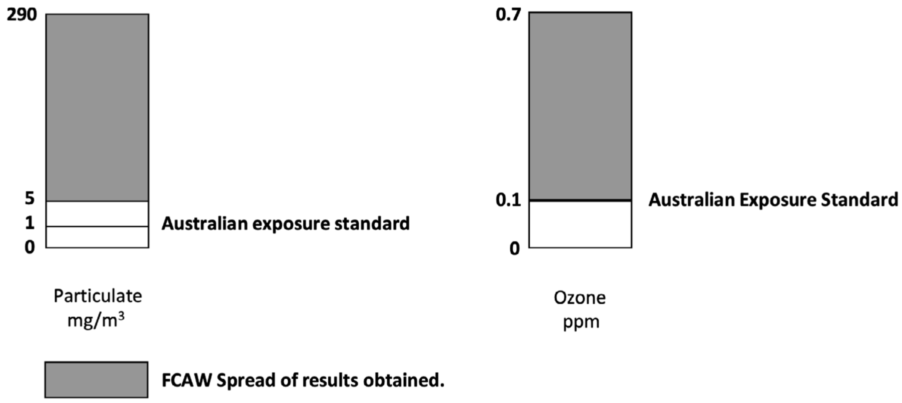



**Figure 7.1.** FCAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

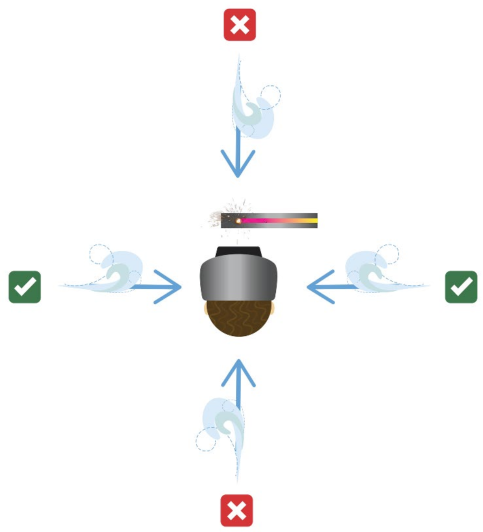


**Figure 7.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

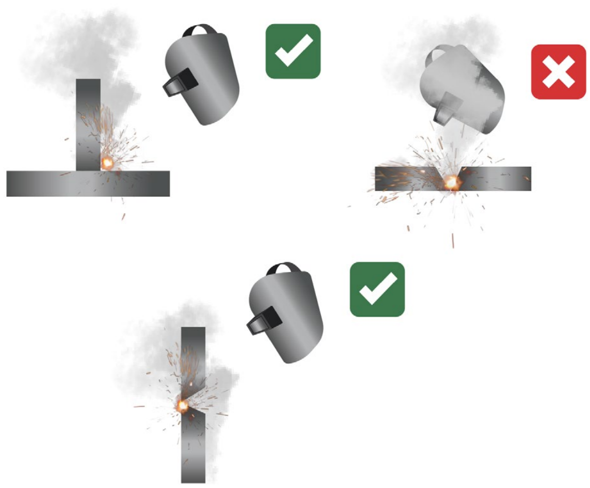


**Figure 7.3.** The welder's head should not enter the visible fume plume.

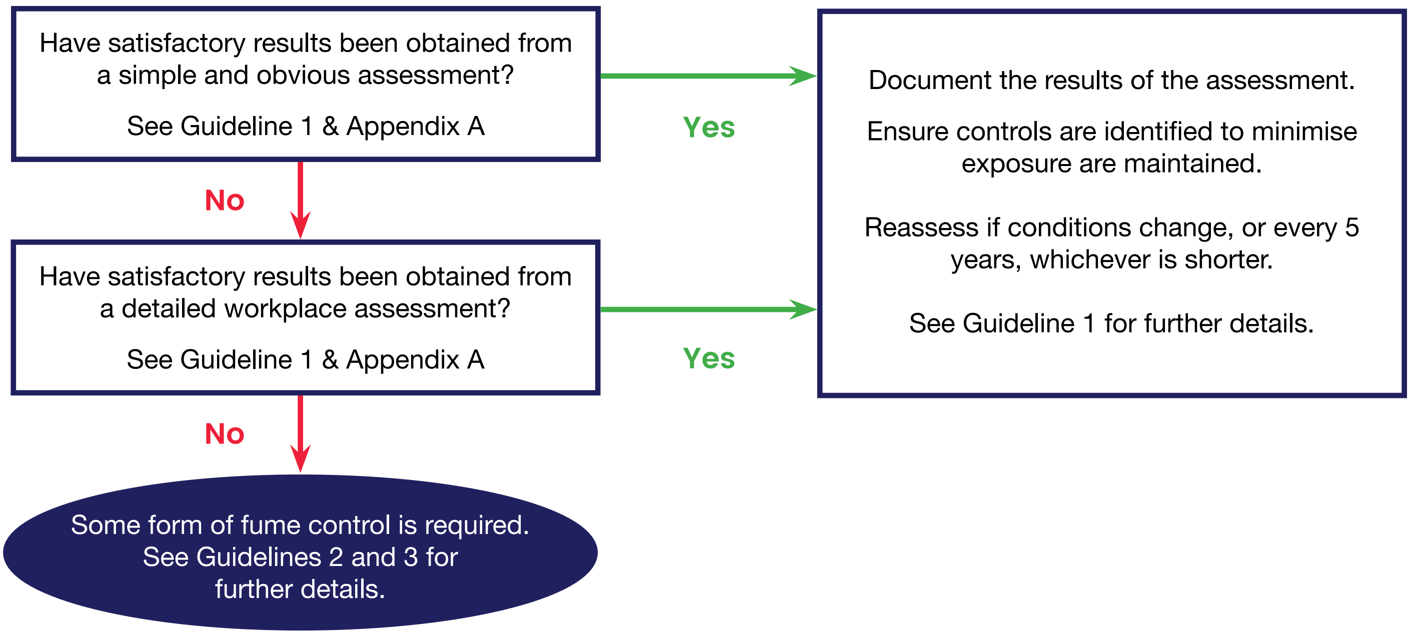
## GUIDELINE 8: Hardfacing

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

It should be noted that in tests conducted under still air conditions, fume from FCAW hardfacing operations usually exceeds the recommended levels (see Figure 8.1). Similarly, due to the high levels of fume generated, there is a greater likelihood of co workers exposure exceeding the relevant exposure standards. The use of fume capture devices may be necessary to protect both the welder and co-workers.

Where clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 8.2), a measure of additional protect will be provided to the welder. Good general ventilation is also required to prevent the accumulation of fumes in the workshop and to provide protection to co-workers. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

Hardfacing consumables are often highly alloyed, and fumes may contain significant levels of manganese and chromium. When the welder's head is in the plume, the use of PPE such as a powered air purifying respirator (PAPR) is generally required. See Guideline 3 for relevant exposure standards and refer to the consumable's SDS for additional information.




### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

Consider using wearplate or alternate processes such as submerged arc surfacing.

Gas Metal Arc and Gas Tungsten Arc surfacing both produce less fume than other "open arc" processes.

#### 2. Process Modifications

Mechanise the process using simple tractors, turntables or robots.

#### 3. Exposure Minimisation

Hard facing consumables give rise to hazardous fume constituents and requirements for their associated low exposure limits. To minimise the welder's exposure to fume, the use of PPE will also be required, especially if the welder's head cannot be kept out of the plume. The use of PAPRs is particularly effective for the protection welders. Due to the hazardous nature of fume from hardfacing, air monitoring may be required to validate the effectiveness of fume controls.

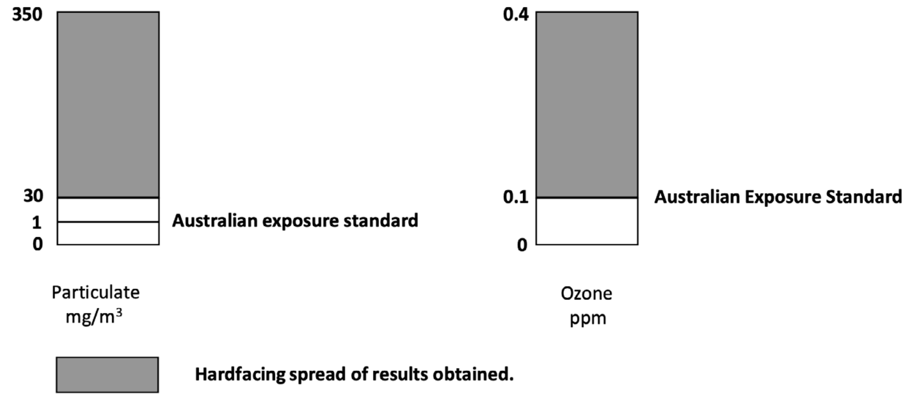



**Figure 8.1.** Hardfacing fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

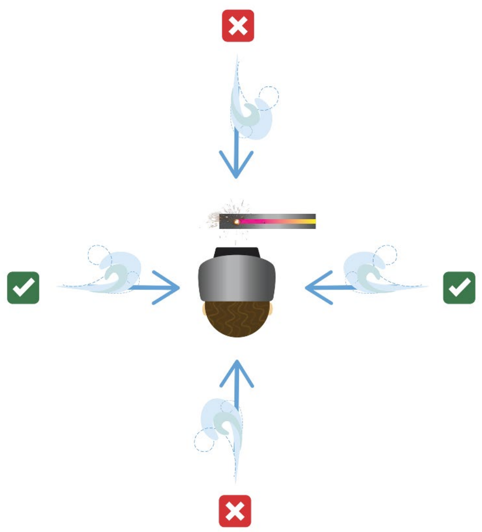


**Figure 8.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

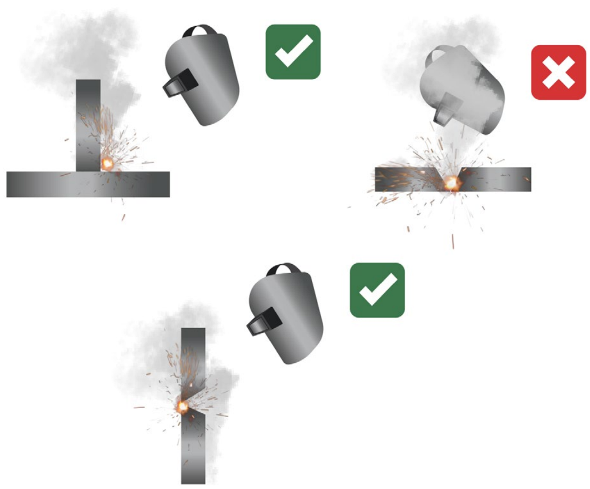


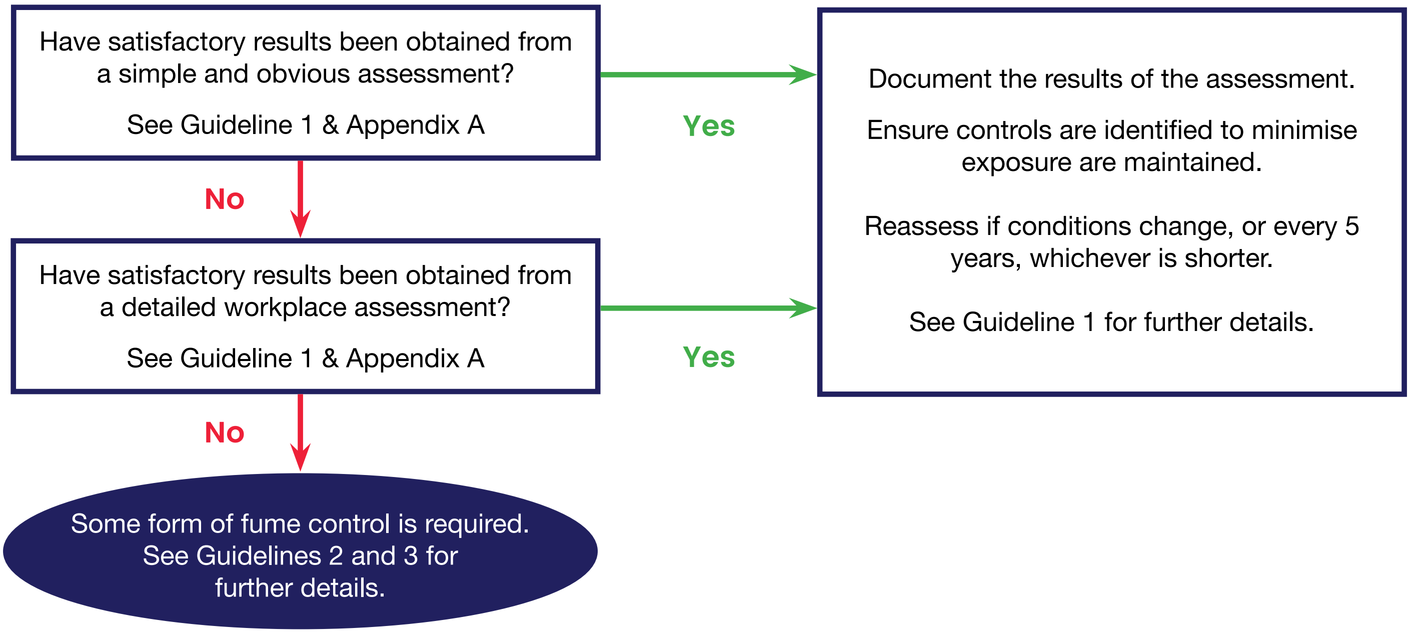
**Figure 8.3.** The welder's head should not enter the visible fume plume.

## 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 chemicals.

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 9.1). Where the process is mechanised, good general ventilation is usually sufficient to protect the operator and co-workers. For plasma cutting operations, provided that there is good general ventilation and there is clean air movement is greater than 0.5 m/s across the operators breathing zone (see Figure 9.2), additional protection measures may not be required. Accumulation of fumes in the workshop must be prevented by general ventilation. Oxides of nitrogen may be a problem with plasma cutting processes using compressed air or nitrogen additions to the shielding gas.

Where the risk assessment identifies the need for additional controls e.g. when the welder's head is in the plume, the use of supplementary PPE such as a powered air purifying respirator (PAPR) should be considered. Air monitoring may be required.




### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

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

#### 2. Process Modifications

(a) Plasma cutting is easily mechanised and readily automated. Cutting underwater or over a water table can further reduce fume exposure.

(b) Arrange cutting to reduce operator exposure as shown in Figure 9.3. This also reduces fatigue and back problems.

***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.*

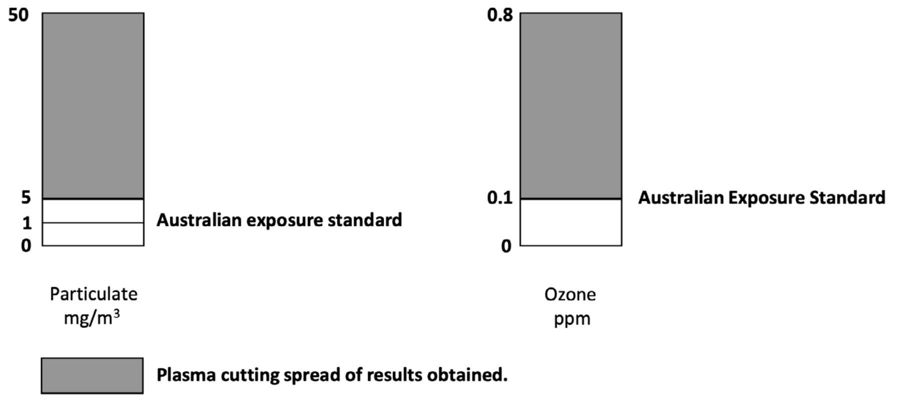



**Figure 9.1.** Plasma cutting fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

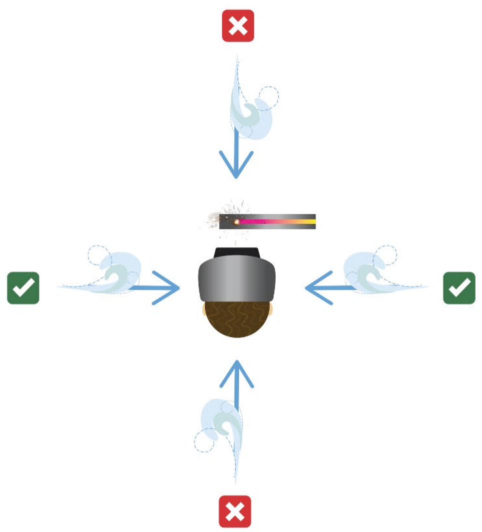


**Figure 9.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

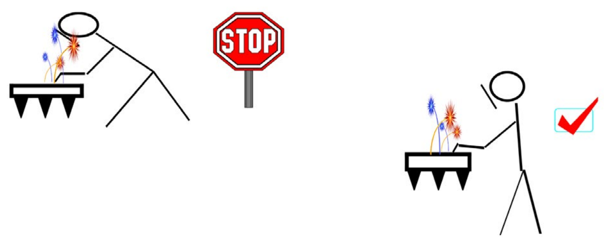


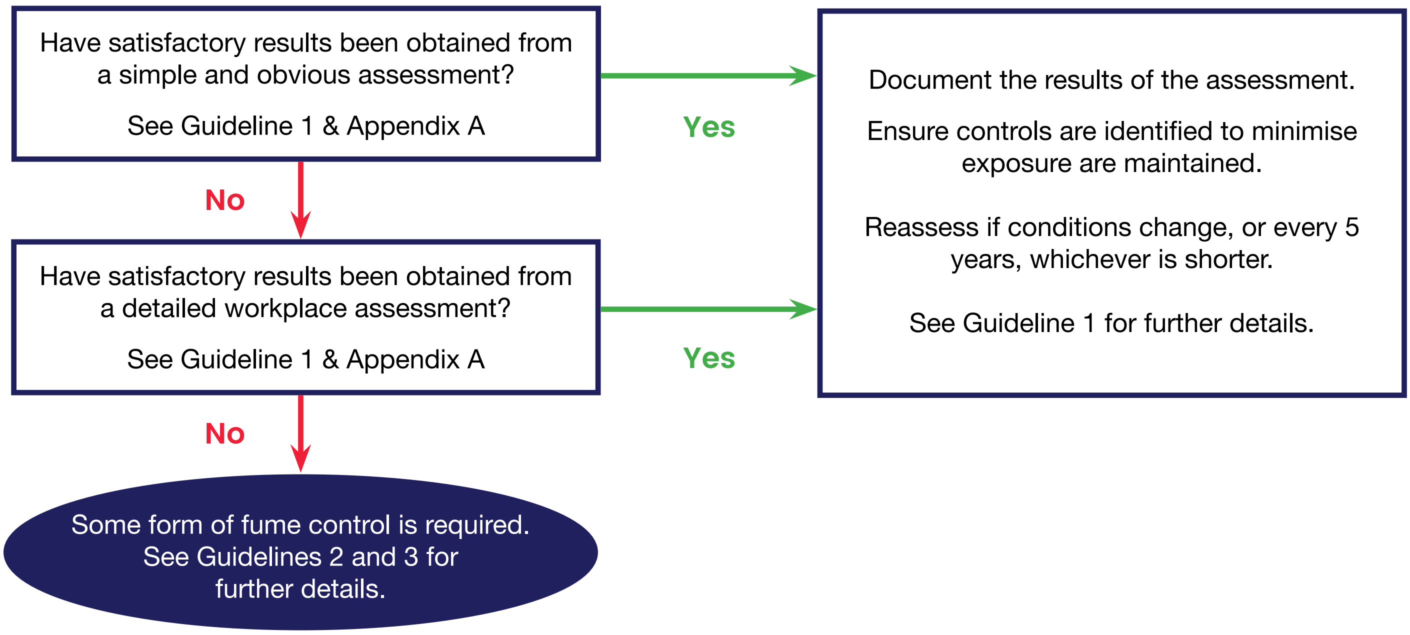

**Figure 9.3.** The operator's head should not enter the visible fume plume.

## 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 chemicals.

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 10.1). Where the process is mechanised, good general ventilation is usually sufficient to protect the operator and co-workers. For manual flame cutting operations, provided that there is good general ventilation and there is clean air movement is greater than 0.5 m/s across the operators breathing zone (see Figure 10.2), additional protection measures may not be required. Accumulation of fumes in the workshop must be prevented by general ventilation.

Where the risk assessment identifies the need for additional controls e.g. when the operator's head is in the plume, as the use of fume capture devices during flame cutting is often not practical and can present a fire hazard, the use of supplementary PPE such as a powered air purifying respirator (PAPR) should be considered. Air monitoring may be required to validate the effectiveness of controls in place.




### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

Consider guillotining, laser or plasma cutting, mechanical cutting or water jet cutting.

#### 2. Process Modifications

(a) Oxy-fuel cutting is easily mechanised and readily automated. Guide wheels are available for manual cutting torches.

(b) Arrange cutting to reduce operator exposure as shown in Figure 10.3. This also reduces fatigue and back problems.

(c) Use the correct cutting tip. This minimises the width of the kerf and the volume of fume produced.

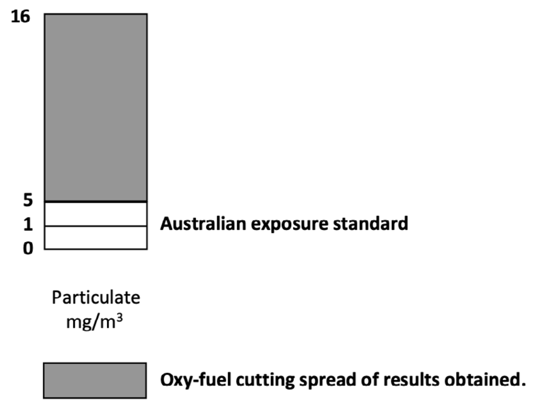



**Figure 10.1.** Oxy-fuel cutting fume production at the breathing zone under still air conditions com pared to the regulations (not to scale).

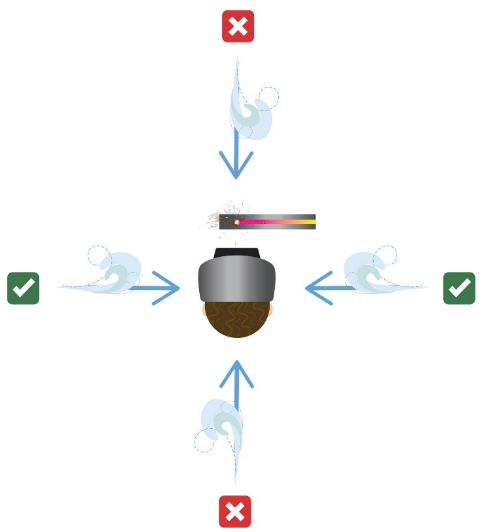


**Figure 10.2.** Preferred and non-preferred direction of cross draft for breathing zone ventilation.

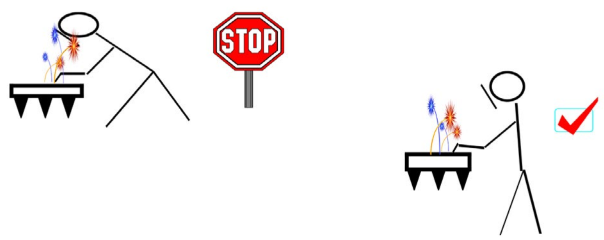



**Figure 10.3.** The operator's head should not enter the visible fume plume.

## GUIDELINE 11: Low Fume Level Processes

### Low Fume Processes

(a) Submerged arc welding (SAW)
(b) Electroslag welding
(c) Water jet cutting
(d) Resistance welding e.g. spot, seam and projection welding
(e) High frequency induction welding
(f) Friction welding
(g) Ultrasonic welding
(h) Semi-automatic stud welding

### Materials

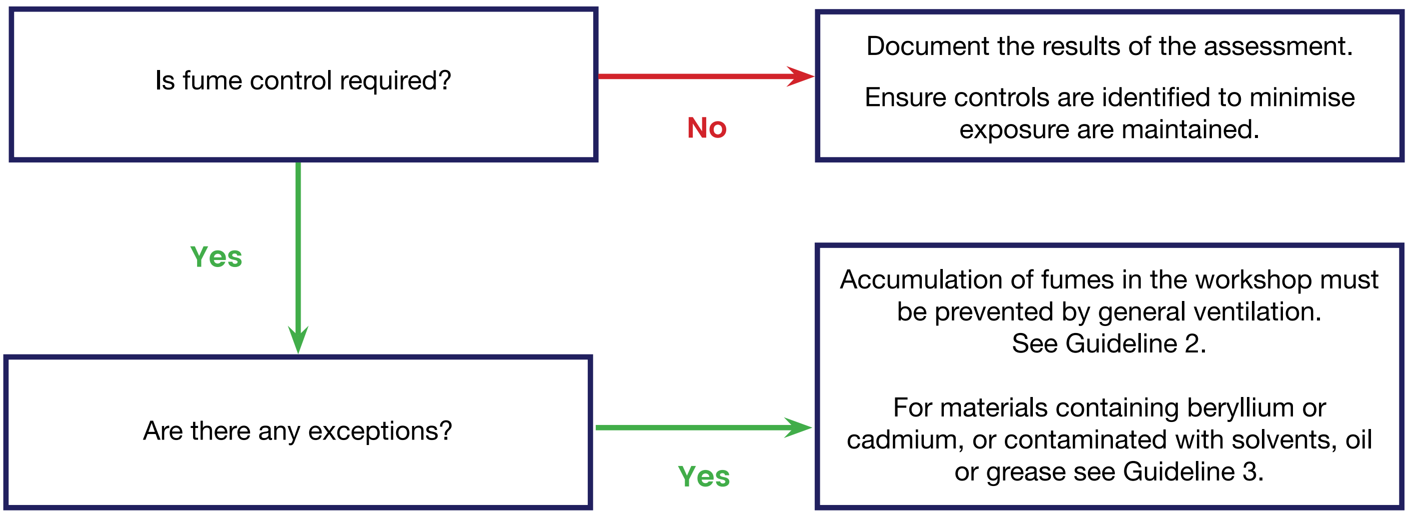
Suitable for all materials known not to contain beryllium or cadmium as an alloying element or as a coating, and not contaminated with solvents, oil or grease. (see Guideline 3).

### Explanation

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

(a) 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
(b) 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.



## 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 the Australian and New Zealand standard AS/NZS 3500.1 *Plumbing and drainage—Water services*. Soft solder must be "lead free" (i.e. containing not more than 0.1% lead) and silver brazing alloys must be "cadmium free" (i.e. containing not more than 0.05% cadmium and a minimum of 1.8% silver).

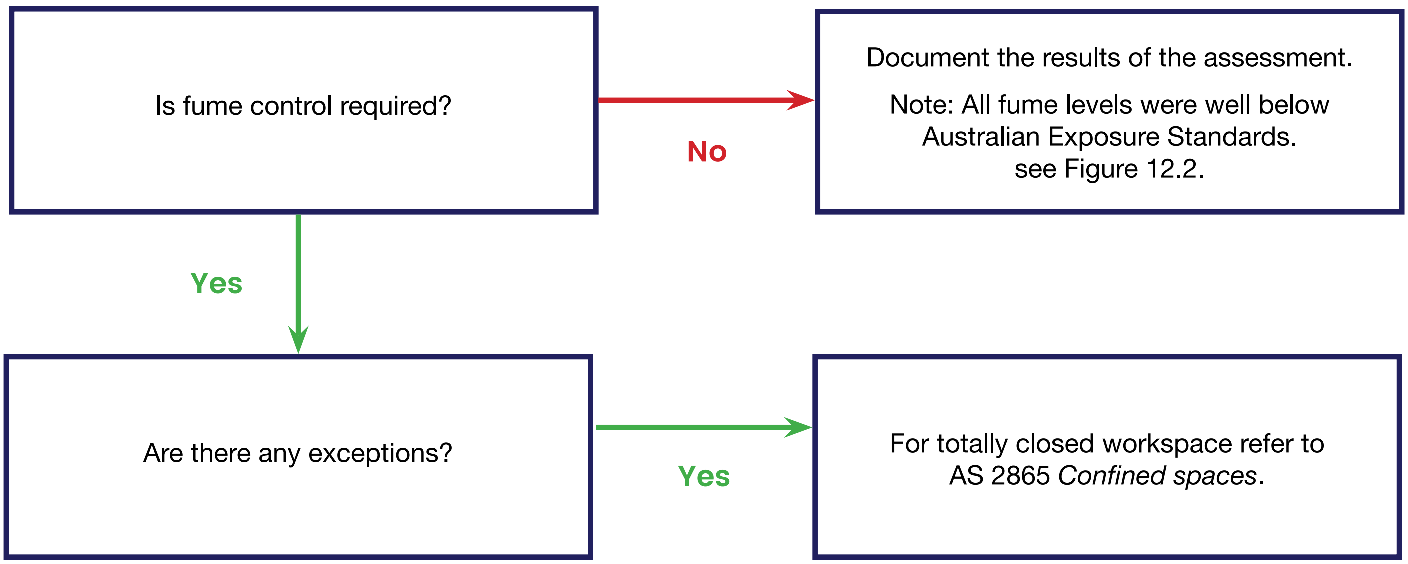
### Overview

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 e.g. DN15 to DN100. 2% silver and 15% silver brazing alloys and *Aquasafe* soft solder (99% tin) were used and where fluxes were required *Eziweld, Laco, Yorkshire and Tenacity* brands were employed. Further tests were performed by CSIRO in conjunction with CRC, WTIA and CDAA using heavy wall large diameter pipe to represent the worst-case scenario. Tube sizes were: AS 1432 Copper: DN150 Type B (152.40x2.03mm); AS 3795 Brass DN100 type D (101.60 x 1.22mm). 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 12.1).

> ***NOTE***: *AS 3795 has been withdrawn.*

### Results



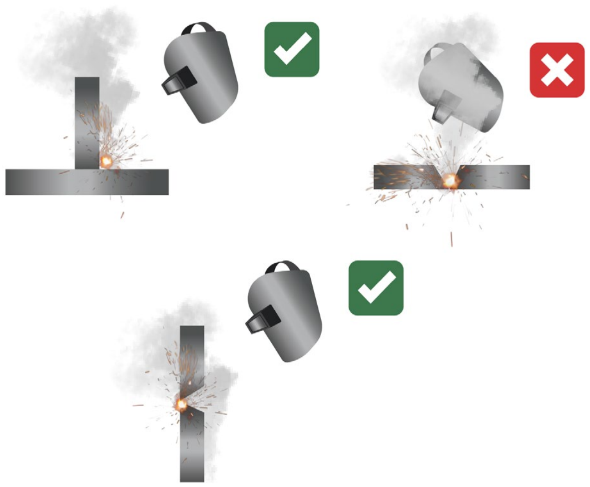


**Figure 12.1.** The operator's head should not enter the visible fume plume.

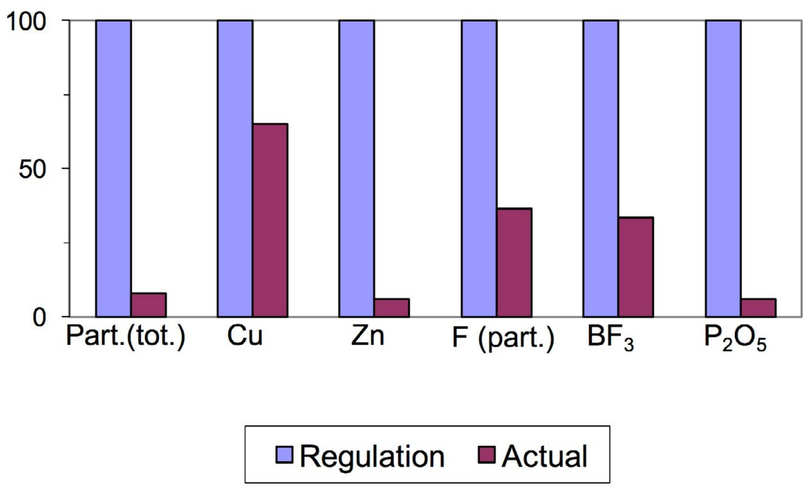



**Figure 12.2.** Plumbing fume production and analysis at the breathing zone as a percentage of Australian Exposure Standard limits.

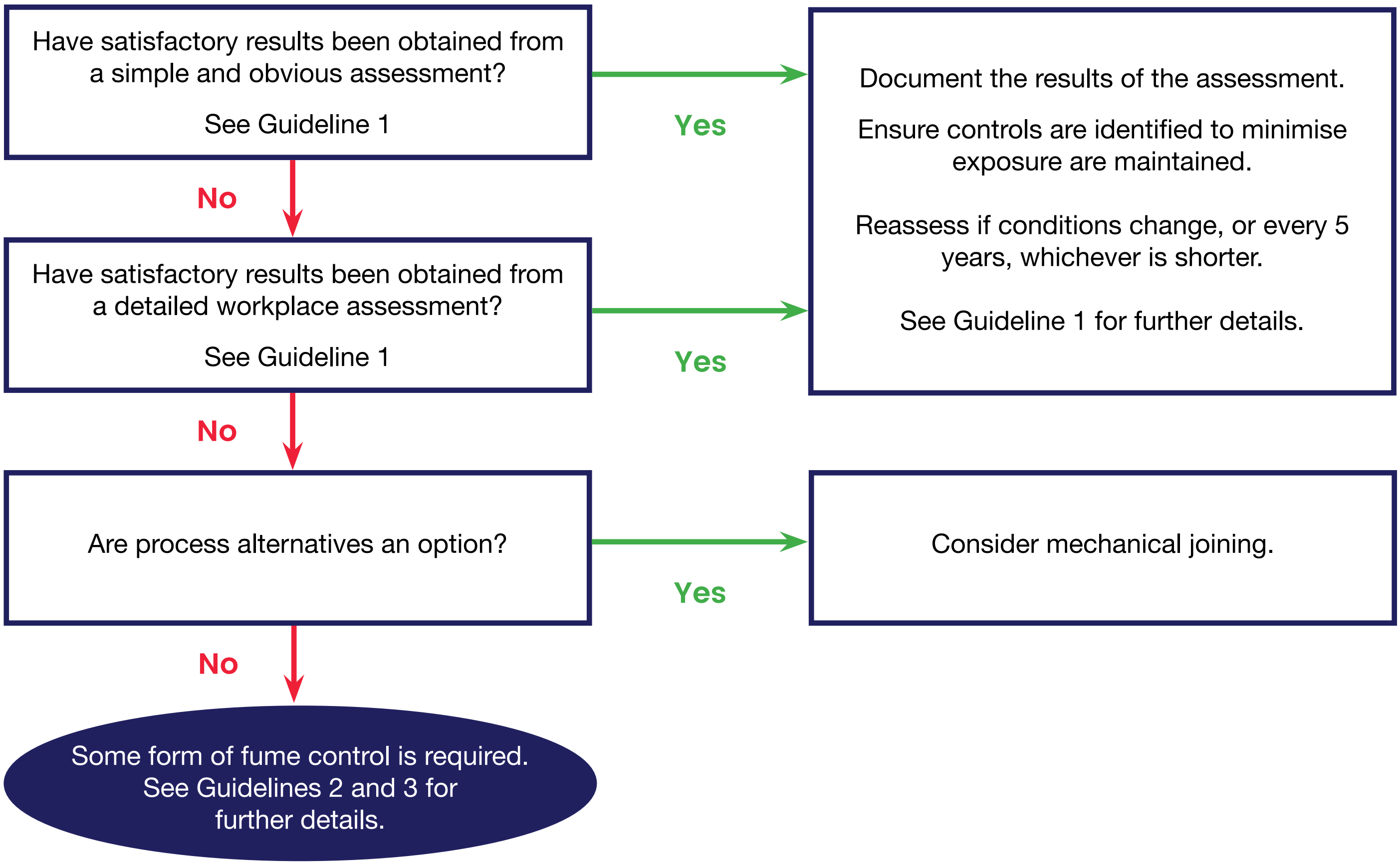
***Note***: *All exposures must be controlled so far as is reasonably practicable.*

## 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 chemicals.

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. When viable, consider the use of lead-free solders to eliminate the risk of lead-fume exposure.




***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 (e.g. 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 um, then a high efficiency particle air filter to remove 99.997% of 0.3 um followed by a gas filter e.g. activated carbon. A preventative maintenance regime is required for such a system.*

## Scope

| Process | Typical Application | Typical Solders | Typical Fluxes |
|---|---|---|---|
| Hand soldering iron | General assembly | • 63/37, 60/40 Sn Pb<br>• 50Sn/48.5 Pb/1.5 Cu (limits tip erosion)<br>• 62 Sn/36Pb/2 Ag (low melting point)<br>• Plain or flux cored wire | Rosin (colophony) with or without halide activator. |
| Wave soldering | PCB plug in devices | • 63/37,60/40 Sn Pb<br>• 62/36/2Ag (board separately fluxed) | Rosin in solvent or "no clean" modified rosin with halide free/carboxylic acid activator |
| Reflow soldering | PCB surface mount devices | 60Sn/40 Pb solder cream incorporating flux. Screen printed. Reflowed under inert atmosphere. | "No clean" modified rosin. Halide free activator. |

## 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

(a) Formaldehyde, abietic acid, isopropyl alcohol, benzene, toluene, hydrochloric or hydrobromic acid from amine/halide activator.

(b) Water soluble resin free fluxes containing phosphorus hexate give hexanoic acid fumes.

## Health Effects

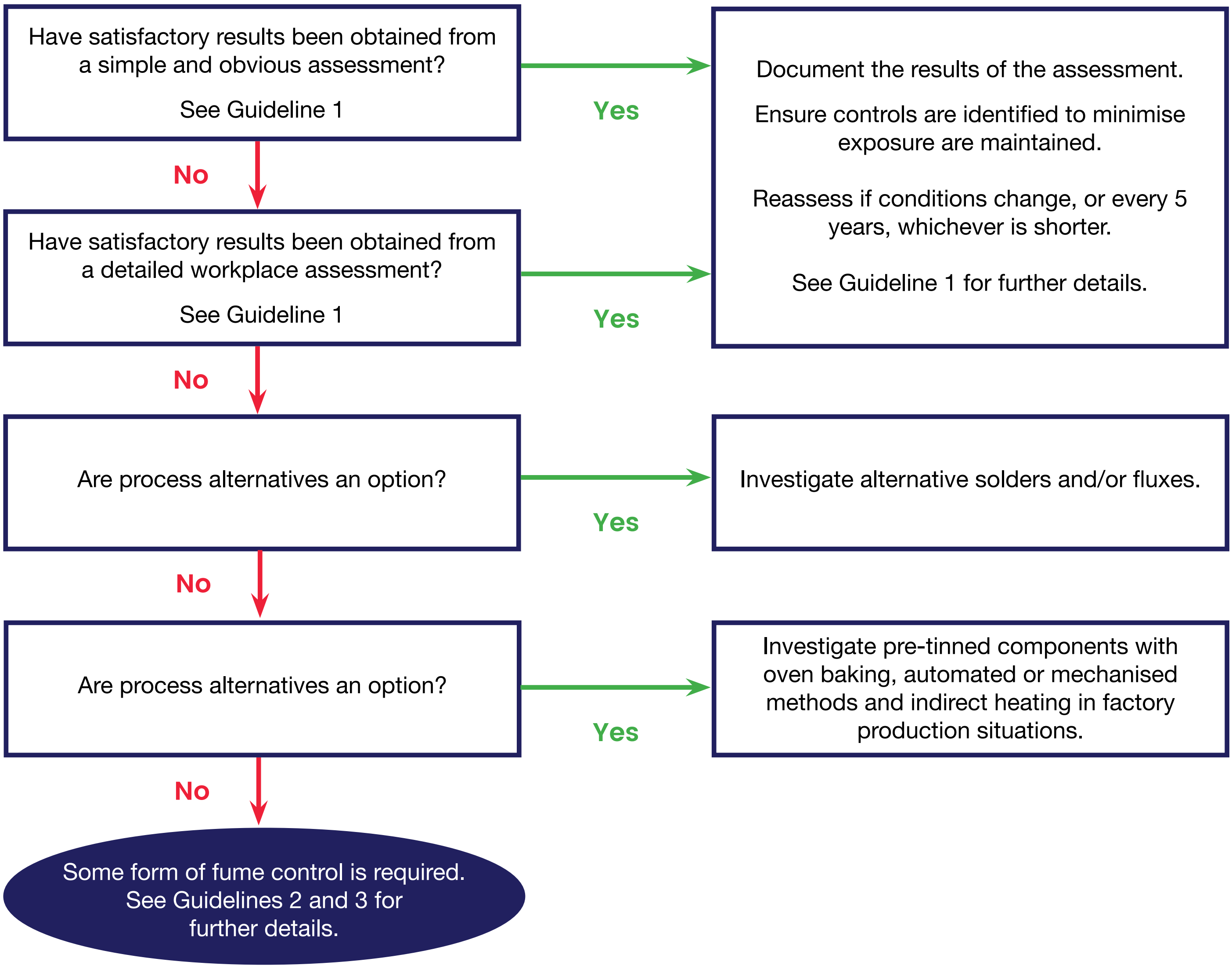
### Solder Fume

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 chemicals.

For intermittent maintenance work, no special measures may be necessary to protect the operator. Consider the use of lead-free solder to eliminate the risk of exposure to lead fume. 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.




***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 (e.g. 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 SDS for the flux used.

## Processes

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

## 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 the 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.*

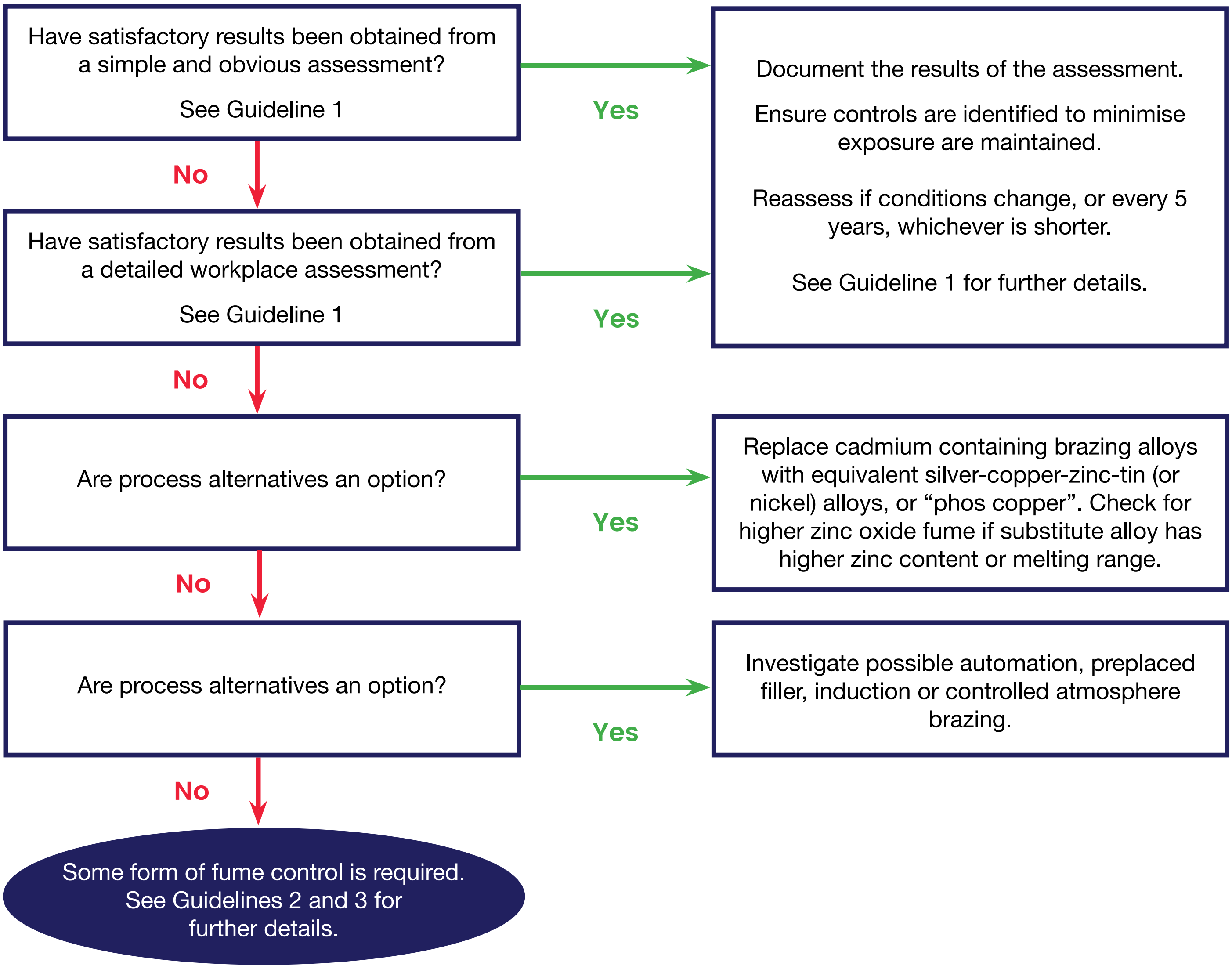
### Flux Fume

Consult relevant SDS. 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.

## GUIDELINE 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 chemicals.

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.




***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 Confined spaces) or where particular hazards are identified in 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:

(a) **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").

(b) **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

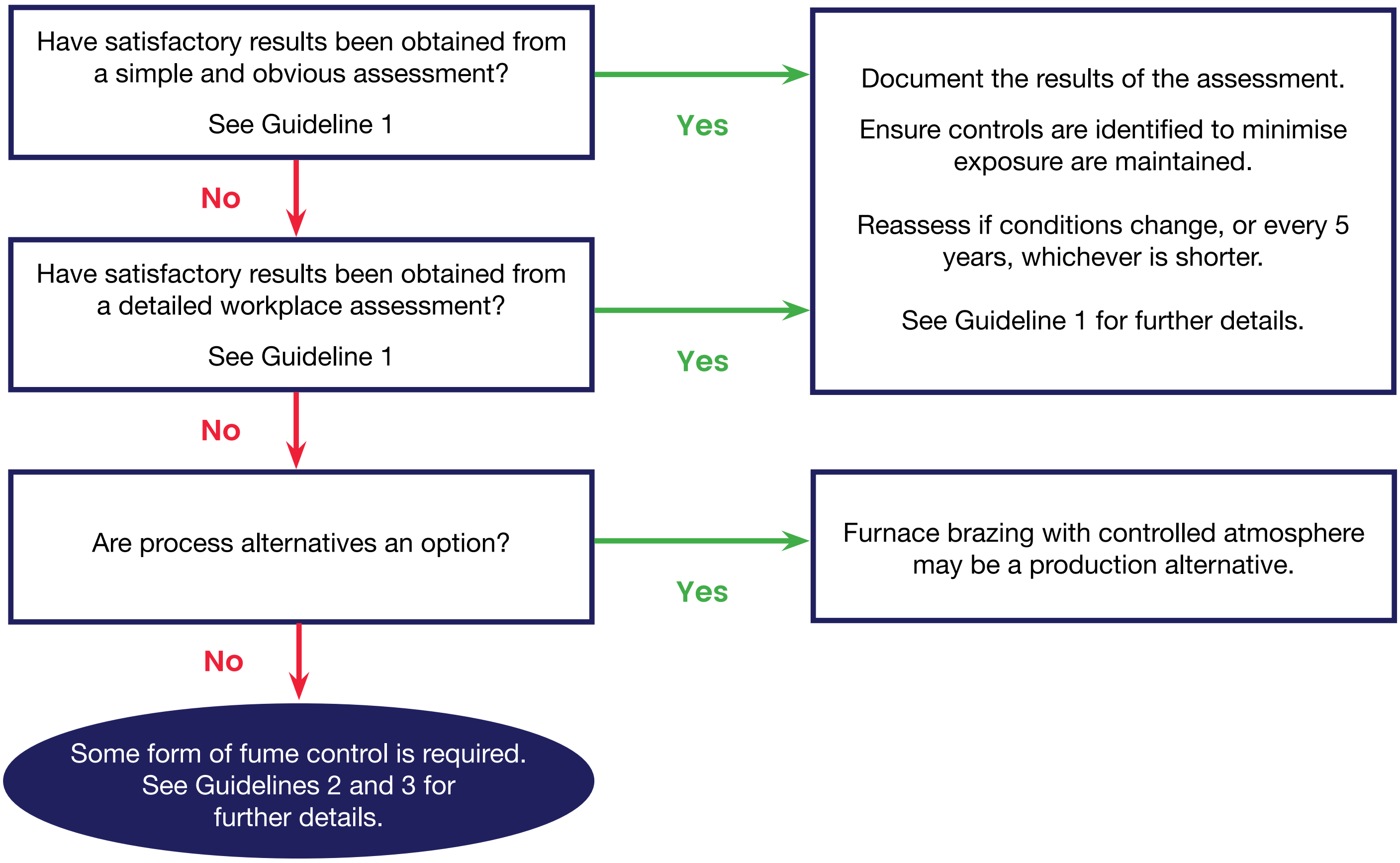
Commonly contain hydrogen fluoride and boron trifluoride also sodium aluminium fluoride and sodium fluoride in some formulations. Dusts of boric acid, potassium hydroxide, potassium chloride and potassium tetraborate can arise dependent on flux type. Toxic and corrosive if swallowed, these fumes (particularly 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

*Appropriate 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 chemicals.

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.




***NOTES**:*

1. *Ventilation by local exhaust will usually be required. For work performed in an enclosed 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 Confined Spaces) or where particular hazards are identified in Safety Data Sheets.*

## Scope

| Process | Typical Application | Typical Filler Metal (rod) |
|---|---|---|
| Gas Braze Welding | Maintenance brazing of cast iron and steel | Manganese bronze (AS/NZS ISO 117672, Cu 681) |
| Gas (Braze and Fusion) Welding | Braze welding of mild steel for low stress applications and welding of high melting point brass and bronze alloys | Tobin bronze (AS/NZS ISO 117672, Cu 470) |

Fluxes either as rod coating or separately applied, are typically boric acid/sodium meta-borate mixtures but some (e.g. 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).

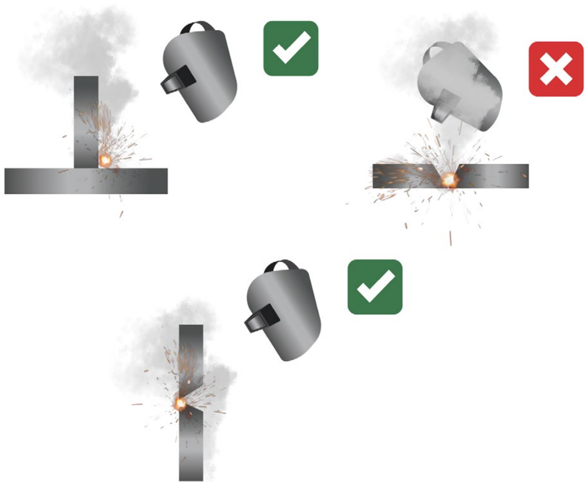


**Figure 16.1.** The welder's head should not enter the visible fume plume.

## GUIDELINE 17: Air-Arc Gouging

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

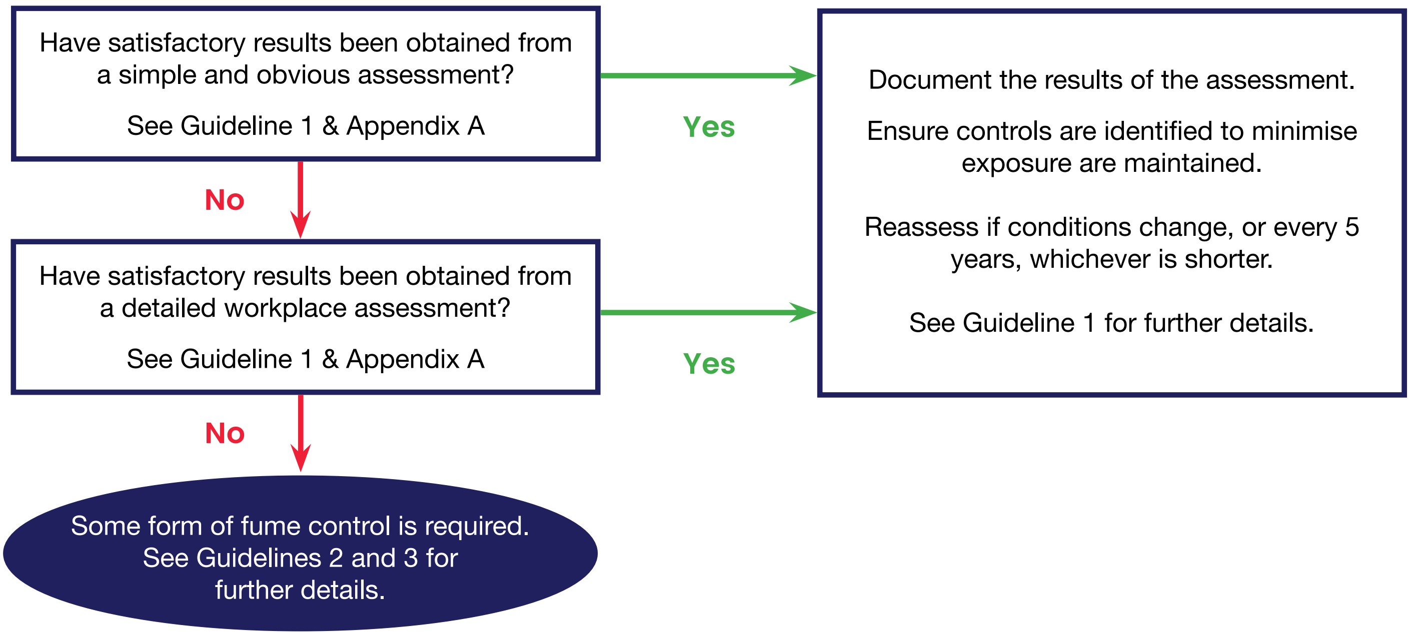
Whilst breathing zone assessments on air-arc gouging have not been conducted, it is known that air-arc gouging readily produces extremely high levels of fume that are difficult to capture due to the high energy particulates produced.

It is generally recommended that air-arc gouging be conducted outdoors, preferably with a cross breeze blowing and the gouging particulate directed away co-workers (see Figure 17.1). Supplementary PPE is likely to be required by the operator and any assistant(s) whilst gouging.

In situations where the air-arc gouging is required to be performed indoors, it should be ideally performed in a sound-absorbent and fire-resistant booth with good general ventilation. Some fume capture, whilst difficult, may be possible where the capture hood is located in-line with the direction of gouging and operator is able to direct the flow of particulates and fume towards the capture hood.

If gouging is necessary in a workshop, consideration should be given to conducting the air-arc gouging during break times whilst co-workers are located well away from the gouging operation. Build-up of fume can be minimised by locating a fume capture hood in-line with the direction of gouging and directing the flow of particulates and fume towards the capture hood. Accumulation of fumes in the workshop must be prevented by general ventilation. Supplementary PPE is likely to be required by the operator and any assistant(s) whilst gouging. Low levels of workshop fume can be confirmed via the use of suitably positioned real-time air quality monitors that measure weld fume particulates.

In all cases, where the risk assessment identifies the need for additional controls, the use of supplementary PPE such as a powered air purifying respirator (PAPR) should be considered. Air monitoring may be required, especially if air-arc gouging is conducted indoors.




### Steps to Reduce the Effect of Fume and Gases

#### 1. Process Alternatives

Consider alternative gouging processes where feasible e.g. machining, grinding, plasma gouging, etc.

#### 2. Process Modifications

(a) Arrange cutting to reduce operator exposure as shown in Figure 17.2. This also reduces fatigue and back problems.
(b) Conduct air-arc gouging outdoors wherever possible.
(c) Direct gouging particulates and fume towards a suitably located capture hood located in-line and on the same plane as the gouging operation.

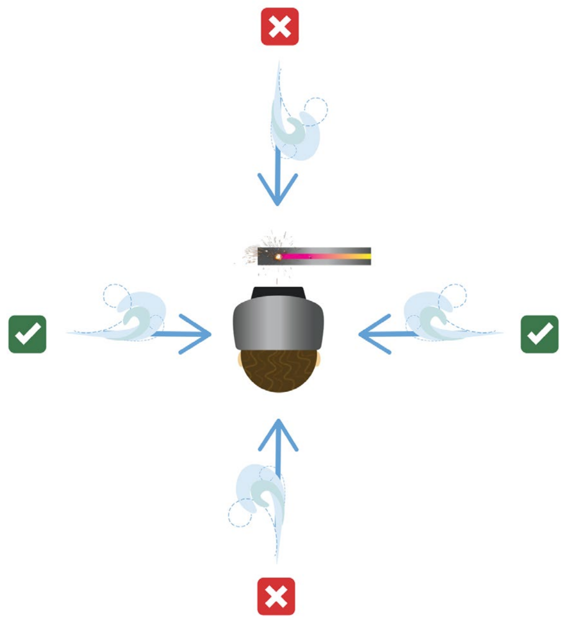


**Figure 17.1.** Preferred and non – preferred direction of cross draft for breathing zone ventilation.

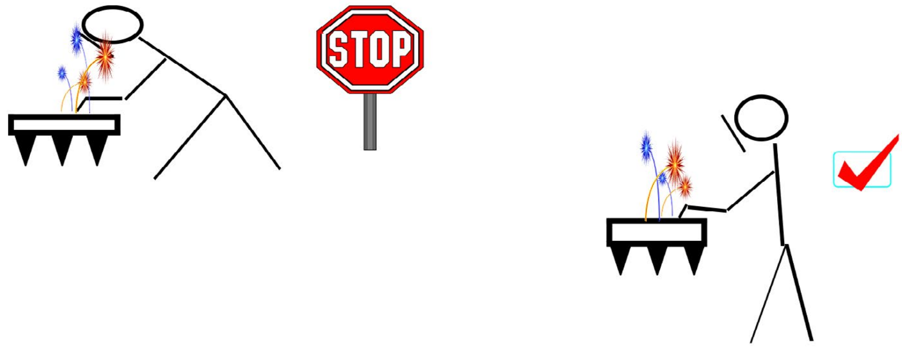



**Figure 17.2.** The operator's head should not enter the visible fume plume.

## APPENDIX A: Self-Audit Form: Assessment of Weld Fume Hazards and Controls

An employer (i.e. the PCBU) has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous chemicals. This includes weld fume.

The self-audit form included in this Appendix will assist the user to identify the hazards associated with weld fume undertake this assessment. Depending on the location, type of work being undertaken, and nature of the materials being welded, a range of controls are likely to be required. Where the user ticks a red box on this self-audit form, comment is required and additional controls may be required to manage the hazard.

The expectation of the regulators is that the hierarchy of controls will be applied to maximise control effectiveness in relation to the hazards present.

Control effectiveness needs to be evaluated, not just for the protection of the welder but also for all personnel working in the vicinity of welding and welding-related tasks. For this reason, whilst welders using PAPR's or air-fed helmets are likely to be well protected from weld fume, a combination of fume control methods that includes the use of fume capture systems and good general ventilation is essential to protect other personnel from excess weld fume exposure. Additional controls are required if welding stainless steels, hardfacing, or through coatings.

Where doubt exists on control effectiveness, WHS regulations requires that air monitoring be undertaken (see Guideline 2 of this Guidance Note). Importantly, where it is evident that there is a lack of engineering controls in use, this will create doubt in the mind of the regulator's inspection personnel and the PCBU is likely to receive a request to engage a hygienist to undertake air monitoring (fume assessment). Portable real-time air monitors are available to assist manufacturers/fabricators to demonstrate compliance for those working near welding operations.

Specialist advice may be sought from an Occupational Hygienist e.g. www.aioh.org.au, particularly in the preparation and implementation of a risk assessment, and the verification of the application of the controls (i.e. air monitoring). air-arc gouging is conducted indoors.

## Self-Audit Form: Assessment of Weld Fume Hazards and Controls

| Weld fume hazards & control | Yes | No |
|---|---|---|
| Has a risk assessment been performed, hazards identified & minimised or eliminated? | | |
| Is weld fume visible in the workshop atmosphere? | | |
| Does weld fume accumulate in any location? | | |
| Is the work area a confined space? | | |
| Is the work area an enclosed workspace? | | |
| Is the work area an open workspace? | | |
| Is the work area well ventilated? | | |
| If fans are used to assist ventilation, are other workers impacted by fume-bearing air flow? | | |
| Is all weld fume captured / extracted at the source? | | |
| Are the fume capture devices used correctly and maintained? | | |
| If hooded capture is used, is the hood set at the correct distance from the arc (~1 hood dia)? | | |
| Is the welder's head in the plume? | | |
| Does the weld process and/or weld procedure minimise welder's exposure to weld fume? | | |
| Is the welding process stable i.e. minimal or no spatter? | | |
| Can a lower fume process be used e.g. waveform controls, lower CO2 shielding gas etc? | | |
| Can the welding/cutting process be automated or mechanised? | | |
| Is air-arc gouging performed indoors? | | |
| Is fume from flame/plasma cutting or gouging captured? | | |
| If half-face or disposable respirators are used, is the device correctly worn and fit tested? | | |
| If half-face or disposable respirators are used, is the user clean shaven? | | |
| Are welders using PAPR or air-fed helmets or similar? | | |
| Does the work require welding with stainless steel consumables? | | |
| Does the work require welding with hardfacing consumables? | | |
| Does the work require welding with non-ferrous consumables? | | |
| Does the work require welding through galvanised coatings? | | |
| Does the work require welding through metallic coatings (other than galvanised/zinc)? | | |
| Does the work require welding through non-metallic coatings (e.g. paint, polymers etc) or surface contaminants (e.g. oil, grease, water etc)? | | |
| Is a real-time air monitor used to verify adequacy of fume controls in the workplace? | | |
| Does air monitoring need to be performed to verify fume controls? | | |
| Have fume controls in place been assessed and confirmed as compliant with WHS regulations? | | |

**Comments**

| | |
|---|---|
| Proceed | Requires comment and additional controls to be put in place before work commences (see Introduction) |

## Weld Australia Technical Notes

### TN 1 - The Weldability of Steels

Gives guidance on the preheat and heat input conditions (run size, current, voltage) required for acceptable welds and to avoid cold cracking in a wide variety of steels. The Note is applicable to a wide range of welding processes.

### TN 2 - Successful Welding of Aluminium

This note covers the major welding processes as they are used for the welding and repair of aluminium and its alloys. Information is given on the processes, equipment, consumables and techniques. It also provides information on the range of alloys available and briefly covers safety, quality assurance, inspection and testing, costing and alternative joining processes.

### TN 3 - Care and Conditioning of Arc Welding Consumables

Gives the basis and details for the correct care, storage and conditioning of welding consumables to control hydrogen and to ensure high quality welding.

### TN 4 - The Industry Guide to Hardfacing for the Control of Wear

Describes wear mechanisms and gives guidance on the selection of hardfacing consumables and processes for a wide range of applications. Includes Australian Hardfacing Suppliers Compendium 1998.

### TN 5 - Flame Cutting of Steels

Gives a wealth of practical guidance on flame cutting including detailed procedures for efficient cutting, selection of equipment and gases, practices for identifying and curing defective cutting, methods of maximising economy and other important guidance on the use of steels with flame cut surfaces.

### TN 6 - Control of Lamellar Tearing

Describes the features and mechanisms of this important mode of failure and the means of controlling tearing through suitable design, material selection, fabrication and inspection. Acceptance standards, repair methods, specification requirements and methods of investigation are proposed. Appendices give details on the mechanism, tests for susceptibility and the important question of restraint.

### TN 7 - Health and Safety in Welding

Provides information on all aspects of health and safety in welding and cutting. Designed to provide this information in such a way that it is readily useable for instruction in the shop and to provide guidance to management. Recommendations are given for safe procedures to be adopted in a wide variety of situations in welding fabrication.

### TN 8 - Economic Design of Weldments

Principles and guidance are given on methods and procedures for optimising design of weldments and welded joints and connections to maximise economy in welding fabrication. Factors influencing the overall cost of weldments which need to be considered at the design stage are discussed.

### TN 9 - Welding Rate in Arc Welding Processes: Part 1 MMAW

Gives practical guidance and information on the selection of welding conditions to improve productivity during manual metal arc welding (MMAW). Graphs are provided showing rates as a function of weld size. The graphs enable a direct comparison of different types of welding electrodes when used for butt and fillet welds in various welding positions.

### TN 10 - Fracture Mechanics

Provides theory and gives practical guidance for the design and fabrication of structures, planning of maintenance and assessment of the likelihood of brittle or ductile initiation from imperfections in ferrous and non-ferrous alloys. Engineering critical assessment case histories are discussed.

### TN 11 - Commentary on the Structural Steel Welding Standard AS/NZS 1554

The Note complements AS/NZS 1554 parts 1 to 7, by presenting background information which could not be included in the Standard. It discusses the requirements of the Standard with particular emphasis on new or revised clauses. In explaining the application of the Standard to welding in steel construction, the commentary emphasises the need to rely on the provisions of the Standard to achieve satisfactory weld quality.

### TN 12 - Minimising Corrosion in Welded Steel Structures

Designed to provide practical guidance and information on corrosion problems associated with the welding of steel structures, together with possible solutions for minimising corrosion.

### TN 13 - Stainless Steels for Corrosive Environments (A Joint publication with ACA)

Provides guidance on the selection of stainless steels for different environments. Austenitic, ferritic and martensitic stainless steels are described together with the various types of corrosive attack. Aspects of welding procedure, design, cleaning and maintenance to minimise corrosion are covered.

### TN 15 - Welding and Fabrication of Quenched and Tempered Steel

Provides information on quenched and tempered steels generally available in Australia and gives guidance on welding processes, consumables and procedures and on the properties and performance of welded joints. Information is also provided on other fabrication operations such as flame cutting, plasma cutting, shearing and forming.

### TN 16 - Welding Stainless Steel

This Technical Note complements Technical Note Number 13 by detailing valuable information on the welding of most types of stainless steels commonly used in industry.

### TN 18 - Welding of Castings

Provides basic information on welding procedures for the welding processes used to weld and repair ferrous and non-ferrous castings. It also provides information on the range of alloys available and briefly covers non-destructive inspection, on-site heating methods and safety.

### TN 19 - Management of Weld Quality—A Guide to AS/NZS ISO 3834

Provides information on the application of AS/NZS ISO 3834 and its parts to the manufacture of welded structures, supplementing the requirements of both quality management standards and application standards where required, on elements of the welded fabrication process requiring control to ensure a quality product.

### TN 20 - Repair of Steel Pipelines

Provides an outline of methods of assessment and repair to a pipeline whilst allowing continuity of supply.

### TN 21 - Submerged Arc Welding

Provides an introduction to submerged arc welding equipment, process variables, consumables, procedures and techniques, characteristic weld defects, applications and limitations. Describes exercises to explore the range of procedures and techniques with the use of solid wire (single and multiple arcs) and provides welding practice sheets, which may be used as instruction sheets to supplement demonstrations and class work, or as self-instruction units.

### TN 22 - Welding Electrical Safety

Provides information and guidance on welding electrical safety issues (welding equipment, the human body and the workplace), including investigation of welding current related electric shock injuries and electrocution.

### TN 23 - Environmental Improvement Guidelines

Provides information and guidance on how to reduce consumption in the Welding and Fabrication industry, while reducing the impact on the environment at the same time.

### TN 25 – Welding Specification for the Water Industry

Published with the Water Services Association of Australia. Applies to all metal fabrication and repair work involving welding, carried out by a Water Agency (WA) and its Contractors/Subcontractors. Prescribes weld preparation, qualification of welding procedures and personnel, workmanship and inspection requirements for welds related to the arc welding by manual metal arc and other processes approved by the WA responsible Welding Coordinator.

## Notes

Weld Australia

**Weld Australia**

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