FUME MINIMISATION GUIDELINES

Welding, Cutting, Brazing and Soldering

INTRODUCTION

1. ABOUT THESE GUIDELINES

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

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

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

2. INTENT OF THESE GUIDELINES

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

3. TABLE OF CONTENTS

4. ACKNOWLEDGEMENTS

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

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

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

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FUME MINIMISATION GUIDELINES

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GUIDELINE 1:

HAZARDOUS SUBSTANCES REGULATIONS

1. OBJECTIVE

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

2. HISTORY

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

3. WHAT IS A "HAZARDOUS SUBSTANCE"?

In general a hazardous substance is a substance that has the potential to adversely affect human health. Hazardous substances may

a) be included in the "List of Designated Hazardous Substances" [NOHSC: 10005 (1994)] or on a list produced by a particular State or Territory ,or,

b) fit the criteria for a hazardous substance set out in "Approved Criteria for Classifying Hazardous Substances" [NOHSC: 1008 (1994)].

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

4. APPLICATION TO WELDING AND ALLIED PROCESSES

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

5. RESPONSIBILITIES

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

Suppliers must-

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

Employers must-

- Develop and subsequently maintain a register of all hazardous substances used or produced in the workplace. This may include consumables, welding fume or any other hazardous substances in the workplace.
- Maintain a collection of MSDS as part of the register. This register must be available for reference by all employees.
- Ensure a suitable and sufficient assessment is made of the risk to health created by welding fume or other hazardous substances. In most circumstances use of these Fume Minimisation Guidelines will assist in the assessment.

- Revise the assessment at least every 5 years or if workplace conditions change significantly.
- Provide training to all employees with the potential for exposure to welding fume.
- Keep records of training and assessment – assessment reports must be available to employees to whom the assessments relate.
- Provide health surveillance for employees assessed as being exposed to a significant health risk in the course of their employment duties.
- Undertake monitoring where the need is indicated in the assessment.
- Ensure that exposure of employees to hazardous substances is prevented or adequately controlled to minimise risk to health. Exposure must not exceed the relevant exposure standards.
- Ensure that engineering controls and safe work practices are effectively maintained.

Employees are required to-

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

6. WORKPLACE ASSESSMENTS FOR FUME

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

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

The possible assessment methods include the following:

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

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

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

Further information on conducting these types of assessments may be found in the Worksafe publication "Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace"[NOHSC:3017(1994)].
Irrespective of the assessment method, *it should be stressed that exposure standards do not represent "no effect" levels for each and every worker*. ***Therefore, the level of exposure should be kept as low as practicable.***

7. ACTIONS FOLLOWING ASSESSMENT

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

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

FUME MINIMISATION GUIDELINES

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GUIDELINE 2:

FUME CONTROL OPTIONS

1. INTRODUCTION

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

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

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

2. WORKPLACE ENVIRONMENT

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

2.1 Outdoor/natural ventilation

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

2.2 Open work space

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

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

2.3 Limited work space

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

2.4 Confined work space

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

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

3. FUME GENERATION

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

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

The gaseous decomposition products of contaminants remaining on the workpiece are more widely distributed, and are generated from the heated portions of the workpiece.

Ozone is generated in a volume of the atmosphere beyond the arc zone. It is not concentrated in the plume to the same extent as particulates. Most welding processes with a visible arc generate levels of ozone which place the welder at some risk of exceeding the exposure standard unless controls are implemented.

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

4. GENERAL VENTILATION

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

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

5. CONTROL MEASURES

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

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

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

Many welding situations will require a combination of these methods.

5.1 *Processes producing less fume*

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

5.2 Modification of processes for less fume

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

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

5.3 Isolate workers from the hazardous fume

Automation of processes allows workers to be remote from the source of all fume components. General ventilation of the workplace must then be adequate to prevent an excessive increase of background levels of fume.

5.4 *Engineering control methods*

There are two types of control methods:

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

5.4.1 *Breathing zone ventilation/mechanical dilution*

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

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

5.4.2 Local exhaust ventilation

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

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

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

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

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

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

5.5 *PPE control methods*

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

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

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.
	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, and deliver a constant flow of air to the wearers face. 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 back pack tank, for situations where air line systems are not possible.

5.6 Relative cost and availability

An indication of the relative cost and availability of the various control measures is provided below.

RELATIVE COSTS OF WELDER PROTECTION OPTIONS

$ PER WELDER / WORK STATION

		Low end		High end		Comments
Air movement	**Unfiltered**	800	Blower only			Spreads the fumes to other areas of the workplace. May be acceptable for external work or one-man operations.
Stand alone hoods **Fume arm extraction**	**Unfiltered**	2,700	Extractor and arm (1.0m)	10,000	Wall-mounted extractor, beam (6.0m), arm (4.0m), ducted exhaust	Unfiltered units may be acceptable for external work or one-man operations otherwise filtering is preferred. Long beams and arms allow work to be carried out over a large radius. Large extraction units are available which can be connected to several arms by a ducted system.
	Filtered	2,900	Extractor and arm (1.0m)	8,000	Wall-mounted extractor, beam (6.0m), arm (4.0m) (ducted exhaust not required)	
On tool **On-gun extraction**	**Filtered**	2,400	Extractor and attachment	3,500	Extractor and attachment	Best option for all wire welding (especially where welding is not continuous or in localised area of the job) but may be limited by wire thickness.
In-bench fixed **Downdraft benches**	**Filtered**	5,000	Un-ducted	10,000	Various configurations available	Usually quite effective but enclosure design often restricts size of job that can be worked on
Overhead canopy hood **Extraction hood**	**Unfiltered**	3,100	Ducted	6,000	Larger duct system	Can suck the fumes through the welder's breathing zone and unfiltered units will spread the fumes around the workplace. If unfiltered units are installed the fumes could be ducted outside depending on local regulations.
	Filtered	5,600	Un-ducted	8,000		

Disposable P2 Respirator		3.20				Simple to use, does not require a respirator maintenance program. Requires staff training.
Half face Respirator		40 Mask		90 Mask	P2 Filters 13 Cartridge 17	Requires a maintenance program. Requires staff training.
Powered Air Purifying Respirator (PAPR)		900 Resp-irator		1,800 Resp-irator	Filters 45 each	Requires battery charging and replacement. Welding mask incorporated in the unit. Requires a maintenance program. Requires staff training. Portable, lightweight and comfortable units that are battery powered designed to last a full eight hour shift.
Air line respirator		600		1,200		Ideal for confined space welding or working environments with limited ventilation with high levels of particle fumes and gases. Suitable for fixed bay welding. Requires a supply of breathable compressed air. Requires staff training.

Availability: All alternatives are readily available in Australia. They are either locally made or imported. They can be purchased direct from the local manufacturer or their distributors and agents. eg Industrial and welding product suppliers or safety products distributors, etc.
Most stand-alone products require no special installation procedures other than the need to ensure sufficient power is available. Some ducted units may require the need of a mechanical services contractor or other skilled tradesman. Design of more elaborate systems can usually be supplied by the manufacturer, mechanical services contractor or a skilled engineer. It is not unusual for the manufacturer or their local agent to perform this task as part of the service

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GUIDELINE 3:

MATERIALS

1. INTRODUCTION

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

2. TYPES OF FUME

The materials found in fume consist of:

Particulates

- metal and metal oxides, lead from paint
- inorganic fluxes yielding halide salts

Gases and liquids

- added and photo-oxidant gases
- from coatings, paints and solvents, which can generate gases such as phosgene
- fluxes from colophony or rosin which can give rise to hydrocarbons, formaldehyde, hydrochloric acid, benzene, styrene, acetone and other chemicals
- inorganic fluxes yielding halide acids

3. SOURCES OF FUME

Materials present in fumes may come from the following sources:

- Consumable – most of the metal fume comes from the consumable
- Surface coatings or surface preparations
- Gases which are added - such as carbon dioxide, argon, helium
- Gases formed by electric arcs - such as ozone and oxides of nitrogen
- Parent metal

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

4. EXPOSURE STANDARDS

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

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

5. CONSUMABLES

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

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

6. COATINGS

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

For welding, a 20-25mm band should be removed prior to welding. For flame cutting, this band should be 50-100mm.

1. *Metallic coatings:* galvanising (zinc), sprayed coatings (aluminium, zinc and others), electroplating (chromium with copper and nickel underlays, cadmium, zinc or tin) are common.
2. *Paints:* give off a complex mixture. Lead, zinc, chromium, cadmium and other metals may arise from pigments and resins.
3. *Plastics:* give off a complex mixture. Ammonia, hydrochloric acid, carbon dioxide, cyanides can arise. These can be irritant, corrosive, asphyxiating and toxic.

7. SURFACE PREPARATIONS

Chlorinated hydrocarbons like trichloroethylene, perchloroethylene, trichloroethane, acetone and freons are used as degreasing agents. Do not breathe vapours of these agents.

Chlorinated hydrocarbons and freons, under certain conditions, can decompose to form phosgene, which is highly toxic. Care must be taken to dry the surface before welding.

8. MAJOR CLASSES OF METALS

Mild steel may contain

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

Stainless steels may contain

- iron, chromium and nickel
- Occasionally molybdenum, manganese, titanium and other elements

Aluminium may contain:

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

Copper, bronze and brass alloys may contain

- copper, zinc, nickel, aluminium, tin, lead, silicon, iron
- Occasionally manganese, tellurium, sulphur, chromium, cadmium, beryllium, silver, cobalt

The specific quantities of additions will vary with the grade of material selected. The relevant industry associations listed in the introduction to these guidelines should be contacted for further information if required.

List of Atmospheric Contaminants, Worksafe Australia's Exposure Standards, and the medical effects.

Substance	Type		TWA ppm	TWA mg/m^3	STEL mg/m^3	Carcinogen Category	Medical Effects
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		2	Very toxic, damages respiratory tract, quick acting, carcinogenic
Boron oxide				10			Eye and respiratory irritant
Cadmium	& compounds	Cd		0.01		2	Very toxic, lung and kidney damage. Quick acting, may be fatal
Calcium Oxide	Fume	CaO		2			Irritant of eyes, mucous membranes and skin
Chromium	Compounds	Cr(II)&(III)		0.5			Toxic, damages respiratory tract, corrosive to skin
		Cr(VI)		0.05		1	Carcinogenic
Cobalt	Metal dust & fume	Co		0.05			Irritant, fibrosis of the lung, sensitizer
Copper	Fume	Cu		0.2			Metal fume fever
Fluorides		F		2.5			Irritant of eyes, mucous membranes, skin and lungs
Iron Oxide	Fume	Fe_2O_3		5			Siderosis (no long term effects)
Lead	Fume	Pb		0.15			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	Mo		5			Irritant
	Insol. Compounds			10			
Nickel	Metal	Ni		1			Metal fume fever, possible carcinogen
	Sol. compounds			0.1			
Nitrogen Dioxide		NO_2	3	5.6	9.4		Irritant
Ozone		O_3	0.1	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
Selenium	Compounds	Se		0.2			Irritant of eyes, mucous membranes and skin. Central nervous system effects with chronic exposure.
Silica	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	Peak	Limitation	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
General Fume				5			

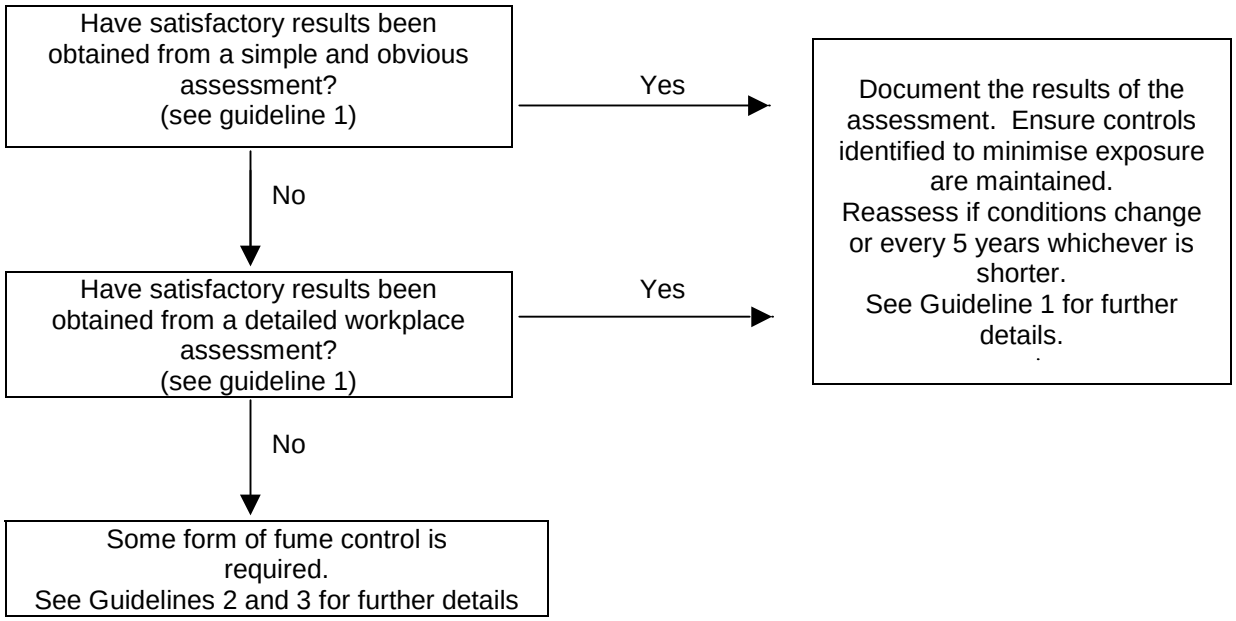
Metal fume fever - The fumes of several metals and their oxides can give rise to metal fume fever. Fever, nausea, cough, shivering, headache, muscle ache, shortness of breath and general malaise may occur. The condition may start a few hours after the end of the working day, and last a day or so. The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

FUME MINIMISATION GUIDELINES

GUIDELINE 4:

MANUAL METAL ARC WELDING (MMAW)

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



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

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

- **Process Modifications**

    1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.

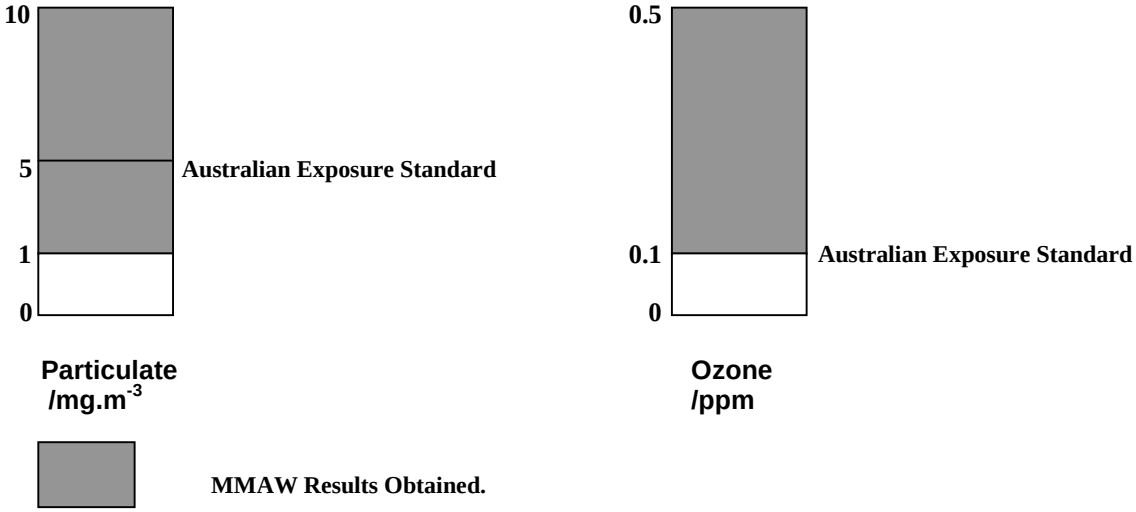


Figure 1. MMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

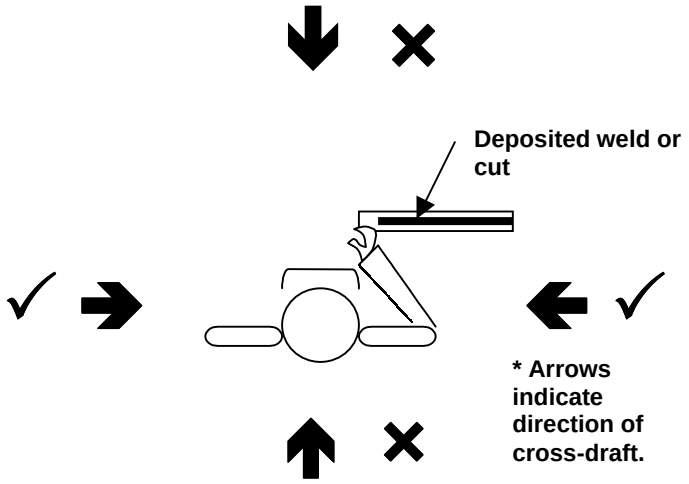


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

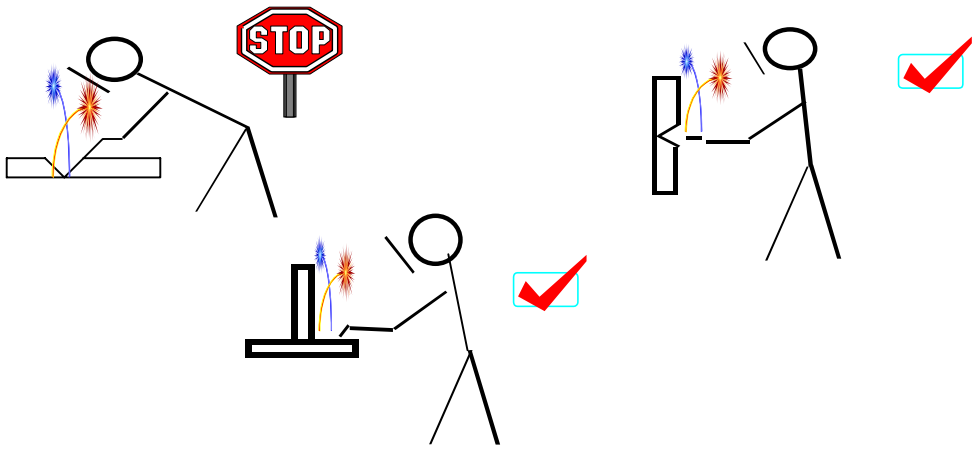


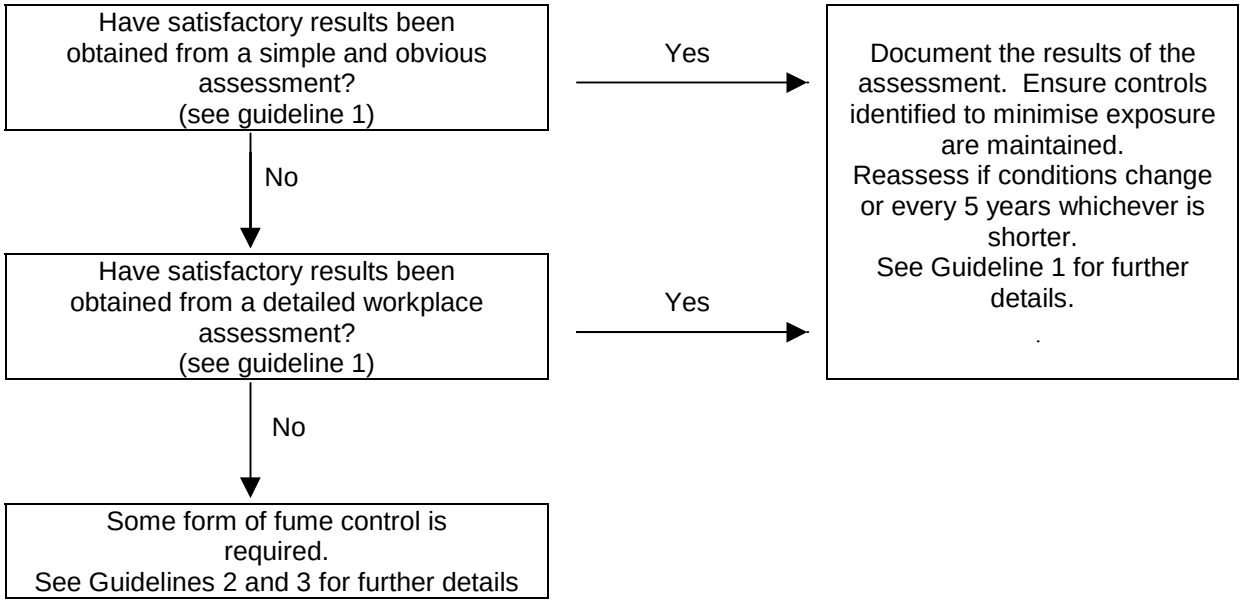
Figure 3. The welder's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 5:

GAS METAL ARC WELDING (GMAW)

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



Steps To Reduce The Effect Of Fume And Gases

- **Process Alternatives**

    1) Consider using SAW for flat position seams in heavier material. Higher capital costs are often offset by higher productivity.

- **Process Modifications**

    1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
    2) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone and, for steel, Argon/CO_2 may reduce particulate).
    3) Mechanize the process using simple tractors, turntables or robots.

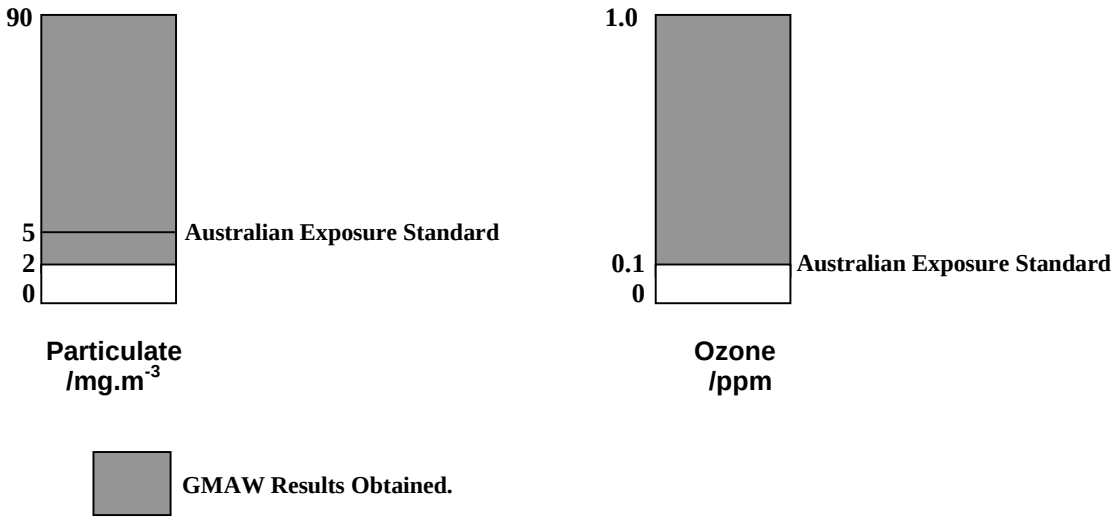


Figure 1. GMAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

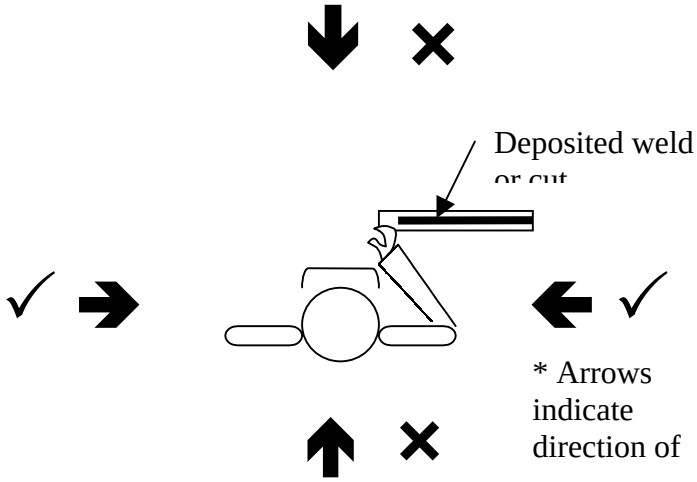


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

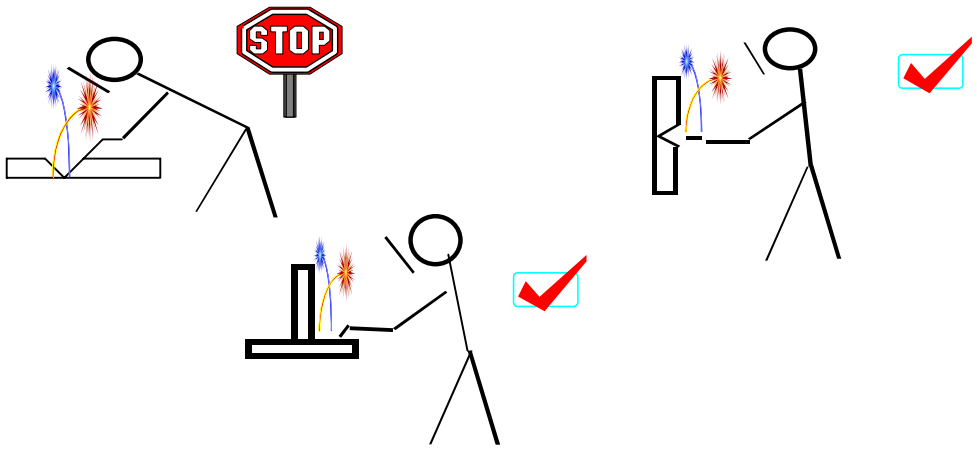


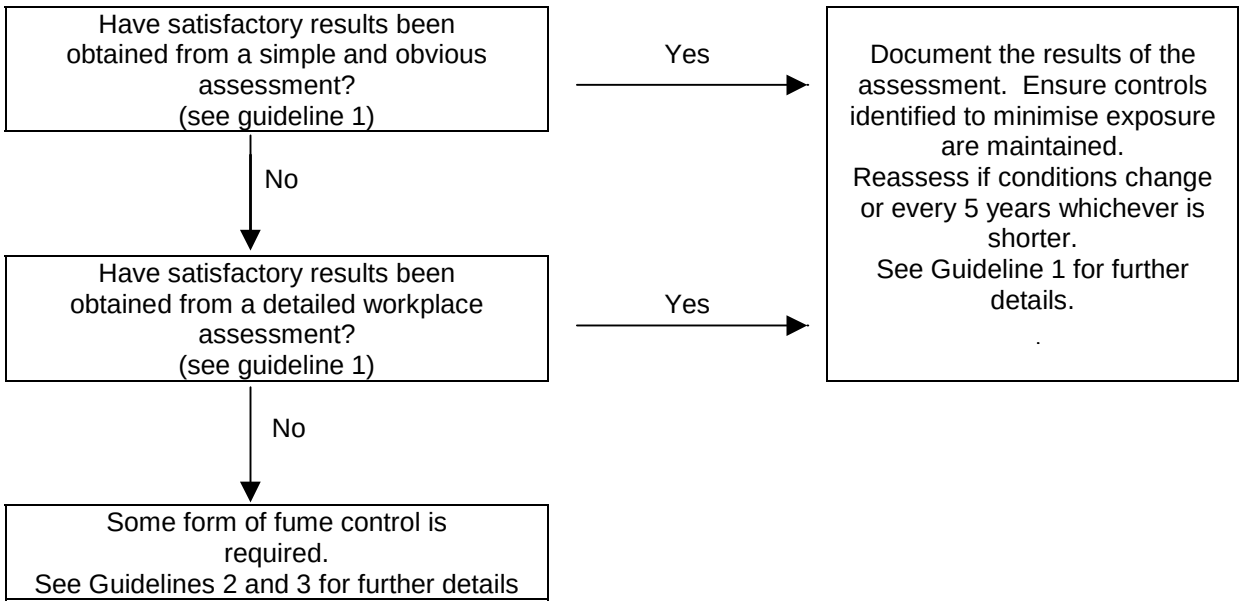
Figure 3. The welder's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 6:

GAS TUNGSTEN ARC WELDING (GTAW)

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



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

    1) Laser and electron beam welding may be viable but higher capital costs must be offset by higher productivity.

- **Process Modifications**

    1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
    2) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone in aluminium welding and Argon/Hydrogen may be used to reduce ozone levels with austenitic stainless steel).
    3) Mechanise or automate the process.

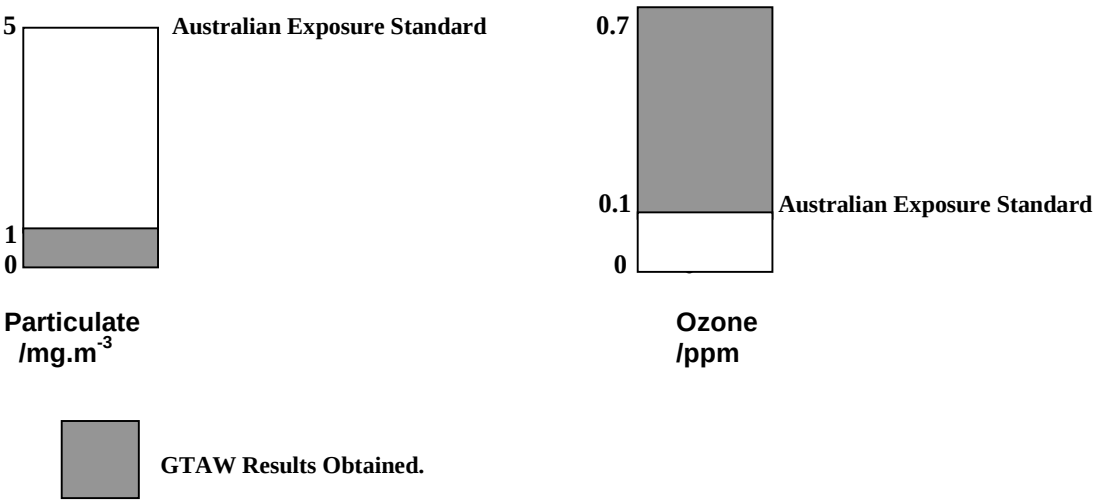


Figure 1. GTAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

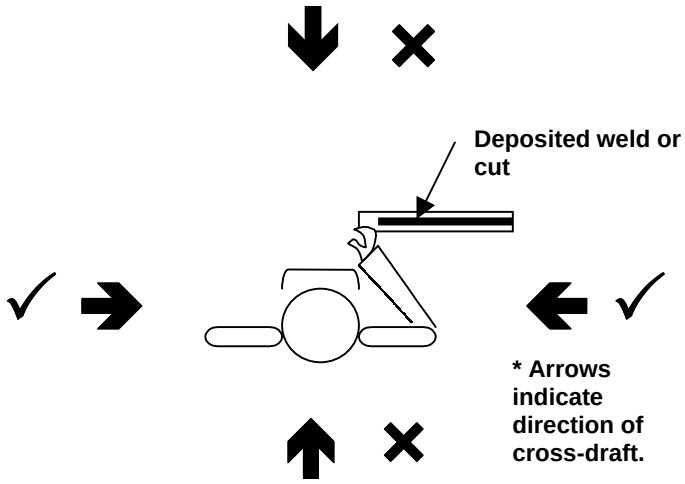


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

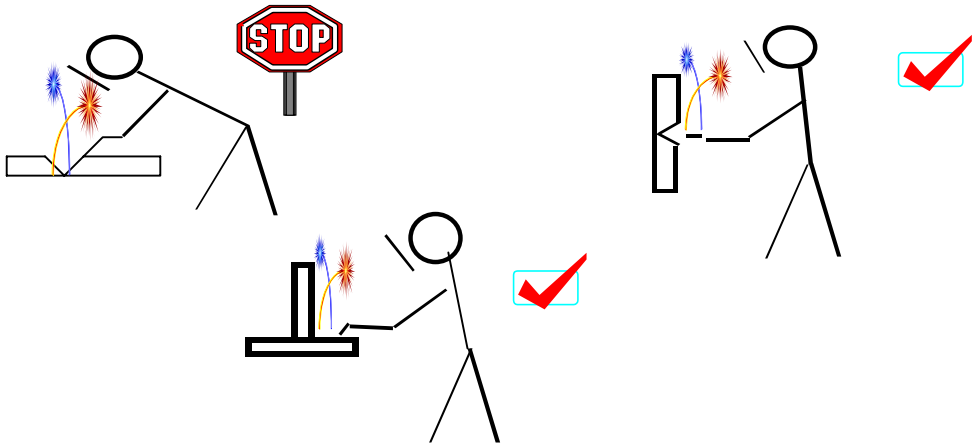


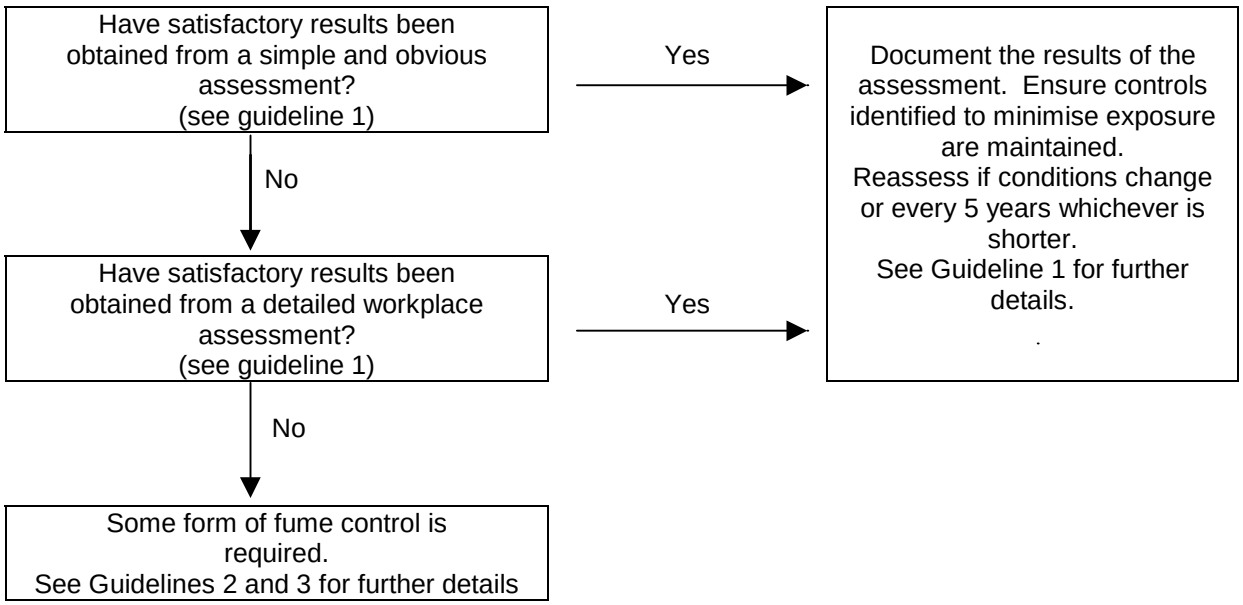
Figure 3. The welder's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 7:

FLUX CORED ARC WELDING (FCAW)

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



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

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

- **Process Modifications**

    1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
    2) Consider using alternative shielding gases (Argon/Helium mixtures reduce ozone and Argon/CO_2 may reduce particulate fume).
    3) Mechanize the process using simple tractors, turntables or robots.

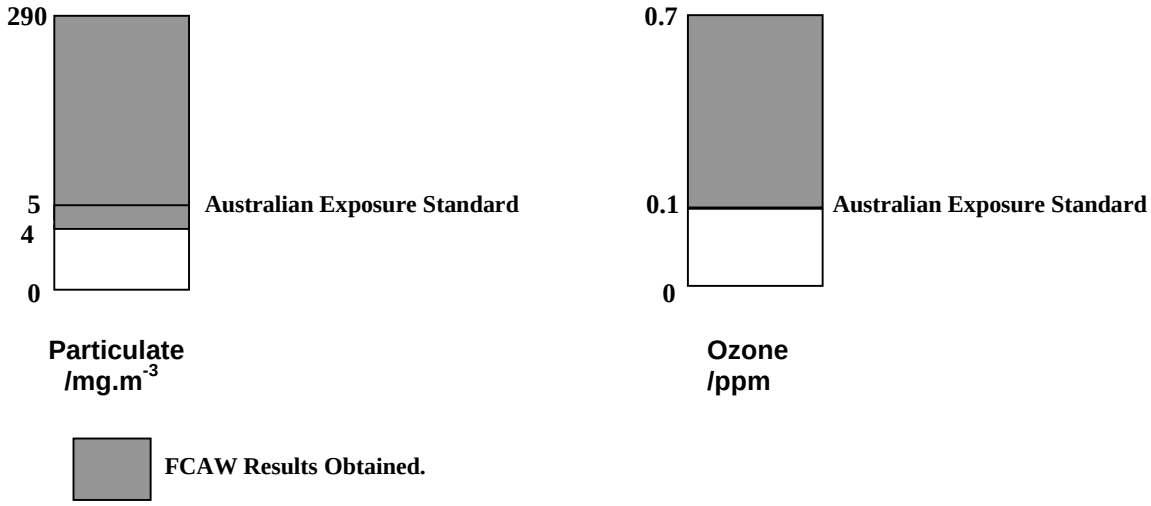


Figure 1. FCAW fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

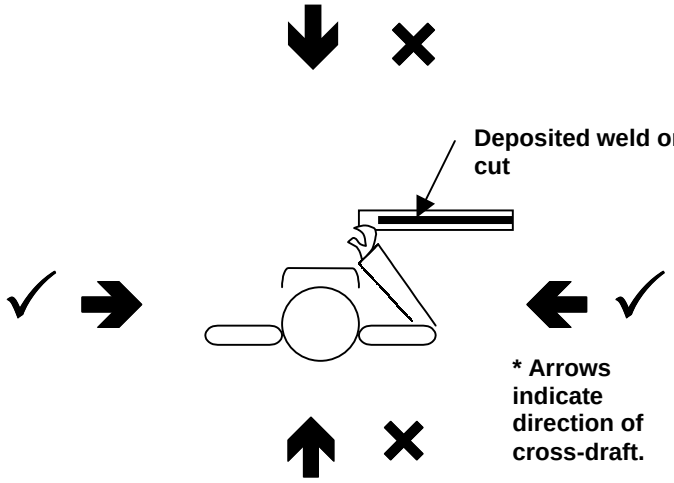


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

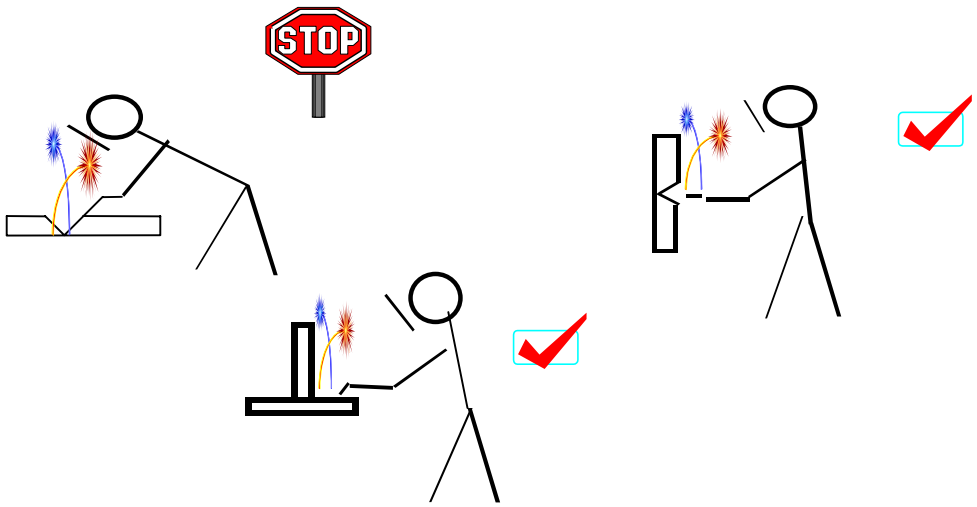


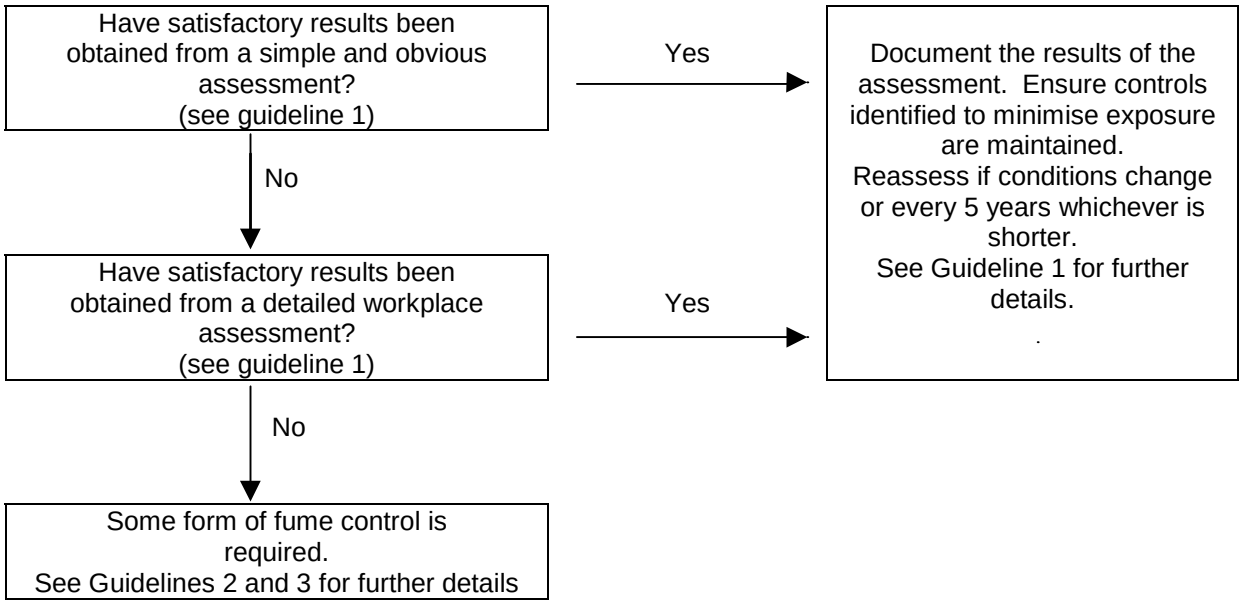
Figure 3. The welder's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 8:

HARDFACING

An employer has a duty to ensure that a suitable and sufficient assessment is made where there is potential for exposure to hazardous substances.
It should be noted that in tests conducted under still air conditions, fume from FCAW hardfacing operations usually exceeds the recommended levels (see Figure 1). No special measures may be necessary to protect the operator provided clean air movement is greater than 0.5 m/s across the welders breathing zone (see Figure 2). Due to the high levels of fume generated, there is a greater likelihood of co-workers exposure exceeding the relevant exposure standards unless good general ventilation is implemented.
Hardfacing consumables are often highly alloyed and fumes may contain significant levels of manganese and chromium. See Guideline 3 for relevant exposure standards.



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

  1) Consider using wearplate or alternate processes such as submerged arc surfacing. Gas Metal Arc and Gas Tungsten Arc surfacing both produce less fume than “open arc” processes.

- **Process Modifications**

  1) Arrange welding to reduce welders exposure as shown in Figure 3. This also reduces fatigue and back problems.
  2) Mechanise the process using simple tractors, turntables or robots.

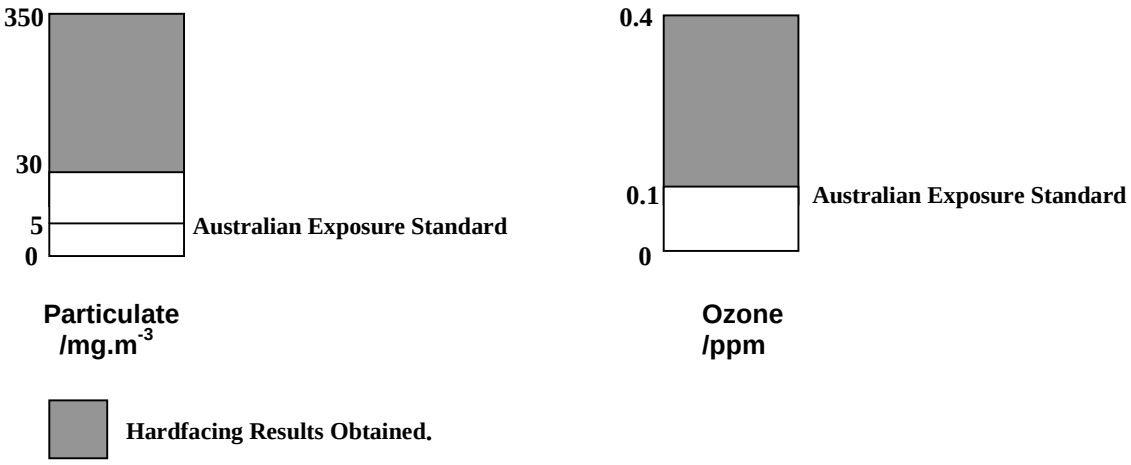


Figure 1. Hardfacing fume production at the breathing zone under still air conditions compared to the regulations (not to scale).

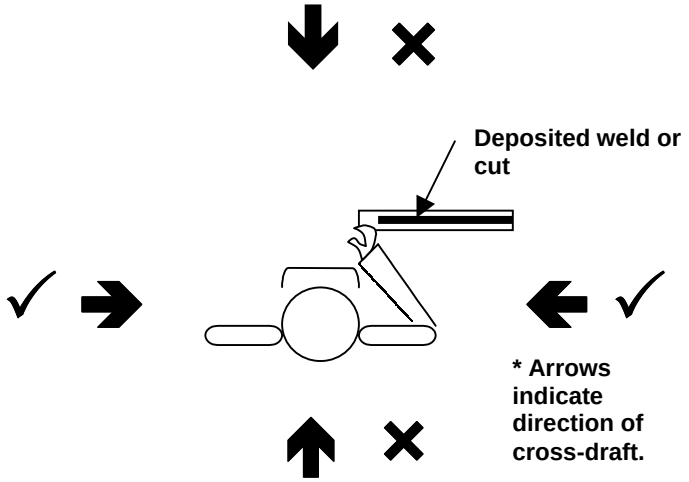


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

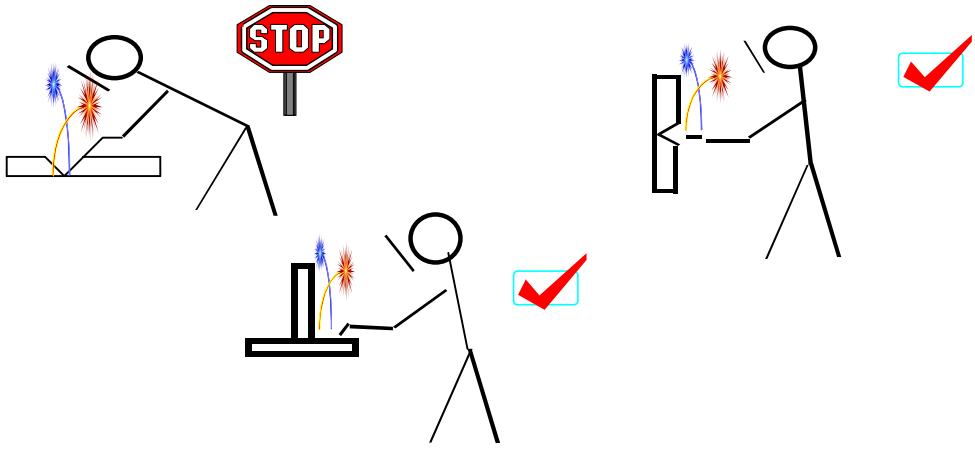


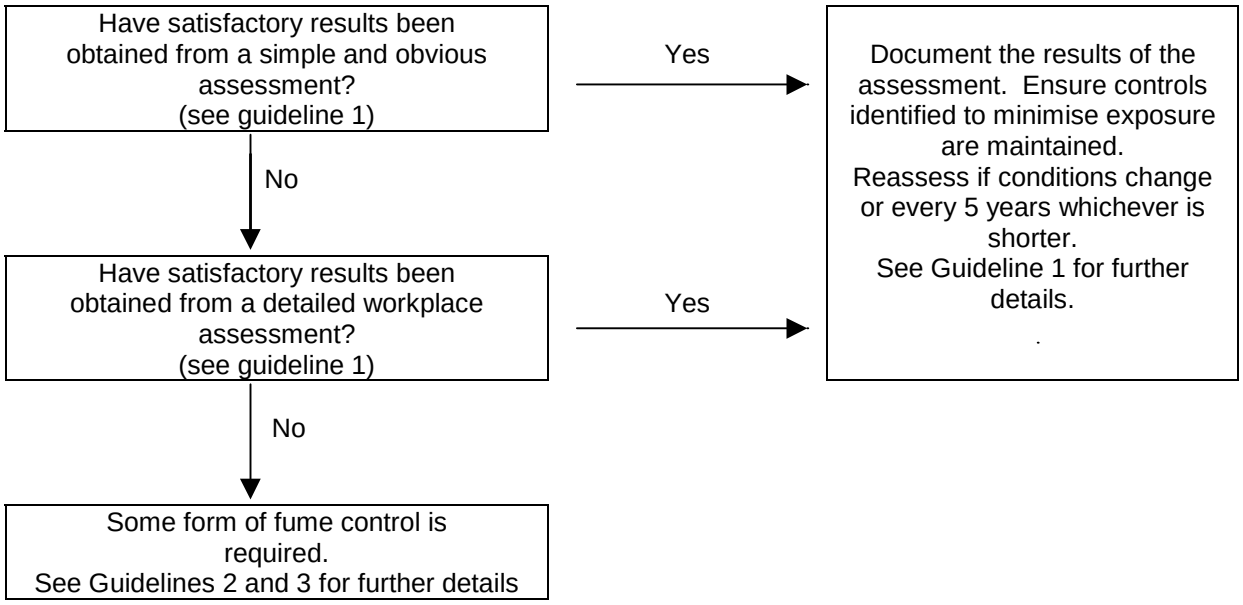
Figure 3. The welder's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 9:

PLASMA CUTTING

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



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

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

- **Process Modifications**

    1) Arrange cutting to reduce operators exposure as shown in Figure 3. This also reduces fatigue and back problems.
    2) Plasma cutting is easily mechanised and readily automated.

Note:
Automatic cutting processes (water table or travelling head) are beyond the scope of this guideline. Please consult the manufacturer for safe use of automated plasma cutting equipment.

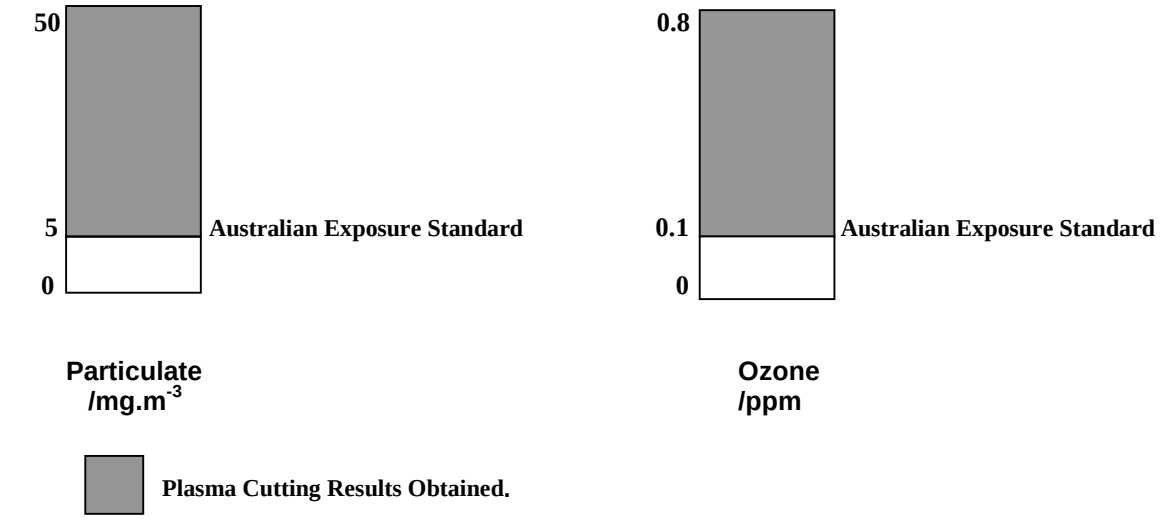


Figure 1. Plasma cutting fume production at the breathing zone under still air conditions compared to the regulations.

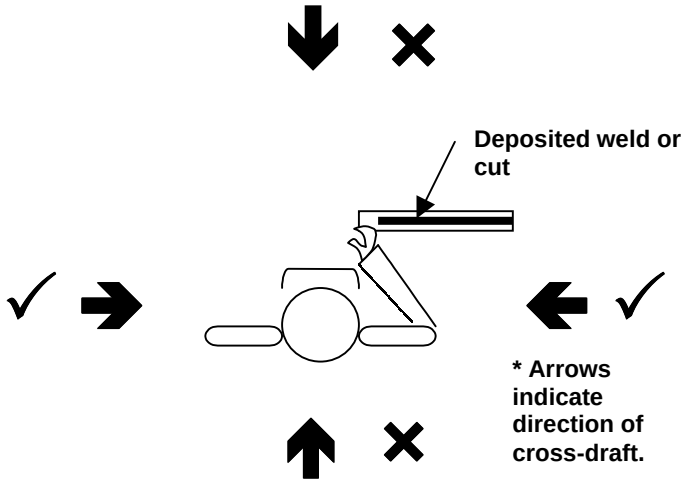


Figure 2. Preferred and non – preferred direction of cross draft for breathing zone ventilation.

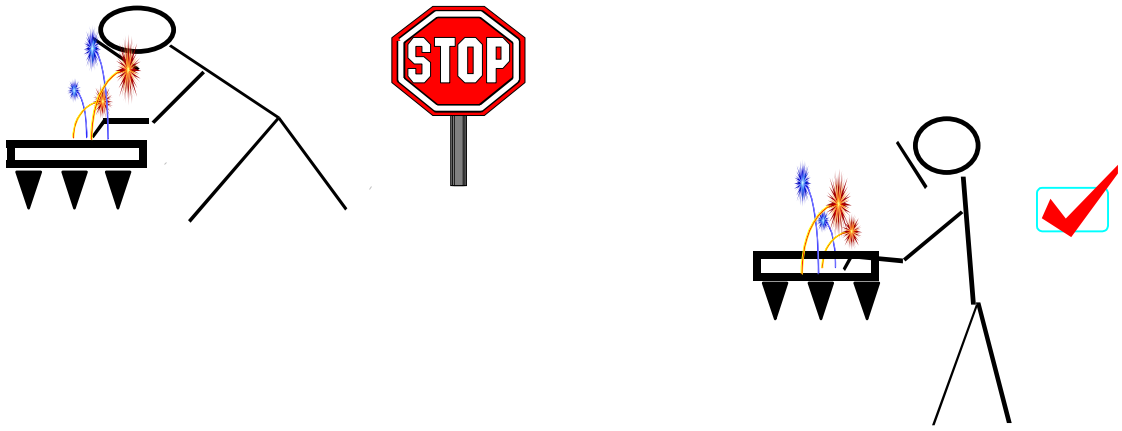


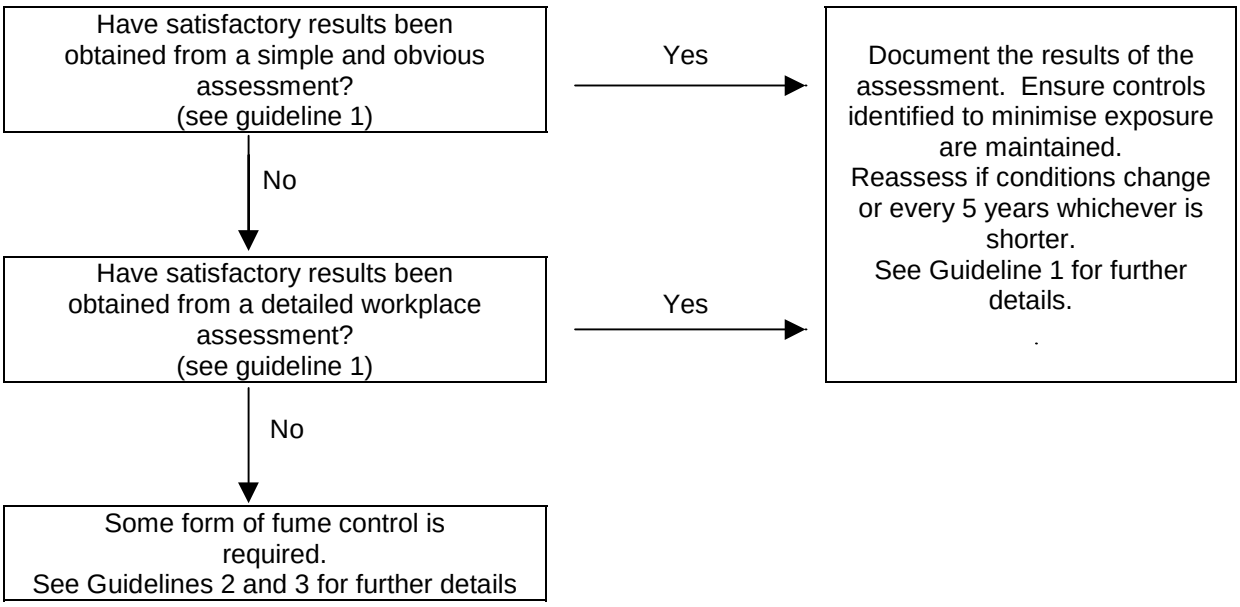
Figure 3. The operator's head should not enter the visible fume plume.

FUME MINIMISATION GUIDELINES

GUIDELINE 10:

OXY-FUEL CUTTING

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



Steps To Reduce The Effect Of Fumes And Gases

- **Process Alternatives**

    1) Consider guillotining, plasma cutting, mechanical cutting or water jet cutting.

- **Process Modifications**

    1) Arrange cutting to reduce operators exposure as shown in Figure 3. This also reduces fatigue and back problems.
    2) Oxy-fuel cutting is easily mechanised and readily automated. Guide wheels are available for manual cutting torches.

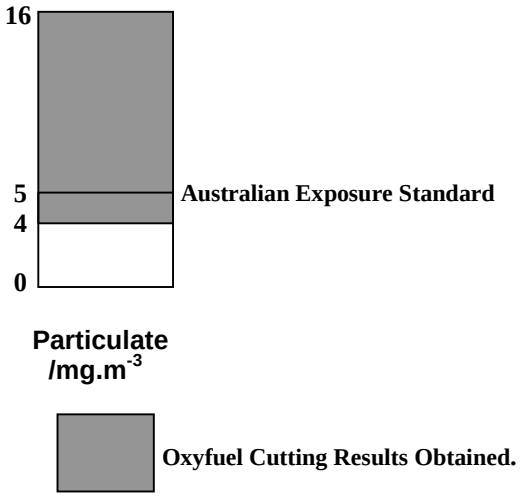


Figure 1. Oxy-fuel cutting fume production at the breathing zone under still air conditions compared to the regulations.

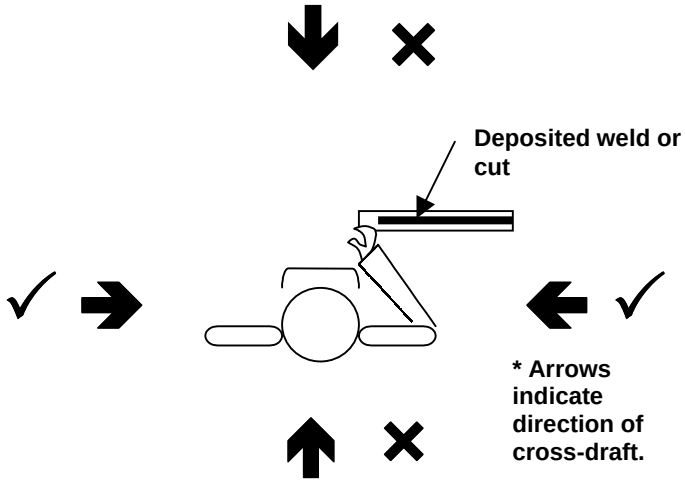


Figure 2. Preferred and non - preferred direction of cross draft for breathing zone ventilation.

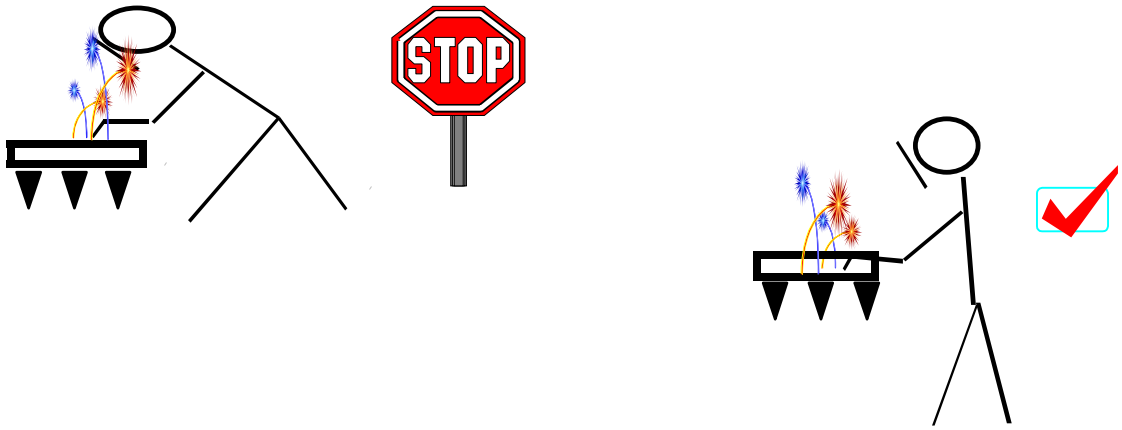


Figure 3. The welder's head should not enter the visible fume plume.