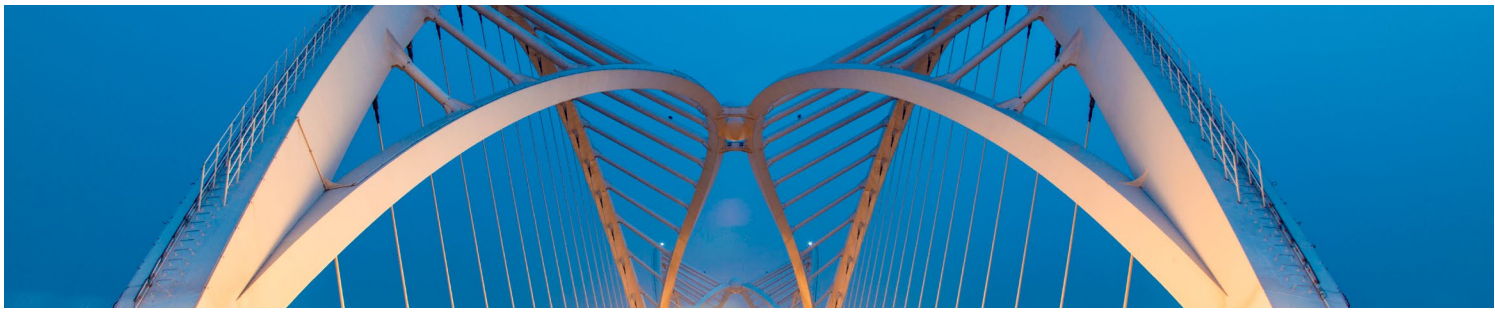


Weld Australia Technical Note 7:
Health and Safety in Welding

Weld Australia



This Technical Note:

- Is the sixth edition and a revision of the fifth edition of Technical Note 7 published in 2020;
- Provides practical guidance and the latest information available from a wide range of research and experience related to safety and health in welding and allied operations including electrical safety;
- Has taken cognisance of WHS regulatory changes, and the IARC ruling regarding weld fume and cancer, and similarly exposure to UV radiation arising from arc welding;
- Gives positive guidance on safe practice together with a brief explanation for such practices;
- Is intended to assist all personnel involved in welding and allied processes including welders, supervisors, inspectors, managers and engineers in industry and Government;
- Has been revised under the direction of an expert working group consisting of:
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- Has been endorsed by Weld Australia's Welding Safety Council consisting representatives from:
    - Safe Work Australia
    - SafeWork New South Wales
    - SafeWork South Australia
    - WorkSafe Tasmania
    - WorkSafe Victoria
    - WorkSafe Western Australia
    - Workplace Health and Safety Queensland
    - Skills Tech, TAFE Queensland
    - Australian Institute of Occupational Hygienists (AIOH)
    - Industry

Future Revisions

This Technical Note will be revised from time to time and comments aimed at improving its value will be welcomed. This publication is copyright and extracts from this publication shall not be re-printed or published without the Publisher's express consent.

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Disclaimer

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Should expert assistance be required, the services of a competent professional person should be sought.

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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 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 Mission

Our mission is to represent the interests of members and safeguard the public by ensuring the integrity of in-service welds, and to promote the use of best practice technology and quality systems.

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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
- A pathway for learning and career development and the opportunity to benchmark against world's best practice

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1. Introduction

This Technical Note gives guidance on health and safety practices in various welding, cutting and allied processes such as brazing, soldering, pre- and post-weld material treatments and metal spraying, for:

a) The prevention of injury to persons.

b) The prevention of ill health and discomfort.

c) The prevention of damage to property, equipment and environment by fire, explosion etc.

Various Chapters deal with:

i) The basic principles of safe working.

ii) The main hazards and safety measures in welding, cutting and allied processes used in industry.

iii) Precautions required in specific working situations.

Whilst it falls outside the scope of this Technical Note, it is important to appreciate that safety also requires proper adherence to welding and related standards and ongoing care of weldments, particularly those that could fail in later service and may result in injury to other persons. Examples include incorrect weld design, use of incorrect materials, incorrect welding and production of defective welds, all of which have resulted in some serious failures in service of structures and pressure equipment. Another example is the fracture of a high strength reinforcing bar due to crack initiation from stray arcing, with subsequent serious injury to a workman.

This Technical Note has been prepared to complement available literature by presenting the latest information on matters of health and safety in thermal cutting and welding. Its objective is to assist all involved, by serving as a basis for the general guidance of industry and for the training of personnel. Information has been drawn from the latest editions of a range of documents listed in Appendix A, however reference should always be made to the specific relevant Standards for more detailed information.

In this Technical Note, it has not been practicable to give detailed guidance on every health and safety matter relating to cutting and welding. Where any doubt exists, advice should be sought from suitably qualified health and safety professionals. Additional resources are available via the Australian Institute of Occupational Hygienists https://www.aioh.org.au/ and https://www.breathefreelyaustralia.org.au/.

Documents referred to within the text of this Technical Note are listed at the end of each Chapter including standards. References to standards should always be made to the latest issue of a standard or code. Australian, New Zealand and other standards are available via the Standards Australia website https://www.standards.org.au/.

Where the Technical Note also makes reference to Safe Work Australia's model codes of practice, readers should be aware that state and territory regulators also produce similar publications for which in some cases compliance is mandatory.

A list of references used in past editions of this Technical Note can be found in Appendix A.

> **Note**: *The forms and pop-out guidance documents included within this Technical Note have been republished by Weld Australia as Technical Guidance Note TGN-SW07 Health and safety in welding—Guides and Forms.*



2. The Changing Workplace

2.1 General

Workplace health and safety legislation and regulations are continually being revised throughout Australia to improve Workplace Health and Safety (WHS) in the workplace, thus leading to:

a) Reduced workplace accidents and injuries and improved health and comfort of workers;

b) Identification of potential risks and long terms effects caused by extended exposure from occupational hazards;

c) Reduced loss of time and services of experienced people due to accidents and ill health;

d) Prevention of and reduced consequential damage to property and equipment by fire, explosion etc;

e) Higher quality, greater efficiency and increased production and competitiveness; and,

f) Greater economy both to industry and to the nation.

Weld Australia has a strong interest in safety and health in welding and is involved in research and support to industry in this field.

All Australian states, territories and the Commonwealth are responsible for making and enforcing their own jurisdiction's WHS legislation. However, to support business and workers a process of harmonisation commenced in the 1990s under agreement at Council of Australian Government (COAG), now replaced by the National Federation Reform Council (NFRC) on 29 May 2020. In December 2011, a set of model WHS legislation was developed which have been substantially adopted in most states except Victoria. Readers should always consider the WHS legislation and regulation that apply in their state or territory.

The national Model legislation brought with it the introduction of model Codes of Practice for specific activities, which in many cases are reformatted and used in state and territory jurisdictions as approved state codes of practice.

Model Codes of Practice have been developed by Safe Work Australia including one on *Welding and Allied Processes*. The welding code has been adopted in most states as a state enforceable Code of Practice. Weld Australia's Technical Note 7 and Technical Note 22 *Welding electrical safety* are referenced in this Code of Practice. The Code of Practice[1] is available free of charge from the Safe Work Australia website www.safeworkaustralia.gov.au.

Of particular importance to gas, fume and dust exposures due to welding and thermal cutting exposures is the introduction of revised Workplace Exposure Limits (WELs) for airborne contaminants under WHS regulations, effective from 1 December 2026. These will replace the Workplace Exposure Standards (WESs). Resources[2] for understanding WHS duties regarding managing risks from airborne contaminants is available from the Safe Work Australia website www.safeworkaustralia.gov.au.

The welding and fabrication industry consists of a large number of people engaged in an extremely wide range of processes and working conditions where significant hazards are present, and injuries and illnesses can occur. When carried out in the correct manner, using appropriate equipment and working under safe conditions, operations such as welding, cutting, gouging, grinding, burring etc, present minor risks to health and safety.

Despite the advances in welding work health and safety practices, injuries and illnesses still occur, almost always involving human error. Significant contributors include the failure to identify and manage all potential hazards e.g. including the use of inappropriate or poorly maintained equipment.

Hazard identification and management (see Chapter 3) must be considered early at the design stage of any project. All personnel involved in the design and fabrication of welded structures must be aware of and consider the management of hazards associated with the use of a particular material and a particular welding process. They should make every effort to apply the hierarchy of control process to minimise potential exposures to hazards during production and ongoing maintenance of welded structures.

2.2 Accidents and Occupational Diseases Among Cutting and Welding Personnel

People employed in welding and allied processes are exposed to a higher than average risk of acquiring injuries and diseases in the respiratory, musculoskeletal, and cardiovascular systems.

There is consistent evidence that welders exposed to excess weld fume die more often of pneumonia, especially lobar pneumonia, are hospitalised more often for lobar and pneumococcal pneumonia, and more often develop invasive pneumococcal disease than the general population[3,4].

A generally high prevalence of musculoskeletal complaints is also a common finding in all types of heavy manual work. Designers need to be aware of the requirements for welding personnel to access and work in areas that can be cramped and confined.

2.2.1 Work Conditions in Different Production Areas

Attracting and sustaining a skilled workforce is becoming more competitive with working conditions becoming increasingly important in the competition for labour. Factors that need to be considered are not confined to addressing just the mechanical aspects and designing tasks to be less physically arduous. It is also necessary to ensure the work is stimulating and rewarding with appropriate levels of challenge to skills, delegated responsibility, training and development potential. These are essential considerations in creating more interesting, safer and more satisfying jobs and a greater degree of involvement and ongoing commitment.

Some considerations to minimise the physical and ergonomic challenges of fabrication are:

a) Design of the cutting and welding environment to enable a particular process to be used;

b) Use of jigs and fixtures;

c) Use of aids to minimise hazardous manual tasks;

d) Use of automation and mechanisation;

e) Design of joints to minimise or eliminate processing in difficult-to-access areas;

f) Welding from one side only, or if this is impractical, minimise processing by welding first from the more difficult access side then back gouging, grinding and welding from the less difficult-to-access side.

2.3 Mechanisation and Automation of Welding

Automation and mechanisation will not only bring changes in welding technology, it will also improve the professional and social lives of welders/operators. The objective of mechanisation and automation is not only to replace the physical effort of people by that of machines, it also transfers the control of a multitude of intricate and difficult to control processes from the welder to automatic welding systems and welding robots. Increasingly, development in capability and steadily reducing cost of microelectronics, computers and information technology now places the achievement of these objectives within our reach, including the use of cobots (see Section 28.3.3) with their collaborative interaction outside of the normal “no-entry” areas associated with the use of robots.

Mechanisation and automation are becoming increasingly accessible even to smaller operations, however this approach is not always practical, economical, or possible depending on production volumes and time frames.

2.4 Productivity and Environment

Significant gains in productivity can be achieved provided all the industrial safety and environmental factors are considered correctly. Environmental costs must be weighed against specified criteria as well as the subjective perception of improvements. Some generalisations can be made based on recent improvements in manufacturing. For example, productivity is enhanced if:

- The welder is more comfortable (see Section 2.4.3);
- Cutting accuracy is high;
- Weld fit-up is accurate and consistent;
- Cutting and welding equipment is well maintained.

2.4.1 New Production Systems

The introduction of production-line technology in steel prefabrication of larger structures has resulted in throughput times being more predictable. Examples of these enabling technologies include:

a) Precision manufacturing with laser cutting and welding in one production line;

b) Modular fabrication methods;

c) High levels of mechanisation and automation utilizing computer-aided design (CAD), computer aided engineering (CAE) and computer-aided manufacturing (CAM) with extensive computer and computer-integrated manufacturing (CIM) use;

d) An increase in operator-machine interfaces in shop floor control systems.

There is a challenge to train and motivate personnel for high-technology production. Human resources are critical in the production environment of the future due to increased complexity of work and machines.



2.4.2 Purchase of Production Machines and Welding Equipment to Improve Process Performance

It is important that when new equipment is purchased with the intention of upgrading to better technology for improvements in productivity, quality, capability or efficiency, there is capability in the company to deal with the inevitable issues around commissioning and implementation, and, the expected improvements are realistic. The purchase of production machines and welding equipment and the initial adaption of the process can result in unnecessary delays or non-conformances, which could have an adverse effect on the workforce.

Work performance must be based on criteria related to the abilities and limitations of the operator. Advice from a supplier may be minimal, inappropriate or inadequate for the specific production environment and lead to a failure to perform because all the relevant environmental factors are not taken into account. Some general guidelines include the following:

a) Power sources and ancillary equipment should be as small, powerful and efficient as practicable;

b) Welding cables and guns should be as light and flexible as possible consistent with power rating, duty cycle and durability;

c) Strain relief systems should be introduced wherever practicable to minimise loads on the operator;

d) Processes such as waveform-controlled Gas Metal Arc Welding (GMAW), Flux Cored Arc Welding (FCAW), Tandem GMAW, Friction Stir Welding etc. should be introduced to enable higher productivity and quality;

e) Use of Manual Metal Arc Welding (MMAW) and Submerged Arc Welding (SAW) where mechanical properties are difficult to achieve;

f) Fixtures and manipulators should be utilised to facilitate assembly and welding with minimal physical labour by welders.

2.4.3 Ergonomics on the Production Floor

Ergonomics combines knowledge from the cognitive, organisational and physical domains in order to optimise the wellbeing of personnel and overall system performance in relation to people's needs, abilities and limitations.

Few ergonomists cover the entire field, and it is usually personal interest that determines the individual's profile of expertise. Teamwork for all levels in any organisation contributes to the total knowledge available, particularly participatory ergonomics giving affected workers direct influence over the outcomes.

For a comprehensive workplace survey for example, team members should include ergonomists to facilitate the search for human and practical solutions. The trained ergonomist should engage with and support the team, and try to identify in advance work situations to facilitate fitting the job to the worker.

Participatory ergonomics involving the direct participation of welders and operators in developing and implementing changes in their workplace, can therefore be especially effective.

Poor ergonomics mean not only impaired quality of work, but also increased risk of acquiring health problems that may force the welder into periods of sick leave and eventually premature retirement. It is well documented that musculoskeletal disorders are a major reason for early retirement of welders.
Ergonomists have been involved in the development of a specialised Welders Chair in Europe.

2.4.4 Competence Training and Management for Welding

Welding personnel should be trained in the most comprehensive way practicable enabling them to act on their own authority within their area of responsibility. Training should address the total skill set required for a particular area of activity. It is not sufficient to pass on selected skills and knowledge in individual, isolated subfields.

Comprehensive knowledge extending across processes and reflecting the latest status of technical and scientific development is a prerequisite for technical decision makers. As it may be difficult to locate or recruit suitably qualified personnel, there is a need to undertake advanced training geared to the specific requirements of welding personnel (welders, machine operators and welding supervisory personnel) to ensure the quality of the product.

2.4.5 Access for Maintenance

Designers should be trained and competent to design components that enable access for initial production and through life maintenance to avoid having to make significant modification e.g. cut holes in the hull of a ship, to provide access for welding, maintenance or repairs.

2.5 References

1. Safe Work Australia, Model Code of Practice: *Welding processes*, July 2020
2. Safe Work Australia, *WES and WEL Resources*
3. Palmer, KT & P Cosgrove, *Vaccinating welders against pneumonia*, Occupational Medicine (London), 2013
4. AIOH Position Paper, *Welding and Thermal Cutting Fume – Potential for Occupational Health Issues*, 2022

3. Principles of Safe Working

3.1 Basic Objective

All industrial operations including cutting and welding, introduce hazards and potential risks that may affect the health and safety of personnel undertaking the operations or those who are bystanders, if adequate precautions are not taken. WHS legislation therefore places legal obligations upon employers or businesses, or anyone who falls under the definition of a *person conducting a business or undertaking* (i.e. a PCBU), to ensure that work is always carried out in such a manner as to maintain:

a) The health (i.e. wellbeing and soundness of body) of personnel directly engaged in the work, their associates and other nearby persons; and,

b) The safety (i.e. minimisation of risk) of all personnel involved including those nearby, and plant, equipment and the environment.

Importantly WHS legislation also includes requirements to consider psychosocial hazards to the safety and wellbeing of personnel. Refer to section 29.11 of this document.

3.2 Managing Hazards and Risks

3.2.1 Hazard Identification

Employers or businesses, or anyone who falls under the definition of a PCBU (i.e. *person conducting a business or undertaking*), as well as other people involved in workplace operations must be aware of all hazards that could arise. The employer and/or PCBU (including the person with management or control) has a legal duty to eliminate or to make sure, so far as is reasonably practicable, that there are no health and safety risks to anyone working in or visiting the workplace.

This includes ensuring that safe work practices are followed.

Whilst the PCBU has ultimately responsibility for workplace health and safety, everyone has a responsibility to look out for the safety of themselves and others.

To achieve a safe workplace, it is necessary to conduct a hazard identification and risk assessment for all procedures, plant and chemicals used in the workplace. The result of a competent hazard identification and risk assessment should include:

a) Identification of hazards in the workplace and the way in which the hazards can cause injury or ill health;

b) Assessment of the magnitude of the risk (see Section 3.3.2.1); and

c) Control of all hazards to eliminate them or minimise risks to health and safety.

The terms HAZARD and RISK are defined as:

- **Hazard** is a situation with potential to harm; and,
- **Risk** is the combination of the likelihood, and consequence(s) of failure to manage a hazard.

  Note*: Risk may also be a multiple of the hazard in some situations e.g. changing MMAW electrodes in an environment with increased risk of electric shock, the measure of risk is the hazard times the number of electrode changes. In this scenario, the risk may be minimised by reducing or eliminating the risk of electric shock through the use of suitable hazard reduction devices (HRDs) to avoid or limit the harm.*

The legislation does not necessarily specify how a business must manage its workplace health and safety risks. The methods that are commonly utilised include:

i) Implementation of a safety management system (e.g. see AS/NZS ISO 45001[1]);

ii) Implementation of a risk management process;

iii) Consultation with employees (and contractors where relevant) about workplace safety, identification of hazards, and implementation of suitable controls;

iv) Maintenance of facilities to ensure a safe, uncluttered work environment;

v) Training appropriate to employee tasks and responsibilities to ensure safe work practices;

vi) Implementation of appropriate procedures for people working alone, or in remote/isolated worksites;

vii) Implementation and practice of emergency plans for foreseeable emergencies (e.g. emergency evacuation drills);

viii) Provision of first-aid equipment and training of first-aid responders.

3.2.2 Assessment of Risk

3.2.2.1 Reasonably Practicable

It is a requirement of WHS legislation that hazards identified in the workplace be eliminated, and where this cannot be done, the hazards must be reduced to as low as reasonably practicable.

Prior to conducting a risk assessment, it is important to understand what the legislation requires in terms of minimising a hazard where it cannot be eliminated. By utilising the term *reasonably practicable* it means that PCBUs must do everything that is reasonable and practical to ensure the health and safety of workers and others when it is not possible to eliminate the health and safety hazards in the workplace.

Hazards need to be identified, risks assessed, and steps taken to eliminate or control these hazards to minimise the associated risks to health and safety. This includes consideration being given to hazards that result from a combination of circumstances that in isolation create little problem e.g. local overheating of a cable connector may set alight adjacent flammable material and cause a fire.

To help determine what is reasonably practicable to meet a health and safety duty, SafeWork Australia has published a guide titled *How to determine what is reasonably practicable to meet a health and safety duty*[2].

This guide indicates that when determining what is reasonably practicable, the following should be considered:

- The likelihood of the hazard or risk occurring;
- The degree of harm that might result from the hazard or risk;
- What the person in control knows or reasonably ought to know about the hazard or the risk and the ways of eliminating or minimising the hazard or risk;
- The availability and suitability of ways to eliminate or minimise the risk;
- After assessing the risk, whether the costs associated to minimise the risk are grossly disproportionate to the risk.

Documents such as Codes of Practice published by the various Regulatory bodies may be used to help identify hazards and determine what is reasonably practicable to eliminate a risk to health and safety in the workplace. Courts may regard a Code of Practice as evidence of what is known (or ought to be known) about a hazard, risk or control. They may also rely on the Codes in determining what is reasonably practicable. Similarly, documents such as Weld Australia's *Technical Note 7* and associated *Technical Guidance Notes* may also be used to identify what is known about a hazard or risk, or ought to be known given the ready availability of such publications.

In some jurisdictions, users should be aware that conformance with some Codes of Practice is now a regulatory requirement. In such situations, the PCBU is required to adhere at least to the minimum requirements specified within the relevant Code unless they can demonstrate that their practices deliver an equivalent or better outcome from a WHS and hazard-management perspective.

> **Note***: Weld Australia's Technical Note 7 and associated Technical Guidance Notes are referenced in many of the Codes of Practice, or in some cases, recognised directly as a Code of Practice in regulations.*

It is important to note that the model WHS Act makes it clear that a person cannot avoid their obligations under the Act by contracting them to someone else.

3.2.2.2 Hierarchy of Control

As previously noted in 3.2.2.1, where the hazards identified in the workplace cannot be eliminated, the hazards must be reduced to as low as reasonably practicable. Where it is necessary to control hazards in a reasonably practical situation, WHS regulations require the application of controls ranging from most effective to least effective in that order.

The hierarchy is a list (or order) of steps that must be followed when managing hazards and risks in the workplace (Figure 3.1):

a) Elimination;

b) Substitution, Isolation, and/or Engineering controls;

c) Administration

d) Personal protective equipment (PPE)

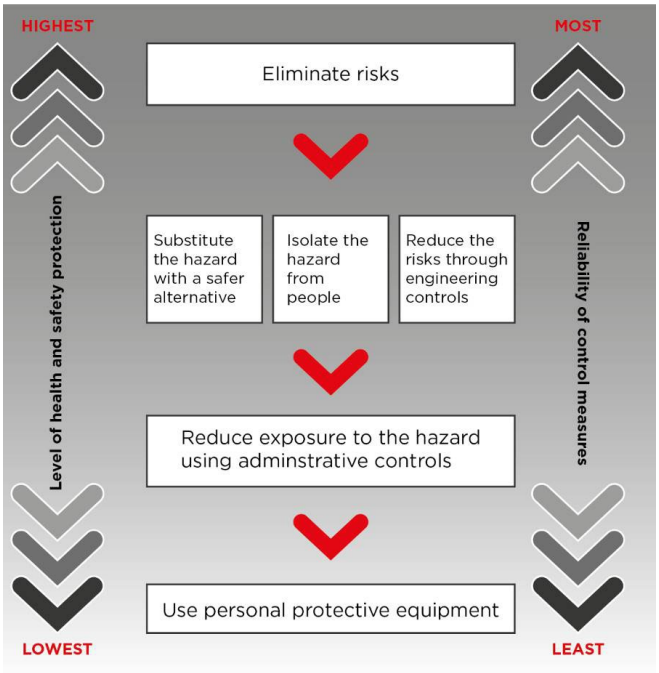


Figure 3.1 **Hierarchy of controls**
Source: Safe Work Australia[3]

For example, Section 17.1 and Figure 17.1 illustrates the use of these methods in relation to controlling the hazards associated with exposure to weld fume.

WHS legislation also advises that a combination of methods may be required to minimise a risk if a single control is deemed insufficient. The hierarchy in order of priority is:

(i) Elimination
Where possible **eliminate** the use of hazardous equipment or methods. For example, remove a dangerous machine from the workplace or stop using a dangerous/hazardous practice.

(ii) Substitution
Where elimination is not possible, **substitute** safer equipment or methods for the hazardous ones. For example, replace a more dangerous AC MMAW welding machine with a less hazardous DC MMAW welding machine fitted with an active voltage reduction device (VRD).

> **Note***: Whilst the use of DC can reduce the risk, it can be just as deadly as AC if a VRD is not used in combination with the DC*[4]*.*

(iii) Isolation
Where elimination or substitution is not possible, enclose or **isolate** the hazard from people. For example, from an electrical perspective, ensure power is off every time the welder changes an electrode when using the MMAW process.

(iv) Engineering Controls
Where elimination, substitution or isolation is not possible, minimise the risk by **engineering controls**. For example:

1. Attach flashback arrestors to both ends of oxygen and acetylene hoses to minimise the risk of and damage to equipment resulting from flashback.
2. Use of local exhaust ventilation (fume extraction) for reducing exposure to welding fume.

(v) Administrative Controls
Where elimination, substitution, isolation or engineering controls are not possible, minimise the risk by **administrative controls**, usually by developing and implementing safer working practices and by providing appropriate training, instruction or information. For example, ensure procedures correctly identify and address strategies to minimise hazards and ensure personnel are adequately trained.

(vi) Personal Protective Equipment
Where elimination, substitution, isolation, engineering controls or administrative controls are not possible, minimise the risk by using **personal protective equipment** (PPE) as a second line of defence when other means are not appropriate or fail e.g. use of gloves, respiratory protection. Due to the nature of some hazards encountered in cutting and welding, PPE such as face shields, welding helmets, gloves, spats, aprons etc.is the first and only line of defence. It is therefore essential that the correct equipment be made available, that it is fit for purpose, correctly fitted and used, and correctly maintained

All PPE should be regularly checked and replaced as necessary. All PPE should be selected, purchased and maintained to meet the requirements of the relevant Australian standards, and be commensurate with the identified hazards.

3.2.3 Limiting the Impact of Hazards

Safe Work Australia and the various State Government authorities have produced a series of approved codes of practice, including codes of practice relevant to the control of workplace hazardous chemicals (formerly referred to as hazardous substances) with welding and cutting (see Appendix A of this Technical Note). These should be consulted in conjunction with this Technical Note to provide detailed information on how to achieve compliance with the relevant work health and safety legislation.

For practical advice and tips on managing risks, Safe Work Australia has published codes of practice specifically dealing with the management of health and safety risks (see also Appendix A of this Technical Note).



3.2.4 Consultation and Review

Consultation with workers is an important component in the management of hazards and risks in the workplace. Consultation can take numerous forms such as:

a) WHS committees;

b) Discussions with WHS representatives nominated by the employees;

c) Toolbox meetings prior to the commencement of a task or process.

Under some State legislation, WHS committees are required to discuss health and safety aspects of the workplace. These committees are particularly relevant in organisations involved in welding, cutting, spraying, brazing or soldering activities.

Through the consultation process, controls in place to eliminate or minimise the risk of injury or illness to workers or others must be regularly reviewed and updated to ensure that they remain the most effective method of controlling hazards in the workplace. Irrespective of how the review is conducted, it should be fully documented and be repeated whenever new procedures, tasks or chemicals are introduced to the workplace, or otherwise at least every 5 years.

The effectiveness of risk controls can also be conducted by alternative methods including:

- Analysing the PCBU's or business's register of injuries;
- Regular site audits/walks/inspections with employees (and contractors);
- Toolbox talks with workers prior to the commencement of work.

3.3 Risk Assessment Methods and Procedures

3.3.1 Work Health and Safety Program

A planned approach to work health and safety must be taken at each plant or work site. A systematic approach that may include the use of cutting and welding specific check lists, discussions with employees and detailed consideration of workplace specific problems should be applied to ensure all foreseeable hazards are identified assessed and controlled. The production of all hazards, including fumes from welding, cutting and allied processes must be addressed in this process.

As part of assessing the risks, the effectiveness of existing controls should be evaluated.

Suitably experienced staff should conduct the risk assessment. It may be "simple and obvious" (SAO) or complex, depending on the nature of the hazards and the threat posed to health and safety. Professional assistance may need to be recruited from outside the organisation for complex situations and serious risks (threats) to health. An outcome of the risk assessment may be improved equipment design or upgraded safety devices. Standard operating procedures and the nature of induction training required to operate plant and other tasks should grow out of the risk assessment process. Documentation, such as Safety Data Sheets (also referred to as an *SDS*), and equipment instructions used in the assessment process should be available for reference.

The standard AS/NZS ISO 45001[1] may be particularly useful in this regard.

3.3.2 Conducting a Risk Assessment

3.3.2.1 Risk Assessment Process

Risk assessment is the process used to determine the level of risk of injury or illness associated with each identified hazard, for the purpose of control. The priority for control increases as the established level of risk increases. For a risk assessment to be carried out, the hazard must be identified and the level of risk is determined. Some legislation requires certain control action to be adopted, regardless of whether the risk has been determined. After identification of hazards, establishing the level of a risk for each identified hazard requires clear specification of the actual components of the risk being considered. Specifically:

(a) Identification of the hazard including the specific scenario or sequence of events;
(b) The exposure to the chosen hazard including the nature of consequences to be considered;
(c) Controls required to manage the hazard including consideration of the probability or likelihood of that scenario taking place;
(d) Review of the assessment.

Importantly, consult and communicate with the workers at all steps in this assessment process.

To combine these components of any risk in assessing its level, the following procedure may be adopted as summarised in Figure 3.2:

- Choose a specific consequence or outcome severity for one possible sequence of events involving the hazard under consideration. Other possible sequences with different possible consequences need to be assessed separately. The number of persons harmed, and the nature of their injuries/illness affect the estimation of the consequence or outcome severity.
- Determine the exposure for the chosen sequence, i.e. how often (frequency); how long (duration) and to what extent the affected persons are exposed

to the particular hazard (for a toxic hazard this would include any time-weighted average or peak exposure).
- Estimate the probability, likelihood or chance that the chosen scenario will lead to the specific consequences being considered. Every scenario considered for any particular hazard has its own specific risk level. The integrity and effectiveness of any existing risk control measures will need to be included in estimating probability.

The level of risk assessment depends on the complexity of the task. This may include, but is not limited to:
- Basic risk assessment
- Process Hazard Analysis (PHA) – detailed study of the hazards of the proposed process, completed by specific team members and facilitated by an experienced PHA leader;
- Failure Mode Effects Analysis (FMEA) – a detailed study of the effects of failures on the modes of operation of the proposed process, completed by specific team members and facilitated by an experienced FMEA leader;
- Hazard Operability (HAZOP) – a study of the hazards of operation of the proposed process, completed by specific team members and facilitated by an experienced HAZOP leader.

Hazard identification and risk assessment may also be conducted in accordance with the guidelines in AS ISO 31000[5]. The assessment should be fully documented and be repeated whenever new procedures, processes or chemicals are introduced in the workplace, or otherwise at least every 5 years.

It is important to note that the appropriate people must be involved in the risk assessment process so that all critical information can be identified, considered and applied.

Notes

1. *Additional information on the assessment of risk can be found in Safe Work Australia's Model Code of Practice[3] and Weld Australia's Technical Note 20.*
2. *Specialist advice may also be sought from an occupational hygienist, particularly in the preparation and implementation of the risk assessment, and the verification of the application of the controls. Refer to the Australian Institute of Occupational Hygienists website at: www.aioh.org.au.*

3.3.2.2 Job Safety and Environmental Analysis (JSEA)

A very common risk assessment process used in industry is the Job Safety and Environmental Analysis or JSEA. The format is generally utilised to conduct initial assessments of tasks and for infrequent activities. Tasks performed on a more regular basis should preferably be controlled by a written procedure with reference made to the job steps, known hazards, and required control measures.

Note*: In some industries, the JSEA may be referred by other titles, including Job safety Analysis (JSA) or Job Hazard Analysis (JHA).*

Risk Score		Consequence				
		Fatality or TPI	LTI	MTI	First Aid Required	Incident Report
Likelihood	Common, repeat event	E	E	E	H	H
	Known to occur	E	E	H	H	M
	Could occur	E	E	H	M	L
	Could occur, but unlikely	E	H	M	L	L
	Rare, unlikely to happen	H	H	M	L	L

Legend

TPI Permanent Disability
LTI Lost Time Injury
MTI Medical Treated Injury

Risk Score:

L = Low
M = Medium
H = High
E = Extreme

Figure 3.2 Risk assessment application

The features of the JSEA and similar forms (Figure 3.3) are as follows:

a) In column 1, list all job steps in sequence order

b) In column 2, list all known risks

c) In column 3, making reference to Figure 3.2, assess the likelihood and consequence for the raw risks.

d) In column 4, record the control measures required to minimise the risks

e) In column 5, making reference to Figure 3.2, assess the likelihood and consequence for the controlled risks.

f) In column 6, record who is responsible to implement each hazard control and the date it is completed.

In compiling the JSEA, reference can be made to Table 3.1 and Section 3.3.3 for information on common welding and related hazards.

As PCBUs are required to do everything that is reasonably practicable to minimise risks to the health and safety of all workers and others (see Section 3.2.2.1), job steps that result in a risk score other than "Low" will most likely require additional control measures to minimise the risk.

The need to perform job steps that result in a risk score of "High" or "Extreme" must be reconsidered, or additional controls put in place to reduce the risk score. For example, a fabricator using the AC MMAW process should be aware that contact with the open circuit voltage (e.g. when changing electrodes, initiating the arc etc) has led to numerous electrocution fatalities in Australia and therefore the process has a risk rating of E or Extreme. To minimise risks when using the MMAW process, DC output in combination with an active voltage reduction device (i.e. a VRD) on the output is essential. When using a DC MMAW welding machine, the risk rating is L or Low if either of the following are used:

- A VRD that limits the output voltage to 12V or less and is used in combination with a secondary hazard reduction device (HRD) such as an in-line switch that ensures 0V at the electrode holder whilst the welder is changing electrodes/repositioning their body in preparation to strike the arc.

3.3.2.3 Safe Work Method Statements (SWMS)

A Safe Work Method Statement or SWMS is a document initially specified for use in the construction industry. Whilst initially used for high-risk construction activities, SWMS documents are also often specified for use when hot work is required in other high-risk industries including e.g. mining and quarrying. The SWMS document:

- Identifies the high-risk construction work activities to be carried out at a workplace;
- The hazards arising from these activities; and,
- The measures required to control the risks.

The SWMS is an administrative control intended to assist supervisors and workers confirm and monitor the control measures required at the workplace. As the SWMS is not a procedure, it varies from other documents that focus on specific tasks or processes such as the JSEA (see Section 3.3.2.2) or Safe Operating Procedure (see Section 3.3.2.4). An example of a SWMS can be found in Appendix D.

> ***Note**: Safe Work Australia has produced an information sheet on the use the SWMS which includes a National SWMS template.*

3.3.2.4 Safe Working Procedures

A safe working procedure document should be completed for each task or activity involved when a JSEA is not being utilised. Having identified feasible hazards, steps must be implemented to prevent damage, incidents or injuries to all persons in the workplace. Such steps include:

a) Regular checking and maintenance of equipment.

b) Induction and periodic training of personnel in health and safety procedures.

c) Ensuring suitable safety devices are installed.

d) Ensuring safe working methods and procedures are known and observed.

e) Ensuring suitable personal protective equipment is provided and maintained.

f) Periodic review of control procedures to determine effectiveness.

g) Procedures to ensure that contract workers are aware of workplace hazards before they begin work.

3.3.3 Common Hazards of Cutting and Welding

The majority of workplace injuries and diseases are related to the type and location of the tasks.

In virtually all injuries, one or more of the following factors have been involved:

a) Failure to identify a hazard;

b) Failure to minimise or avoid (i.e control or eliminate) the hazard;

c) Lack of knowledge of the materials being used;

d) Inadequate controls (e.g. safety precautions);

Company .....

Job Details ..... Date .....

Location .....

Participants .....

Job Steps	Hazards	Raw Risk	Control Measures	Control Risk	Who /When

Authorised by ..... Participants signatures ....

Date ....

Figure 3.3 Job Safety and Environmental Analysis example proforma



Table 3.1 Examples of Hazards Associated with Welding and Allied Processes

Event	Details
Electric Shock	Contact with electrically live components on both primary and secondary circuits of cutting and welding power sources (i.e. the welding machine used for electric welding processes).
Radiation Burns	Burns to the eyes or body due to the welding arc. High intensity infrared (IR) and ultraviolet (UV) energy from welding power sources.
Thermal Burns	Burns due to weld spatter or contact with hot or molten materials; or due to burning of clothing etc. especially in oxygen enriched atmospheres.
Fire	Fire in the surrounding environment due to flammable materials, gases or liquids and particles due to hot metal, arc, flame, sparks, hot metal or spatter or electrical faults.
Explosion	Explosion of fuel gases, flammable gases contained within or flammable gaseous mixtures created within containers during hot work ignited by arcs, flames, sparks, hot metal or spatter or electrical faults in combination with flammable materials, gases or liquids.
Eye Injury	Radiation – excessive visible, IR or UV radiation, fume and foreign matter such as high velocity particles and falling dusts can cause injury.
Respiratory Problems	May result from inhalation of fume from cutting, welding, brazing, soldering or metallising and may be exacerbated by surface coatings and contaminants on the material being dealt with, from breakdown of contaminants such as residual chemicals in drums, paint or plastic bonded to metals.
Asphyxiation	Displacement of oxygen by non-toxic gases can be dangerous, particularly in unventilated environments and confined spaces.
Exposure to Fumes and Gases	i. Toxic gases – Gases used or produced during welding and allied tasks. ii. Inhalation – Inhalation of fume and dust.
Toxic Materials	i. Skin /eye contact with residues of hazardous chemicals and materials used in surface preparation such as solvents, cleaners, fluxes or residues of coatings, lubricants, etc. on surfaces affected by cutting and welding. ii. Ingestion of chemicals, dust and particles from residues on hands and face.
Hearing Impairment	Excessive noise exposure should be avoided. Noise may be generated by the process or transmitted to the operator by surrounding metal.
Physical Injuries	i. Muscular skeletal injuries – particularly when working in situations that are poorly ergonomically designed. Cutting and welding is often required in cramped, confined and awkward positions and often requires holding or manipulating equipment in ergonomically challenging situations. ii. Slips and trips – crowded and confined work locations increase the risk of slips and trips. iii. High velocity particles – grinding, chipping slag. iv. Striking injuries – there is a risk of physical injury when using any form of mechanised or robotic welding. v. Pinch points – older wire feeders are poorly guarded against personnel interaction with moving parts vi. Falling objects – striking injuries from larger objects
Falls	Working at heights or above openings increases risk.
Delayed Emergency Response	Ability to reach, treat or rescue an injured person in an appropriate time frame. Part of confined space management which may otherwise be overlooked.
Changes	Changes in work environment or working conditions.
Other Hazards	Those typically found in general engineering or in special areas e.g. radioactive NDE materials.

e) Poor equipment design or maintenance;

f) Poor working procedures, methods, or supervision;

g) Worker inexperience or lack of knowledge of operation;

h) Failure to monitor changing working environment and conditions e.g. damp clothing.

Hazards, injuries and illness that welding and cutting personnel (including supervisors and inspectors) are exposed to more frequently than other workers include those reported in Table 3.1. Younger and inexperienced welding personnel are particularly at risk.

3.4 Control Effectiveness

Conventional risk analysis is based on analysis of likelihood or probability (L) and consequences (C) and maybe biased by either procedural and or application errors. An alternative to the *L x C* risk analysis approach is to consider control effectiveness to determine acceptable risk.

The following are extracts from AS ISO 31000:2018 *Risk management – Guidelines*[5]

a) Clause 5.4.3 Assigning organizational roles, authorities, responsibilities and accountabilities

"Top management and oversight bodies, where applicable, should ensure that the authorities, responsibilities and accountabilities for relevant roles with respect to risk management are assigned and communicated at all levels of the organization, and should:

- *emphasize that risk management is a core responsibility;*
- *identify individuals who have the accountability and authority to manage risk (risk owners)."*

b) Clause 6.6 Monitoring and review

"The purpose of monitoring and review is to assure and improve the quality and effectiveness of process design, implementation and outcomes. Ongoing monitoring and periodic review of the risk management process and its outcomes should be a planned part of the risk management process, with responsibilities clearly defined.

Monitoring and review should take place in all stages of the process. Monitoring and review includes planning, gathering and analysing information, recording results and providing feedback.

The results of monitoring and review should be incorporated throughout the organization's performance management, measurement and reporting activities."

3.5 Energy Isolation

In the workplace, there may be many energy sources that have the potential to cause major injuries or death. Prior to any hot work being undertaken, it is imperative that all energy sources are identified, and requirements for their separation (i.e. isolation) from personnel and/or control are defined and implemented as they are critical requirements for protecting people.

Energy comes in many different forms, and each has to be considered before undertaking work. Using a systematic planned approach to isolation of energy sources provides a safe work environment.
A key element in a WHS Management System is the development, documentation and implementation of an isolation information system.

This may include but is not limited to:
- Individual isolation procedures and isolation plans
- Equipment manuals
- Schematic diagrams
- Equipment and isolator labelling
- Isolator location diagrams
- Standard v/s custom or one-off jobs
- Lists of assigned and authorized Isolation Planners, Isolating Persons, Responsible Managers, and Department/Location Managers.

Isolation plans must be controlled documents.

Key personnel involved in isolation management including Isolation Planners, Isolating Persons and Protected Persons must all be trained and have current authorization for the specific areas of operation.

3.5.1 Provision of Isolation Equipment

Typical isolation equipment includes:
- Lockable isolators;
- Colour coded locks – for example:
  - Personal locks (red)
  - Equipment locks (yellow)
  - Group locks (green)
- Identification (ID) tags;
- Multi-lock devices.

Other equipment that may be required includes:
- Lockout stations
- Isolation boards
- Hasps, chains, covers
- Warning tags.

Isolators should be uniquely and permanently labelled and fit for duty.



3.5.2 Isolation Planning

The Isolation Planner is responsible for planning, developing and clearly documenting the isolation procedure. Isolations should be planned to achieve total isolation.

Isolation plans require:
- An evaluation of the job(s)
- Identification of the energy types
- Assessment of the hazards
- Identification of the method of controlling the hazards
- A procedure for stopping the machine
- Identification of each isolator and its safe position
- A method for securing the isolator
- A method for restraining or dissipating any stored or residual energy (preventing re-accumulated energy)
- A method to verify the effectiveness of the isolation
- A procedure for returning to service, including sequence of de-isolation.

3.5.3 Performing Isolations

Only authorised Isolating Persons should perform isolations. The following outlines the typical steps:
- Obtain permission from the Plant Owner before isolating plant and equipment
- Use approved isolating equipment
- Conduct the isolation according to the isolation plan, including, in the following order, to:
  1. Check that equipment is stopped and safe to isolate
  2. Place each isolator in the safe position and confirm the identity of the isolator
  3. Lock/secure each isolator and dissipate or restrain any stored or residual energy
  4. Carry out necessary verification.
- Notify Protected Persons that the isolation has been completed.

3.5.3.1 Individual Isolations
- Use yellow equipment lock to secure isolator/s prior to verification
- After verification, attach a multi-lock device on each isolator, and place yellow equipment lock onto each multi-lock device. A multi-lock device secured with an equipment lock indicates that the isolation has been verified.
- Check that each yellow equipment lock identifies the Isolating Person

3.5.3.2 Group Isolations
- Attach a yellow equipment lock on each isolator
- Check that each yellow equipment lock identifies the group isolation board
- Secure the checklist and the keys of each yellow equipment lock in the group isolation board with a green group lock

3.5.3.3 Working Alone Isolations
- Check that 'working alone' isolation is permitted;
- Some sites may not allow 'working alone' isolations due to the level of risk on the site;
- Only use 'working alone' isolation when the Isolating Person is the only person required to secure the isolator for personal protection;
- Attach a red personal lock directly onto the isolator. This applies to an Isolating Person performing a 'working alone' isolation.

3.5.4 Protected Persons Working Under an Isolation

All people working under an isolation should be Protected Persons. People who have not been trained and assessed as competent Protected Persons should not be permitted to work under an isolation. The Protected Person should ensure that:
- Each isolator or group isolation board isolates the correct equipment that is consistent with the work instruction, plan or other documentation;
- Their own red personal lock is attached to the multi-lock device or to group isolation board before commencing work;
- They only work on plant and equipment with the appropriate level of isolation in place;
- Attachment of their red personal lock secures the multi-lock device or the group board;
- For individual isolations, only attach red personal lock to multi-lock device that has yellow equipment lock attached; and,
- For group isolations, only attach red personal lock to a group isolation board that has been secured by a green group lock, which signifies that the group isolation has been verified.

3.6 Safe Working by Personnel Exposed To Hot Work

It is essential that each worker is advised by their employer of any hazards specific to the work environment. It should be recognised that while safety devices and safe working practices will greatly reduce the number of incidents that occur, each worker plays a major role in overall safety. Hence, each worker and assistant should:

a) Ensure that work environment hazards are eliminated where possible, or controlled (managed).

b) Know and use the safe working method and procedures, and when in doubt, ask.

c) Ensure all equipment used is maintained in a safe condition.

d) Make use of appropriate personal protective clothing and equipment.

e) Ensure fume control or ventilation systems function properly.

f) Maintain a high standard of housekeeping.

g) Ensure any unsafe condition is made safe before working.

h) Ensure dangerous areas are properly sign-posted and enter such areas only when necessary e.g. highly flammable or toxic areas.

i) Ensure the use of adequate lighting.

j) Be aware that many occupational hazards are exacerbated in smokers. Best practice is to never smoke cigarettes on the job.

k) Immediately sign-post or tag with a specially designed tag and report any defective or hazardous equipment to persons responsible for equipment maintenance.

3.7 References

1. Standards Australia, AS/NZS ISO 45001 *Requirements with guidance for use Occupational health and safety management systems—Requirements with guidance for use*
2. Safe Work Australia, *How to determine what is reasonably practicable to meet a health and safety duty*, May 2013
3. Safe Work Australia, Model Code of practice: *How to manage work health and safety risks*
4. Hisey D, *A review of welder electrode shock injuries and fatalities*, International Institute of Welding Document VIII-70-19

1.5. Standards Australia, AS ISO 31000 *Risk management – Guidelines*

4. Electric Arc Welding, Cutting and Gouging

4.1 Introduction

4.1.1 General

This Chapter refers to measures that should be adopted for safety in the use of processes that use an electric arc between an electrode and workpiece or between electrodes to develop heat for welding, cutting or gouging. These processes require specific safety consideration in respect of the possible hazards in Table 4.1 i.e. electric shock, radiation, burns, fume and noise. Specific recommendations to minimise these hazards can be found by referring to the following Chapters within this document:

(a) Electric shock – Chapter 14;
(b) Arc radiation – Chapter 15;
(c) Fume – Chapter 17;
(d) Noise – Chater 18.

4.1.2 Release of 'Stored Energy' (Spring-Back)

In addition to the hazards listed in Table 4.1, users of cutting and gouging processes should give consideration to the presence and release of 'stored energy' when cutting or gouging deformed or fabricated structures, particularly if under stress or otherwise loaded. The release of 'stored energy' can occur suddenly and without warning, often as a sudden and uncontrolled movement of the structure or section of the structure or spring-back with considerable force, as attaching welds or parent material is removed. This sudden movement or spring-back, has been known to cause severe injuries, including fatalities[1].

4.2 Basic Requirements of Electrical Equipment

All main and ancillary equipment necessary for these welding operations should be selected and used on the basis that it has the required capacity or rating and is safe. This equipment should also comply with the requirements of electrical supply authorities that are usually based on relevant Australian Standards (see also Section 4.3.2).

4.3 Welding Power Sources

4.3.1 Types of Welding Power Sources or Welding Machines

A wide range of direct current (DC) and alternating current (AC) power source types are available for electric arc welding:

a) Low frequency AC, including mains frequency (50 Hz).
b) High frequency (HF) AC, typically 5-6 kHz.
c) DC (some types of rectifiers impose a mains frequency wave form on the DC).
d) Pulsed current (some of the above current types may be pulsed at, e.g. 25-500 Hz).

Power supplies to provide such current types are:

i) Welding power sources driven by electric motors, petrol or diesel engines.
   I. Generators provide DC
   II. Alternators provide AC or, with rectifier, DC.

ii) Transformers that reduce mains voltage to that required for welding
   I. Transformers provide AC.
   II. Transformer/rectifiers provide DC.

iii) Solid-state power supplies (including pulsed welding units).
   I. Solid state DC units.
   II. Solid state AC units.
   III. Primary rectifier-inverter usually known as Inverter units, AC. and DC. Some AC inverter units may include features such as:
      - Square wave low frequency AC.
      - HF AC including HF ignition or re-ignition devices added on to DC or low frequency AC supplies.

Many welding power sources, especially engine-driven units, also provide a 240V AC (50 Hz) outlet for power tools.

Table 4.1 Hazards in Arc Welding, Arc Cutting and Arc Gouging

Process		Arc Exposure	Hazards					
Title	**Abbreviation**		Electric Shock	Radiation (Note 2)	Burns (Note 3)	Fume (Note 4)	Particulates (Note 4)	Noise
Manual Metal Arc Welding	MMAW	Open	X	X	X	X	X	(Note 9)
Gas Tungsten Arc Welding	GTAW or TIG Welding (Note 5)	Open	X	X	X	X	—	— (Note 9)
Gas Metal Arc Welding	GMAW or MIG / MAG or CO_2 Welding	Open	X	X	X	X (Note 5)	X (Note 10)	— (Note 9)
Flux Cored Arc Welding	FCAW							
With gas	FCAW(C) or FCAW(M) (Note 5)	Open	X	X	X	X	X (Note 11)	— (Note 9)
Without gas	FCAW(N)	Open	X	X	X	X	X (Note 12)	— (Note 9)
Submerged Arc Welding	SAW	Enclosed	X	— (Note 6)	X	X (Note 7)	X (Note 7)	—
Electroslag Welding (consumable guide)	ESW-CG	Effectively Enclosed	X	X (Note 6)	X	X (Note 8)	X (Note 8)	—
Electrogas Welding	EGW	Partially Enclosed	X	X	X	X (Note 8)	X (Note 8)	X
Plasma Arc Welding	PAW	Open	X	X	X	X	X	X
Plasma Arc Cutting	PAC							
Open		Open	X	X	X	X	X	X
Water shrouded		Enclosed	X	—	—	—	—	X
Submerged		Enclosed	X	—	—	—	—	—
Air-arc Cutting	AAC	Open	X	X	X	X	X	X
Air-arc Gouging	AAG	Open	X	X	X	X	X	X

Notes:
1. X indicates hazard.
2. Ultraviolet, visible and infrared radiation.
3. Includes hot objects and particles.
4. Due to consumables, materials and coatings.
5. Shielding gas also introduces hazards from high-pressure cylinders and risk of asphyxiation.
6. Slight risk of accidental exposure. Limited protection is advisable.
7. Fume level is low, and welder is remote from arc.
8. Welder is remote from fume.
9. Noise levels relatively low – main source is motor driven equipment.
10. Varies according to arc (transfer) mode
11. Low levels of fine spatter produced if the consumable is used within recommended settings
12. Higher levels and larger particles produced by this process



4.4 Risk of Electrocution

The risk of electrocution (death by electric shock) is primarily related to:

- The voltage of an electric source;
- The type of current i.e. AC, DC rectified from AC with a component of ripple, or DC without ripple; and,
- The available current.

With welding power sources, the available current is always thousands of times higher than the level that poses a threat to human life. Current of the order of 40mA can cause ventricular fibrillation, heart failure and death. Electrical voltages at both input cable and the output cables of the welding power source may be high enough to cause sufficient current to flow through the body to inflict serious injury, even death. Welders, operators and other personnel in the area must be familiar with the risk and must undertake the precautions described herein and in Chapter 14 to avoid electric shock or at worst electrocution. Limiting current flow in people depends on maintaining a high circuit resistance. This is dependent on the use of dry personal protective equipment including protective electrically resistive clothing and the absence of moisture including sweat.

The standard IEC 60479-1:2018[2] describes the effects of direct current passing through the human body in Clause 6 and notes:

> *"The term "direct current" means ripple-free direct current. However, as regards fibrillation effects, the data given in this clause are considered to be conservative for direct currents having a sinusoidal ripple content of not more than 10% RMS."*

Consequently, the open circuit voltage of a DC welding power source should be measured by a procedure capable of quantifying any AC component such as using a true RMS voltmeter, or preferably an oscilloscope or dedicated data acquisition device for a more accurate measurement. If the AC ripple exceeds 10% of the DC voltage, then the welding power source should be considered as an AC welding power source in terms of hazard level (see AS 1674.2[3]).

Whilst the hazard level of AC is higher than that of DC, in welding terms, both can be lethal in the event of welders or other personnel coming into contact with either the open circuit voltage or welding voltages[4, 5].

4.4.1 Inverter-Based Power Sources

Inverter-based power sources have the following advantages:

- Lighter and therefore easier to move around.
- Higher electrical efficiency, extremely low no-load current and higher power factor generating far less heat at the power source.
- Much higher response rates than conventional power sources allowing improved process control.
- Ability to accept a wide range of input voltages and stable output power not determined by stability of input voltage, hence no-load voltages are more stable and controllable.

Inverter power sources are required by Electromagnetic Compatibility (EMC) regulations to have filtering to prevent unwanted noise and interference being propagated from the device back into the input power supply.

Users should be aware that in the event of an open circuit earth connection fault, the EMC filter can produce a potential of approximately half the input supply voltage on the case of the welding power source and in some inverter power sources this voltage can appear on the work return outlet. In the event of an open circuit of both the earth and neutral connections, the full supply voltage can appear on the case or work return outlet. The current is only a few milliamperes but enough to cause a significant shock.

In the event of an open circuit of both the earth and neutral connections, the full supply voltage can appear on the case or work return outlet. The current is only a few milliamperes but enough to cause a significant shock.

Therefore, it is imperative that the integrity of the power supply connection both in the welding power source and in the plug is checked regularly as specified within AS 1674.2[3], including electrical testing and tagging in conformance with AS/NZS 3760[6]. It should be noted that extremely high voltages are generated in the internal power circuits of these machines and they must never be operated or connected to the primary supply unless the full protective case is secure and undamaged.

Connection to mains power via a residual current device or RCD (also referred to as a core-balance relay or an earth-leakage device, ELD – see AS/NZS 3190[7]) may reduce the risk of electric shock in the event of a mains power supply fault (especially earth or neutral connector faults), and is highly recommended for all welding power sources.

4.4.2 Compliance

Industrial welding power sources intended for professional use, are generally manufactured to AS 60974.1[8]. Single-phase portable welding power sources generally intended for limited duty use by laymen (i.e. non-professional or home use) with a rated

input not exceeding 3.6 kVA are required to conform to IEC 60974.6[9].

Welding power sources are required by these standards to have a clearly visible nameplate that legibly and indelibly provides information relevant to the operating conditions of the welding power source. Nameplates should not be interfered with in any manner.

It is recommended that purchasers of welding equipment seek a statement of compliance to the relevant manufacturing standard from the manufacturer or supplier of the equipment as stated on the nameplate of the equipment.

In the case of equipment stated to comply to IEC 60974-6[9], it is further advised that the purchaser verify that the welding equipment in question is properly registered.

Welding equipment with stated compliance to IEC 60974-6[9] are Level 3 prescribed articles in AS/NZS 4417.2[10]. Level 3 equipment is classified as potentially high-risk equipment, and must meet the following requirements:

- Be linked to a registered responsible supplier;
- Be registered on the National Database (https://www.eess.gov.au/);
- Have a valid Certificate of Conformity (Certificate) from an industry recognised certifying body; and
- Be marked with the Regulatory Compliance Mark (RCM – see Figure 4.1).



Figure 4.1 RCM compliance marking

Welding equipment conforming with AS 60974.1[8] and AS 4417.2 Level 1[10], or IEC 60974-6[9] and AS 4417.2 Level 3[10], is readily available from suppliers registered on the National Database (https://www.eess.gov.au/).

> **Note***: Whilst welding equipment conforming with AS 60974.1 is intended as for commercial use (i.e. AS/NZS 4417.2 Level 1), limited duty cycle welding equipment conforming with IEC 60974-6 and AS/NZS 4417.2 Level 3 may be manufactured for the home market and use by laymen.*

4.4.3 Open Circuit Voltage or No-load Voltage

Welding power sources generally operate within the following voltage range:
Open Circuit Voltage (OCV) ..... 35-113 V
Operating Arc Voltage ..... 10-36 V

The OCV (i.e. voltage between welding terminals ready for welding but carrying no current), sometimes referred to as the no-load voltage, poses the greater hazard. OCV is accordingly restricted by AS 1674.2 for three working environment classifications (refer to Table 4.2):

- Category A
- Category B
- Category C

Users should be aware that during the striking of the arc and for a short period (see Section 14.7) after extinguishing of the arc, the OCV may be much higher than the limited voltage shown in Table 4.2.

4.4.4 High Frequency Equipment

A high frequency (HF) high voltage pilot arc is often used to facilitate arc starting e.g. to eliminate scratch or lift-arc starting in GTAW (TIG). In the event of high frequency system failure, the output voltage must not exceed the levels shown in Table 4.2.

It is not recommended that HF be used in confined spaces. Wherever HF is used, the circuit must be such that HF current will not create a danger for the welder or other personnel e.g. inside confined spaces with metal walls (see Chapter 20). Additionally, precautions should be made to avoid interference by electromagnetic fields created by HF currents and voltages with other equipment (see AS CISPR 11:2017[11]).

Improved technology in power sources such as lift arc GTAW and square wave AC output enable easy starting and stable arc conditions without the need for high voltage pilot arcs, effectively eliminating the hazard.

> **Note***: Canadian Standard CSA W117.2-19[9] warns that persons with metal implants should be aware that at least one case (2 persons using the same welding machine) has been reported in which the welder experienced a burning sensation around the metal implant while using a high frequency welding process.*

Table 4.2 Maximum Open CIrcuit Voltage Permitted by AS 1674.2:2025[3]

<table>
<tr><th>Working Environment Categories</th><th colspan="2">Maximum Permitted Open Circuit Voltage (OCV)</th></tr>
<tr><td>Category A: A dry environment where the risk of electric shock or electrocution is low due to controls to prevent the possibility of the welder or other personnel being in contact with the workpiece in the event of being in contact with a live part of the welding circuit. See Note 8.</td><td colspan="2">DC 113V peak, or
AC 113V peak and 80V RMS</td></tr>
<tr><td rowspan="2">Category B: A dry environment where there is a high probability of the welder or other personnel being in contact with the workpiece. Freedom of movement may be restricted. See Note 8.</td><td>DC 35V peak, with an observer (Note 6)</td><td>DC 35V peak & 0V during elec-trode changes and welder reposi-tioning, without an observer (Note 6)</td></tr>
<tr><td>AC 35V peak and 25 V RMS, with an observer (Notes 2, 6)</td><td>For other than GTAW, not permitted without an observer.

For GTAW, AC 35V peak and 25V 15V RMS, without an observer (Notes 2, 6)</td></tr>
<tr><td>Category C: A damp environment where there is a high probability of the welder or other personnel being in contact with the workpiece and the risk of an electric shock or electrocution is greatly increased due to the presence of moisture, e.g. from humidity, high ambient temperature, perspiration or water.</td><td colspan="2">DC 35V peak and 0V during electrode changes and welder repositioning, always with an observer, or

For GTAW only, AC 35V peak and 15V RMS., and 0V during electrode changes and welder repositioning, always with an observer.

(Note 7)</td></tr>
<tr><td>Plasma cutting</td><td colspan="2">DC 500V peak</td></tr>
</table>

Notes:

1. Refer toSection 14 and AS 1674.2 for more detailed descriptions of categories of environments for welding. Refer to Weld Australia's *Technical Note 22* for more information on management of the categories of environments.
2. AC power sources, complying with IEC 60974-1 marked with a symbol comprising the letter "S" in a square box, usually. Box 7 of the rating plate or sometimes on the front panel, is limited to a maximum OCV of 68V AC peak and 48V RMS. They may require the use of a hazard-reducing device (HRD) to meet Category B voltage limits.
3. MMAW and GTAW power sources to old standards may supply excessively high AC voltages for Category B and Category C environments. It is necessary to measure the open-circuit voltage to determine suitability and, if necessary, fit a hazard-reduction device. The use of AC power sources is not permitted in Category C environments for other than the GTAW process.
4. Power sources to be used in Category B or Category C environments are likely to require a hazard-reducing device (HRD) e.g. integrated voltage reduction device (VRD), and in some situations, may require a secondary HRD (see Technical Note 22 and AS 1674.2).
5. Most GMAW and FCAW, and some GTAW equipment will meet Category C requirements because welding voltage and current is switched with a trigger switch – see AS 1674.2.
6. For AS 1674.2 Category B environments, if the welder is working without an observer, the maximum permitted OCV is reduced to the same levels as those for a Category C environment. The use of AC power sources is not permitted in Category C environments for other than the GTAW process.An observer is required at all times for AS 1674.2 Category C environments.
7. Recent research has shown that the amount of moisture required to produce 'Category C' conditions in the welders clothing is very small and can easily be produced by perspiration. If there is any doubt about the 'presence of moisture', category C restrictions must be observed[4].

4.4.5 Service Conditions

Welding power sources that comply with AS 60974.1[8] and IEC 60974-6[9] shall be capable of delivering their rated output when the following environmental conditions prevail:

a) Range of the temperature of the ambient air:
   i) During welding: –10°C to +40°C;
   ii) After transport and storage at: –25°C to +55°C;

b) Relative humidity of the air:
   i) Up to 50 % at 40°C;
   ii) Up to 90 % at 20°C;

c) Ambient air, free from abnormal amounts of dust, acids, corrosive gases or substances etc. other than those generated by the welding process;

d) Altitude above sea level up to 1,000m;

e) Base of the welding power source inclined up to 15°.

Welding power sources should be located in clean, dry conditions away from high temperatures. Dust, oil and moisture may cause deterioration or overheating of plant, possibly making it unsafe or inoperative. Where welding power sources are required to be located out of doors, suitable protection must be provided to protect them from the environment. Special protection is required for welding power sources exposed to corrosive fumes, steam, shock loading or severe weather.

Many industrial situations contain hose down areas as defined in the Australian/New Zealand Wiring Rules AS/NZS 3000[13]. Unless the welding power source has the correct rating i.e. IP23 in accordance with AS 60529[14], it should not be used in hose down areas.

Electric welding equipment must not be used in hazardous atmospheres, e.g. environments containing flammable gases or combustible dusts where an explosion could occur.

Welding power sources that comply with AS 60974.1 are marked with a degree of protection on their compliance plate. Welding power sources for use outdoors are rated with a degree of protection IP23 in accordance with AS 60529[14].

> **Note***: IP23 is a minimum for outdoor conditions but a higher rating may be appropriate pending assessment of the environmental conditions.*

Welding power sources with a degree of protection IP21 are only suitable for use indoors. If the degree of protection is not stated on the welding power source, or, if the welding power source will be used in an unusual environment, the manufacturer should be consulted as regards its suitability.

Examples of unusual environments include conditions such as high humidity, unusual corrosive fumes, steam, excessive oil vapour, abnormal vibration, abnormal shock, excessive dust, severe weather conditions, vermin infestation and atmospheres conducive to the growth of fungus.

4.4.6 Welding Power Source Loading

Care should be taken to ensure that:

a) The current rating of the selected welding power source is adequate to handle the welding job.

b) The welding power source is not operated above the maker's current rating at the appropriate rated duty cycle (see AS 60974.1[8] or IEC 60974-6[9]).

Caution must be exercised when using low duty cycle or low current rated welding power sources for processes that readily allow the duty cycle or rating to be exceeded.

The following must be indicated on the welding power source nameplate for compliance to AS 60974.1[8] and IEC 60974-6[9]:

- I_{1max} – the highest value of supply current drawn by the welding power source at its highest current setting. (I_{1max} is referred to as "Rated maximum supply current" in AS 60974.1)
- I_{1eff} – the maximum effective value of supply current (i.e. average value of supply current with duty cycle considered)
- Duty cycle

These values are required to determine if the welding power source supply current is as stated on the nameplate, and whether the fitted input cable and plug rating exceeds the value of I_{1eff} as required for compliance to AS 60974.1[8] and IEC 60974-6[9].

4.4.7 Installation, Operation and Maintenance

A competent person, as defined in AS/NZS 3000[13], must directly connect welding power sources not provided with a connecting plug to the electricity supply. Flexible, trailing cables must be used for welding power sources that are moved around. Figure 4.2 indicates a typical method for connection of plant to the electrical supply and to work.

Do NOT connect the work terminal to electrical system's earth, or, to the welding power source

case. Any connection between the output terminals and the welding power source case or earth, may cause potentially damaging welding currents to flow through structures, bearings, gearboxes and electronic equipment. It may also expose others to the risk of electric shock.

> **Note**: *The work (or return) cable is commonly referred to as the "earth" in a welding circuit. This is incorrect terminology and reinforces a misunderstanding of the function of the work cable. Potentially hazardous situations are caused when welding currents find alternative return paths to the welding power source.*

Where welding power sources are installed adjacent to each other or where welders or other personnel are working in close proximity to each other, special care is required to avoid the risk of shock due to exposure to the combined voltage of the adjacent welding power sources. Open circuit voltage between electrode holders should be checked to ensure this does not exceed 113V for DC welding power sources and 113V peak 80V RMS for AC welding power sources, unless positive screens or barriers prevent physical contact between either welders or other personnel and workpieces (see Figure 4.3 and refer to AS 1674.2[3]).

The voltage between the electrode holders or torches of power sources connected to the same workpiece can be up to twice the normal open-circuit voltage. This occurs where any of the following apply:

a) DC power sources of different polarity are connected.

b) AC power sources are connected with primary cables opposed or out of phase.

c) AC power sources are connected with secondary cables opposed and primary cables in phase.

The operator should carry out a pre-start check before powering up the welding equipment and commencing welding operations. Routine inspection and testing should be carried out by a competent person to ensure the electrical safety of the equipment and accessories. Refer to AS 60974.4[15] and Section 5 of AS 1674.2:2025[3] for minimum frequencies and items to be checked during routine inspections. It is a requirement of AS 1674.2[3] that the owners of the welding power source keep suitable records of periodic tests and a system of tagging including the date of the most recent inspection.

An inspection of the work environment should be carried out to determine if all hazards, e.g. wet areas etc., are controlled before and during welding processes. Maintenance of equipment should only be carried out by a competent person.

4.5 Wire Feeders

Where wire-feeding equipment is used in continuous wire processes, the whole coil of wire is at welding potential with respect to the work, when welding is in progress. The equipment should therefore be installed and maintained in a safe condition and in accordance with the manufacturer's recommendations.
Guarding of the wire spool and the wire feeding mechanism is recommended to protect against the possibility of electric shock or contact with moving parts e.g. Figure 4.4. In many workplaces, guarding of mechanical components and insulation of electrical parts is mandatory, making some wire feeders unsuitable.

Wire feeders should comply with the requirements of IEC 60974-5.

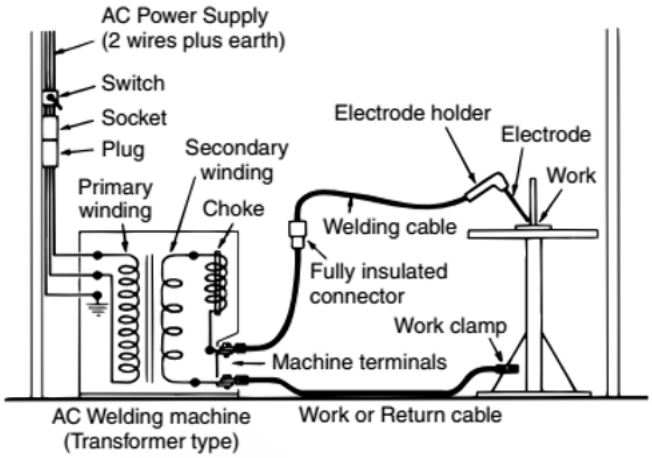
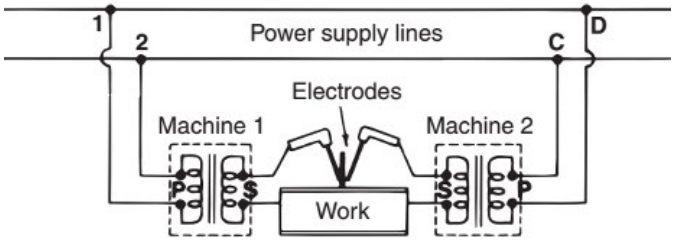


Figure 4.2 Typical electrical connections for manual metal arc power sources



Notes:
1. An unsafe condition will arise if the supply cable connections 1 and 2 are interchanged or if connections C and D are interchanged, i.e. voltage between the electrodes will be twice (2 x) OCV.
2. Supply connections 1 and 2 are either active or neutral respectively of a single-phase supply, or two wires of a three-phase supply, depending on the voltage for which the welding power sources are designed.

Figure 4.3 Safe connection of adjacent welding power sources for simultaneous operation



Figure 4.4 **Example of a fully enclosed and insulated wire feeder**
Image courtesy BOC

4.6 Welding Cables

4.6.1 General

The electrical welding circuit consists of a “welding” cable (or welding lead) to take the electrical output from the welding power source to the electrode holder and a “work” (or “return”) cable to complete the electrical circuit from the work being welded back to the welding power source.

The welding and work cables must be of sufficient capacity for the welding current (Table 4.3) and the insulation must be sound.

Cables should conform to AS/NZS 1995[17] (Figure 4.6) and only be replaced or repaired by a competent person. They are not to be replaced or repaired by unauthorised personnel. Cable lengths should be as short as possible to avoid increased risk of cable damage and voltage drop, and the length of the electrode cable should not exceed 9 m except with the consent of authorised person as per AS 1674.2. All cables should be kept clear of other personnel and away from areas where they can be damaged. Frayed cable or damaged insulation can cause fire or injury. Damaged cable should be repaired or replaced. As cable length increases there is a progressive voltage drop that must be considered (see Clauses 4.2.2 and 4.2.3 of AS 1674.2: 2025[3]). The maximum cable length can be calculated using the welding power source OCV, the cable resistance in Ohms/km and the welding current.

4.6.2 Cable Connections

Where connections to welding cables or joining of cables are required, such connections must be insulated metallic connectors of an appropriate type and current capacity. Frayed connections provide a risk of fire or electrical shock and should not be used.

When connecting to terminal posts, the use of undersized bolts or oversized washers makes an unsafe connection that is prone to work loose and overheat. Always use the correct size brass bolts, brass nuts and brass washers. All connections shall be of adequate current-carrying capacity and made so they cannot slacken or overheat under normal conditions of use.

All jointing of connectors and terminals to cables shall be made to the requirements of AS/NZS 3000[13]. Each joint or connection shall have a resistance of not more than the equivalent resistance of a length of cable equal to the total length of the conductors that are joined.

The fitting of all hardware to cables including in-line connectors, terminal lugs, electrode holders and work clamps should be carried out by a competent person (eg. see AS/NZS 3760[6]). It is commonly found that connectors that have been fitted or modified, by persons who do not possess the necessary skills, in a manner that results in poor electrical conductivity, reduces the overall efficiency of the circuit and causes localised overheating.

Output cable connections should have clean contact surfaces, be properly tightened and fully insulated. Connection of flexible output cables to the welding power source or to extend cables may be carried out by the welder. The power source should be switched off or otherwise isolated from the power supply before the connection or disconnection of the output cables to the output terminals.

4.6.3 Work Return Cable

The function of the “work return” cable or lead (see also AS 1674.2[3]) is to provide a safe and low resistance electrical return path from the work being welded to the welding power source. The work return cable should not be referred to as the “earth” cable. It is an active part of the welding circuit and must remain insulated from earth.

Often work return cables (and their connections) used in welding are inadequate. Always take the following precautions:

a) Avoid faulty work return connections. These can cause electrical shock or fire due to overheating.

b) Always connect the work return cable clamp as close to the work or worktable as practicable.

c) Never connect work return cables to structural systems, piping in plant or the like (Figure 4.5). This practice may cause electrical shock to others, malfunction of protection control equipment, fire at

another location, destroy electrical wiring or cause corrosion due to (very high) impressed electrical currents. Corrosion can occur to hulls of ships during maintenance welding and a similar situation will occur in any situation where an electrolyte is involved in the welding circuit, such as wet floors.

d) Ensure the current-carrying capacity of the work return cables is not less than that of the electrode cables.

e) Fully tighten work connections so they have a firm contact and provide a good electrical connection.

4.6.4 Inspection

Welding cables are easily damaged and then become an electrical hazard. Welding cables should always be inspected by the operator before use and at least monthly by a competent person in accordance with AS 1674.2.

4.7 Electrode Holders

Electrode holders should conform to IEC 60974-11[18].

4.7.1 Type A Electrode Holder

A type A electrode holder is an electrode holder in which no live part is accessible to the standard test finger as described in AS 60529[14], and, IEC 60974-11[18], Clause 3.6.

Type A electrode holders are the preferred fully insulated electrode holder for Category C welding environments and for MMAW welding in confined spaces.

4.7.2 Type B Electrode Holder

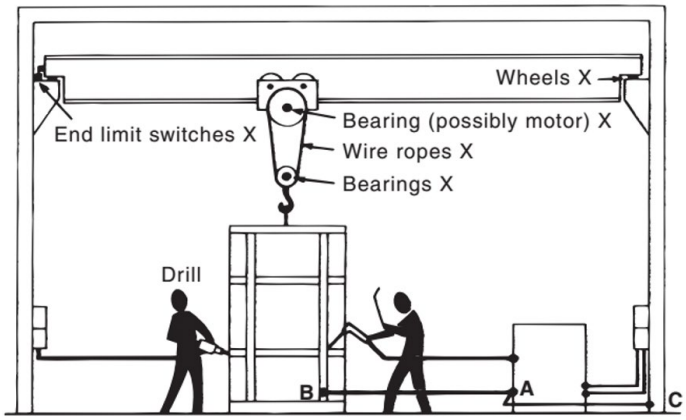
A type B electrode holder is an electrode holder in which, deviating from type A, no live part is accessible at the head to a sphere with a diameter related to the maximum diameter of the electrode (see IEC 60974-11 Clauses 3.7 and 8.1b[18]).

4.7.3 Protection Against Electric Shock

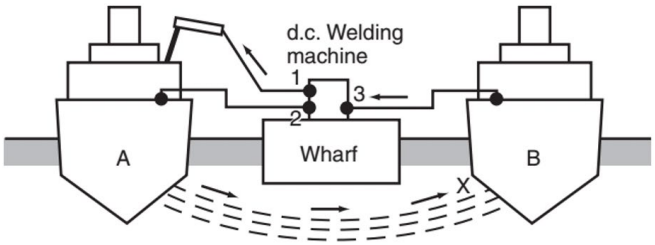
4.7.3.1 Protection from Direct Contact

It is a requirement of AS 60974.11[18] that:

"In order to meet the requirements of AS 60974.11, an electrode holder without an electrode, fitted with a welding cable of minimum cross-sectional area as specified by the manufacturer, shall be protected against unintentional contact with live parts.



a) **Defective work return leads causing damage and injury**
If work return lead AB or its connections are defective, high current may leak through incorrect alternate connection AC, causing damage to:
drill– causing burnt-out drill, injury to fitter and damage to machine parts
crane – causing damage to points marked X; limit switches have been completely destroyed.
Work connection AB – **right**
Earth connection AC – **wrong**



b) Defective work return lead causing corrosion
If work return 2 is broken or of high resistance current will return via sea, ship B and return lead 3 or via steel wharf piles. If electrode is positive, corrosion and breakdown of any paint will occur at X.

Figure 4.5 Work return leads—incorrect connection points



Figure 4.6 Cable correctly marked to AS/NZS 1995
Image courtesy CIGWELD

Table 4.3 Capacities of Welding Cables (Leads) Compiled from AS/NZS 1995:2003[17]

Nominal Cross-sectional Area of Conductor	Current Rating (Amperes) at 10 Minute Duty Cycle (Note)			
mm²	100%	60%	30%	25%
10	90	91	99	102
16	125	129	145	151
25	165	175	206	218
35	205	223	270	288
50	260	289	361	386
70	325	370	471	507
95	390	454	590	637
120	455	536	705	763
150	535	636	843	914
185	600	723	968	1051
240	715	870	1174	1276

Note: Current ratings are based on 100, 60, 30 and 25% duty cycles over a 10-minute period based on a cable temperature of 90°C and an ambient air temperature of 40°C.

In the case of type A electrode holders, this requirement is also valid for the part of the electrode inserted into the electrode holder. Electrodes having the minimum and maximum diameter as specified by the manufacturer shall be tested.

Conformity shall be checked by testing as specified in AS 60974.11.
The springs not designed for carrying the welding current shall be insulated from other metal parts of the electrode holder.

Conformity shall be checked by visual inspection."

4.7.3.2 Insulation Resistance
It is a requirement of IEC 60974-11[18] that:

"The insulation resistance shall, after the humidity treatment, be not less than 1 M Ohm."

4.7.3.3 Dielectric Strength
It is a requirement of IEC 60974-11[18] that:

"The insulation shall withstand an AC test voltage of 1,000V RMS. without flashover or breakdown. Any charges unaccompanied by a voltage drop are disregarded."

4.7.4 Dimensional Requirements for an Electrode Holder

Refer IEC 60974-11[18] Table 1 for dimensional requirements. Conformity shall be checked by measurement

4.7.5 Marking

It is a requirement of IEC 60974-11[18] that:

"The following information shall be legibly and indelibly marked on each electrode holder:

a) Name of the manufacturer, distributor, importer or the registered trademark;

b) Type (identification) as given by the manufacturer;

c) *Rated current;*

d) *Reference to this part of IEC 60974, confirming that the electrode holder complies with the requirements.*

Example:

STAR

B 200 / IEC 60974-11

This example is for an electrode holder with the trademark STAR being of type B, having a rated current of 200A and complying with this part of IEC 60974."

4.7.6 Electrode Gripping/Clamping Action

Spring or screw gripping/clamping action types are preferred as they provide more uniform contact with the electrode and less overheating of the holder.

4.7.7 Cable, Anchorage and Connection

The cable to the holder should be light and flexible to avoid operator fatigue. Although the anchorage of the cable to electrode holder is required to fulfil test requirements on manufacture to IEC 60974-11[18], frequent flexing and use may result in breakage of the cable wires, deterioration of the anchorage or exposure of the electrical conductors. This causes overheating of the holder, discomfort and risk of shock.

Broken cable wire or insulation may be repaired by removing the damaged part of the cable. Deterioration of the anchorage may require the electrode holder to be replaced.



Figure 4.7 **Electrode holder with identification marking conforming to IEC 60974-11**
Image courtesy CIGWELD

4.7.8 Routine Inspection

This should include checks for:

a) Loosened metallic screws in the holder;

b) Burnt or cracked insulation that exposes electrical conductors; and,

c) Overheating and damage at cable connections.

4.7.9 Use

Holders can be damaged by careless use (Figure 4.8), throwing or dropping. Care should therefore be exercised in handling this equipment as faulty electrode holders are a major cause of serious electrical shocks and the most common factor in electrocutions (see Technical Note 22). Welding electrodes should be removed from holders after use.

4.8 Welding Torches and Guns

Welding guns are used in continuous wire welding processes and welding torches in gas tungsten arc (TIG) welding. Construction can be complex where provision for gas shielding and water-cooling is also required. For safe use:

a) Amperage rating and duty cycle specified by the manufacturer should be adhered to;

Note*: Argon and argon mixtures can have a major effect in de-rating a torch designed for carbon dioxide shielding.*

b) Maintenance procedures specified by the manufacturer should be observed and no modifications attempted; and,

c) Heat shields or cooling devices provided should be maintained and always used where necessary to prevent discomfort or burning of skin or deterioration of the equipment.

For additional information refer to IEC 60974-7[19].



Figure 4.8 **Damaged electrode holders should not be used**

4.9 Shielding Gas Cylinders, Regulators and Hose

Shielding gas cylinders and pressure hose are required for external gas shielded welding processes and water-cooled torches. Hose types are generally designed for use with specific gases only and they should not be used for other gases unless approved by the supplier. To avoid leakage of gas or water, only approved, well-maintained hose should be used, together with correct fittings. See Chapter 5 for requirements for cylinders, hoses and fittings and their proper use.

Pressure hoses should comply with AS/NZS 1335 (ISO 3821)[20].

4.10 Safe Installation, Maintenance and Use of Arc Welding, Arc Cutting and Arc Gouging Equipment

The following precautions apply to all electrical equipment i.e. welding power sources, wire feeders, supply cables, welding cables, electrode holders and guns.

4.10.1 Management

a) All operations must be carried out in a safe manner and in a safe workplace. Particular requirements in respect of electrical shock, radiation, fire and explosion are given in Chapters 14 to 16.

b) All welders should be provided with, or have access to, printed instructions concerning safe operations with the equipment being used. Special measures may be required for personnel having English as a second language.

c) Metal or metal oxide dusts may be hazardous with regard to fire, explosion or be detrimental to the health of operators. Accumulation of dusts, especially in certain combinations, should be regularly cleaned up and recommendations in Sections 16.3 and 19.6 observed.

d) Under no circumstances should welding plant be moved whilst the electrical supply is connected to it.

e) Special provisions related to the location of the work, e.g. at heights or within vessels, as outlined in Chapters 20-28, should be understood and adhered to.

f) The type of material being welded or cut can influence the necessary safety provisions (see Chapter 13).

g) Fume generated is dependent upon processes and materials and requires a fume control plan (see Chapter 17).

4.10.2 Installation and Handling of Equipment Connected to Electrical Supply

a) Ensure equipment has the required voltage and current capacity.

b) Connect to main supply safely and locate safely (Section 4.3). Only an authorised person can install such equipment.

c) Locate main switch adjacent to equipment to allow ready isolation from supply.

d) Ensure correct earthing of welding power sources and wire feeders.

e) Check welding and work cables for full insulation along their length. Do not use damaged or worn cables.

f) Locate welding and work cables safely to avoid damage. In wet conditions run cables above the wet surface out of contact with the water.

g) Ensure work cable is secure (Section 4.6.3).

4.10.3 Installation and Handling of Engine Driven Equipment

a) Check capacity and electrical requirements as in Section 4.6.

b) Locate engine so persons are not exposed to exhaust gases and excessive noise.

c) Locate on level base and prevent any possibility of plant moving, e.g. by chocking wheels.

d) Locate where protected from weather. If outdoors, equipment may require temporary shelter.

e) Electrical connections etc, as for equipment in Section 4.6.

f) Ensure fuel tank has no leaks and cooling fan is guarded.

4.10.4 Maintenance and Inspection by Maintenance Personnel

Mobile welding power sources should be inspected on a minimum three-monthly basis. Fixed equipment should be inspected on a minimum annual basis. Refer to AS 60974.4[15] and Section 5 of AS 1674.2[3] for more details on inspection required.

Some recommendations for routine maintenance and inspection checks are:

a) Implement routine periodic inspection, maintenance and repair carried out by competent persons.

b) Keep records of inspection, maintenance and repair.

c) For engine driven equipment, also carry out routine inspection and maintenance on the engine.

d) Implement routine checks of oil level and moisture content in oil cooled transformers.

e) Clean equipment by periodically blowing out with, e.g. reduced pressure compressed dry air with safety nozzles. Do not use other gases for this purpose. Increased frequency of cleaning is required where metallic dust may be present. Printed circuit boards may be adversely affected by dust.

f) Check the operation of any fitted HRD.

4.10.5 Safe Operation by Welders and Operators

4.10.5.1 Pre-start Inspection of Welding Equipment

Before using any electric welding equipment, the welder or operator of that equipment should carry out a pre-start safety inspection. A summary of these items can be found in the pop-out guide at the end of this Chapter.

a) **Power supply**. Disconnect and isolate the power supply to the welding power source prior to performing these pre-start checks. Check the function of any RCD connected to the power supply.

b) **Mains supply socket and switch**. Inspect for any obvious damage and defects to switch or socket. Ensure the correct size plug is fitted for the welding power source for the rated current and duty cycle of the welding power source. Refer AS/NZS 3000[13].

c) **Plug and primary cable supply to the welding power source**. Check the power supply cable is of the correct rating for the welding power source and for any damage to plug. Special attention should be given to any cuts, burns, abrasions, and fraying or other damage to the cable insulation, which may expose live wires. Ensure the mains supply cable is located away from welding cables and connections. Ensure the cable is securely anchored onto welding power source and plug.

d) **Welding power source**. Inspect the welding power source for obvious damage to the cabinet, power switches, indicator lights or controls. Refer AS 60974.1[8] or IEC 60974-6[9].

e) **Welding cable connections**. Ensure that welding cable connections to the welding power source are in good condition; contact surfaces are clean and are properly tightened. If terminal posts are used ensure only brass washers and the correct insulated type brass nut is used. Any unused terminal posts shall have an insulated brass nut in place. Ensure that all connections are fully insulated and cables are firmly anchored to fittings. For AC output welding power sources, check that electrode and work cables are correctly connected to the welding power source. For DC output welding power sources, check polarity and ensure electrode and work cables are correctly connected for the procedure in use and that any other DC welding power sources in the vicinity are connected with the same polarity. Refer AS 1674.2[3].

f) **Welding cables (electrode and work cables)**. Examine all cables (leads) for damage such as cuts or abrasions, burns, damaged insulation or frayed wires or any other damage that may expose live wires. Electrode and work cables should be of similar length. Electrode and work cables should be of the same current carrying capacity and rated for the maximum current rating and duty cycle of the welding activity. Building steelwork must not be used as a work return path. Refer AS/NZS 1995[17] and AS 1674.2[3].

g) **Welding cable extension connections**. Check that both the male and female connections are fully insulated with clean contact surfaces and all fittings are tightened properly with no conductors exposed. Refer AS 1674.2[3].

h) **Welding hand pieces**. Check that the welding hand piece is in good condition and is fully insulated. The hand piece must be rated for the maximum current rating and duty cycle of the welding activity. Cracked or damaged hand pieces shall be taken out of service immediately. Refer IEC 60974-11[18].

i) **Work clamp**. Check that the work-return clamp or connection is securely connected to the work cable and the job close to the welding activity. Refer AS 1674.2[3].

j) **Engine drive welding power sources**. Check that all exhaust fume emissions are dispersed away from the work area and any other personnel working in the immediate vicinity. Do not use in an enclosed area or building.

k) **Hazard reduction device (HRD)**. If a HRD such as a positive isolation switch or voltage reducing device (VRD) is used, ensure that the indicator lights or voltmeter are functioning and indicating low voltage or zero voltage (Safe: green) and high or welding voltage (Unsafe: green flashing or red) condition as the welding power source is operated in a normal welding cycle. This check is done with power on – refer AS 1674.2[3].

l) **Electrical inspection tag**. Check that a current electrical inspection tag, traceable to your

equipment maintenance register, is attached to the welding power source.

Notes:

1. *If on completion of this pre-start checklist you are unsure of the safety of any part of this equipment - DO NOT USE. Isolate the equipment and notify your supervisor immediately, in order that remedial action can be taken.*
2. *Residual current devices (RCD's) do not usually require daily or pre-start testing, however they should be tested by pressing the "Test" button at least every three months (the RCD is working correctly if the power goes off).*
3. *Fumes are generated by hot work. Take adequate precautions to limit exposure to fumes from welding consumables or surface coatings and contaminants.*
4. *Ensure that you have all necessary Personal Protective Equipment in place, in good order and dry, before turning on the power source.*

4.10.5.2 Safe Working Practices by Welders and Operators

a) Ensure the welding power source is in good condition before use. Tag defective equipment so it cannot be used before it is repaired.

b) Use only insulated cable as per Table 4.2 for the welding and work cables. Avoid using bare metal straps as work cables. Never use gas or water pipes as part of the welding circuit. Connect the work cable as close as possible to the weld location. Ensure the welding power source work terminal is connected only to the workpiece or pieces being joined.

c) It is a good practice to equipotential bond the workpiece to other conductive structures in the vicinity of the welding work. This is particularly important when working from an elevated work platform, boom lift or free-standing scaffolding. Equipotential bonding cables should have at least the same capacity as the welding cable and be clearly marked to distinguish them from the work cable.

d) Connect all cables, including the electrode hot box if it is powered by the welding power source output, before turning on the power source. All 240V outlets from a welding power source should be RCD protected (see also AS/NZS 3190). All cables should be checked for sound insulation and tight connections after every break in work. Poor connections in the electrode and work circuit generate resistive heating, increase the risk of fire, damage to equipment, electric shock and electrocution as well as reduce the performance of welding arcs by introducing voltage and current drops.

e) Keep welding cables as short as possible. Only coil them using a pattern to minimise inductance (see Figure 4.9). Tangles of cables can overheat. Keep connection points (work cable clamp, welding power source terminals, etc.) clear of flammable materials, particularly insulated electrical cables, compressed air, oxygen and flammable gas hoses.

f) Be especially careful with welding processes such as manual metal arc welding or arc gouging, which have a live electrode holder whenever the power source is turned on (see Chapter 14). Ensure a hazard-reducing device (HRD) is used in accordance with requirements of AS 1674.2[3].

g) Do not drag live welding cables to the work. Ensure the electrode holder has no electrodes in it before turning on the welding power source.

h) Remove stubs from electrode holders before placing the electrode holder on the job.

i) Ensure the welder and any other personnel in the vicinity of welding operations are properly insulated from the workpiece. Use heat resisting mats, wooden duckboards or other means as insulation from the job and flooring.

j) Wear at least two layers of dry clothing inclusive of AS/NZS ISO 11611[21] compliant work wear in good condition (i.e. hole free), underneath dry welding jackets and rubber soled safety boots (steel toe caps must not be exposed). If insulation from the earth and job is difficult, ensure the welding power source has suitable IP23 rating, in accordance with AS 60529[14], for hazardous environments.

k) Use dry welding gloves on both hands, for handling the electrode holder or gun, and when changing electrodes. Welding gloves need to be dry and free from holes. Cotton glove liners are recommended and can assist with keeping the gloves dry.

l) Do not hold electrodes or electrode holders under the armpit while changing them.

m) Do not wrap the electrode cable around yourself.

n) Keep yourself and the work area dry.

   i) Do not use leaking water-cooled equipment.
   ii) Dry up any condensation.
   iii) Keep clothing and gloves dry from perspiration.
   iv) Avoid working in rain or close to water (see Chapter 14).
   v) Do not cool the electrode holder with water.

o) Work in a tidy manner. Where there are multiple welders or other personnel and multiple welding power sources, know which cables belong to each welding power source and keep them separated. Discard hot stub ends, off-cuts, and wire snips into a suitable receptacle, not on the floor. They are a slip/trip hazard.

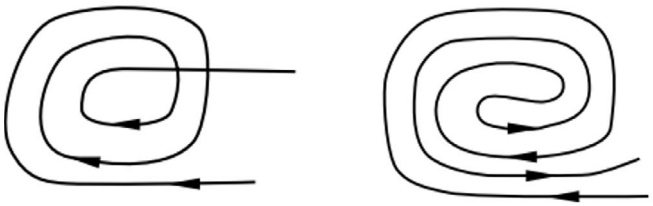
p) When MMAW is finished or interrupted, switch off the power source and remove the electrode stub from the electrode holder.

q) Only use welding equipment for its intended purpose. Misuse, such as lighting cigarettes or horseplay, can lead to severe burns, electrocution, arc flash and damage to equipment.

r) Be aware of the possible impact from spatter e.g. glass fracture, ignition of flammable insulation materials, and damage to painted surfaces.

4.10.6 Further Information

For welding electrical safety see also AS 1674.2 and Weld Australia's Technical Note 22 particularly in relation to hazard reducing devices, effects on the human body, and case studies of electrical accidents.



WRONG: Current flows in one direction. High inductance.

RIGHT: Current flows in both directions. Low inductance.

Figure 4.9 Welding cable storage

4.11 References

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18. International Electrotechnical Commission, IEC 60974-11, A*rc welding equipment Part 11: Electrode holders*
19. International Electrotechnical Commission, IEC 60974-7, *Arc welding equipment Part 11: Torches*
20. Standards Australia, AS/NZS 1335, *Gas welding equipment - Rubber hoses for welding, cutting and allied processes (ISO 3821:2019 IDT)*
21. Standards Australia, AS/NZS ISO 11611, *Protective clothing for use in welding and allied processes*

Recommended Power Source Daily Inspection and Pre-Start Check List	
Item	**Description of Inspections to be Carried Out**
Power supply	Disconnect and isolate the power supply to the welding machine prior to performing these pre-start checks.
Plug and primary cable supply to the welding machine	Check the power supply cable and plug is for the rated current for the welding machine, and for any damage to plug. Special attention should be given to any cuts, burns, abrasions, and fraying or other damage to the cable insulation, which may expose live wires. Ensure the mains supply cable is located away from welding cables and connections. Ensure the cable is securely anchored onto welding machine and plug.
Power source	Inspect the welding machine for obvious damage to the cabinet, power switches, indicator lights or controls.
Welding cable connections	Ensure that welding cable connections to the welding machine are in good condition; contact surfaces are clean and are properly tightened. If terminal posts are used ensure only brass washers and the correct insulated type brass nut is used. Any unused terminal posts must have an insulated brass nut in place. Ensure that all connections are fully insulated and cables are firmly anchored to fittings. • For AC welding machines check that electrode and work return cables are correctly connected to the welding machine. • For DC welding machines check polarity and ensure electrode and work cables are correctly connected for the procedure in use and that any other DC welding machines in the vicinity are connected with the same polarity.
Welding cables (Electrode and work return cables)	Examine all cables (leads) for damage such as cuts or abrasions, burns, damaged insulation or frayed wires or any other damage that may expose live wires. Electrode and work return cables should be of similar length. Electrode and work return cables should be of the same current carrying capacity and rated for the maximum current rating and duty cycle of the welding activity. Building steelwork must not be used as a work return path.
Welding cable extension connections	Check that both the male and female connections are fully insulated with clean contact surfaces and all fittings are tightened properly with no conductors exposed.
Electrode holder	Check that the electrode holder/welding torch is in good condition and is fully insulated. The electrode holder must be rated for the maximum current rating and duty cycle of the welding activity. Cracked or damaged electrode holders must be taken out of service immediately.
Work return clamp	Check that the work return clamp or connection is securely connected to the work return cable and the job close to the welding activity.
Engine drive welding machines	Check that all exhaust fume emissions are dispersed away from the work area and any other personnel working in the immediate vicinity. Do not use in an enclosed area or building.
Voltage reduction device (VRD)	If a voltage reduction device (VRD) is used ensure that the indicator lights or voltmeter are functioning and indicating low voltage (Safe ⟶ green) and high or welding voltage (Unsafe ⟶ green flashing or red) condition as the welding machine is operated in a normal welding cycle. *Note: This check is done with power on.*
Electrical inspection tag	Check that a current electrical inspection tag, traceable to your equipment maintenance register, is attached to the welding machine.
Environment category	Check that the power source is suitable for use in the environment category anticipated during the welding activity.

Notes:
- If on completion of this pre-start checklist you are unsure of the safety of any part of this equipment - DO NOT USE. Isolate the equipment and notify your supervisor immediately so that remedial action can be taken.
- Residual current devices (RCDs) do not usually require daily or pre-start testing, however they should be tested by pressing the “Test” button at least every three months (the RCD is working correctly if the power goes off).
- Fumes are generated by hot work. Take adequate precautions to limit exposure to fumes from welding consumables or surface coatings and contaminants.
- Ensure that you have all necessary Personal Protective Equipment in place, in good order and dry, before turning on the welding power source.



5. Welding, Cutting, Heating, Brazing and Gouging Using Industrial Gases

5.1 Introduction

This Chapter refers to safety measures for those processes that use a flame to provide the heat required for welding, brazing, soldering, heating, metal cutting and gouging applications. It also refers to similar applications e.g. flame straightening, bending, preheating and post weld heat treatment (PWHT).

The heat source is produced in the majority of applications by mixing compressed oxygen with a fuel gas and igniting the resulting mixture. Some additional processes may use the oxygen content of atmospheric or compressed air instead of pure compressed oxygen, but the same general principles apply.

Gas-shielded welding applications involving compressed inert gases e.g. GMAW are included in part in this Chapter for convenience due the similarities in dealing with high-pressure gas cylinders and gas reticulation systems; hence this Chapter also provides general information on the storage of gas in cylinders, including flammable gases, non-flammable gases, and inert gases used in welding and allied processes.

When using any of these processes, specific safety considerations apply in respect of:

a) Burns from flames, hot objects, malfunctioning hand-held equipment, molten particles etc.

b) Explosion from mixed gas concentrations created by fuel gas leakage from cylinders, bulk supplies, hoses, welding equipment breakable connections, etc.

c) Fire caused by ignition of flammable materials, leakage of fuel gases, contact with hot slag, welding equipment in poor condition etc. Plant, buildings, ship and bush fires have occurred.

d) Ignition of materials not normally considered flammable due to oxygen enrichment (see Sections 5.2.2 and 5.6.3).

e) Violent rupture or explosion of components due to being pressurised beyond their design pressures.

f) Sudden spring-back or movement of the structure whilst gouging or removing welds etc (see Section 4.1.2).

g) Asphyxiation due to displacement of atmospheric, breathable air by inert or toxic gases, e.g. leakages in confined spaces or lack of oxygen resulting from excessive rusting in confined spaces (Chapter 20).

h) Radiation damage (to eyes principally).

i) Fumes originating from the materials being welded, heated or cut.

j) Influence on the workplace from the above hazards (containers, vessels, heights, etc.). Refer to Chapters 20-28 for details relating to the workplace.

k) Production of flammable gases such as hydrogen and carbon monoxide due to incomplete combustion of fuel gas (especially when preheating).

Note: *Explosions have occurred when preheating items when incomplete combustion has provided a source of hydrogen and carbon monoxide that has accumulated in a poorly ventilated space and subsequently ignited on contact with air. Both hydrogen and carbon monoxide have very wide flammability limits, increasing the probability of a potentially hazardous mixture occurring between their lower explosive limit (LEL) and upper explosive limit (UEL).*

5.2 Gas Properties and Particular Hazards

5.2.1 Gases Used

The flames used in gas welding, cutting and allied processes operations are obtained by the ignition of mixtures of oxygen or air with appropriate fuel gases, the most common being acetylene, LPG, natural gas and hydrogen.

These fuel gases, especially when mixed with compressed oxygen, are capable of releasing very large amounts energy in the form of heat or explosion, requiring minimum energy to ignite the reaction.

Accordingly, fuel gases must be treated with great care and in accordance with well-defined safety procedures. Some industrial gases may be flammable, oxidising, toxic or corrosive, and users need to take special precautions in handling them. Users should always have on hand Safety Data Sheets, normally available from gas suppliers, for each of the gases stored and at each location they are used.

The properties of these and other commonly used gases are listed in Table 5.1. A summary of the properties, characteristics and hazards of the more common gases used in gas welding, cutting and allied processes are given in the tables on the following pages.

5.2.2 Oxygen

Cylinder colour is black. Oxygen has no smell, and is generally considered non-toxic at atmospheric pressure.

Oxygen normally constitutes 21% of air and when the concentration of oxygen exceeds 21%, flammable materials become increasingly easier to ignite and burn more rapidly and with a higher flame temperature. Oxygen itself does not burn, but supports and accelerates combustion in other substances including those not normally considered combustible, which may be readily ignited by sparks. Metals may also burn.

Hence, great caution must be exercised in preventing oxygen enrichment of the atmosphere, particularly in confined space situations. Oxygen should never be called “air”.

Oxygen in contact with oil, grease, other hydrocarbons or oil-based substances can cause spontaneous ignition and consequential fire or explosion. Hence all oxygen systems (e.g. cylinders, pipework, regulators, and blowpipes) must be kept completely free of oil or grease or coal dust.

Proper advice should be sought, e.g. from gas suppliers and equipment manufacturers, before using any materials for oxygen service, especially lubricants, seals and thread sealants, including PTFE tape, that have not been supplied for use with oxygen and marked accordingly.

When the oxygen concentration in the atmosphere is less than 21%, gradual and sometimes undetectable changes occur in operator's alertness and efficiency. Each year many accidents ranging from minor to fatalities occur through either misuse of oxygen or failure to understand its properties and their significance.

Some lessons that have been learnt through misuse or unsafe use of oxygen[3] are:

a) DO NOT use oxygen to refresh air: There is often a temptation to use oxygen to 'sweeten' air when welding or cutting operations have been carried out in confined spaces. Large amounts of oxygen can be released locally in a short time from gas cylinders under pressure. In one situation where this was done, hot work in the form of flame cutting was carried out with a subsequent ignition of worker's clothes and fatal burns.

b) TAKE CARE in confined spaces: Do not leave blowpipes or hoses connected to the supply gases within confined spaces during work breaks or overnight. Even slow leaks can result in very hazardous situations, with possible fire and explosion on re-ignition of the blowpipe.

c) VENTILATE confined spaces: In flame cutting not all of the oxygen released from the cutting nozzle is necessarily used in cutting. In confined spaces this may result in a dangerous increase in oxygen content in the air, pointing to the need for adequate ventilation in such situations.

Table 5.1 Physical and Safety Properties of Gases (see AS/NZS 80079.20.1[1])

							Non-Flammable Gases for Gas Shielding		
Property	**Oxygen (O_2)**	**Acetylene (C_2H_2) Note 1**	**LP Gas $CH_3CH_2CH_3$) (C_3H8) Note 2**	**Natural Gas (CH_4) Note 3**	**Hydrogen (H_2)**	**Coal Gas Mixture Note 4**	**Argon (Ar)**	**Carbon Dioxide (CO_2)**	**Helium (He)**
CAS No.	7782-44-7	74-86-2	74-98-6	74-82-8	1333-74-0	—	7440-37-1	124-38-9	7440-54-7
Density relative to air	1.103	0.901	1.52 to 2	0.55 app.	0.070	0.5 app.	1.38	1.52	0.138
Ignition (flammability) limits V% – in air (Note 6)	—	2.3 to 80*	1.7 to 10.9	4.4 to 17.0	4 to 77	6 to 32	—	—	—
Ignition (flammability) limits V% – in oxygen	—	3.0 to 95	2 to 57	5 to 60	5 to 94	8 to 70	—	—	—
Ignition temp °C – in air	—	305	466	537	585	560	—	—	—
Ignition (flammability) limits V% – in air (Note 6)	—	2.3 to 80*	1.7 to 10.9	4.4 to 17.0	4 to 77	6 to 32	—	—	—
Ignition (flammability) limits V% – in oxygen	—	3.0 to 95	2 to 57	5 to 60	5 to 94	8 to 70	—	—	—
Ignition temp °C – in air	—	305	466	537	585	560	—	—	—
Flame temp in air (Note 5)	—	2500	1980	1950	2210	~ 1650	—	—	—
Flame temp in oxygen (Note 5)	—	3480	2526	2750	3200	~ 2000	—	—	—
Smell	Odourless	Pungent (Sweet)	Pungent	Pungent	Odourless	Pungent	Odourless	Slightly acid	Odourless
Gas cylinder colour (AS 4484)	Black	Claret	Silver/Grey	Silver/Grey	Signal Red	—	Peacock blue	Green/Grey	Brown
Regulator colour (AS 4267, AS 4840)	Black	Red	Orange	Red	Red	Red	Blue	Green/Grey	Blue

Table 5.1 Physical and Safety Properties of Gases (see AS/NZS 60079.20.1) (continued)

							Non-Flammable Gases for Gas Shielding		
Property	**Oxygen (O_2)**	**Acetylene (C_2H_2) Note 1**	**LP Gas $CH_3CH_2CH_3$) (C_3H8) Note 2**	**Natural Gas (CH_4) Note 3**	**Hydrogen (H_2)**	**Coal Gas Mixture Note 4**	**Argon (Ar)**	**Carbon Dioxide (CO_2)**	**Helium (He)**
Welding hose colour (AS/NZS 1335 - see Note 8)	Blue	Red	Orange	Orange	Red/Orange	Orange	Black	Black	Black
Safety device colour (AS 4603)	Blue	Red	Red	Red	Red	Red	—	—	—
Blowpipe inlet connection colour	Blue	Red	Red	Red	Red	Red	—	—	—
Connection thread for fittings and hoses	RH	LH	LH	LH	LH	LH	RH	RH	RH

Notes

1. Acetylene is quite unstable and can ignite by decomposition at pressures above 200 kPa, therefore the UEL is considered to be 100% if the ignition source is of sufficient intensity. Many references therefore quote the flammability range in air as 2.3% to 100%.
2. LP Gas consists primarily of Propane ($CH_3CH_2CH_3$ or C_3H_8) – other constituents include artificial odorises for safety.
3. Natural Gas consists primarily of Methane (CH_4) and contains artificial odorises for safety.
4. Coal gas composition varies but consists chiefly of methane (CH_4), Hydrogen (H_2) and carbon monoxide (CO). Coal gas and the former town gas are similar.
5. Approximate calculated adiabatic values only – there is considerable scatter in the literature.
6. Also regarded as the lower explosive limit (LEL) and the upper explosive limit (UEL). Below the LEL the mixture is too lean in fuel to burn and above the UEL the mixture is too rich in fuel to burn.
7. Flammability limits, also called flammable limits, give the proportion of combustible gases in a mixture, between which limits this mixture is flammable on contact with an ignition source. Gas mixtures consisting of combustible, oxidizing, and inert gases are only flammable under certain conditions. The lower flammable limit (LFL) describes the leanest mixture that still sustains a flame, i.e. the mixture with the smallest fraction of combustible gas, while the upper flammable limit (UFL) gives the richest flammable mixture. There is a quantitative difference between flammability limits and explosive limits. In an explosive mixture the fuel oxidizer mixture is closer to stoichiometric proportion. This difference has no practical application in safety engineering as the flammable vapour cloud is turbulent and the exact mixture of fuel and oxidizer varies greatly. Therefore, many references use the term flammability limit (LFL, UFL) and explosive limit (LEL, UEL) interchangeably.
8. AS/NZS 1335[2] recommends that the hose manufacturer be consulted to confirm the suitability of the hose for use with hydrogen, and similarly for helium. Dedicated hoses may be required, particularly for hydrogen fuel gas.

d) DO NOT use oxygen as a substitute for compressed air: There are many examples of this situation where oxygen has been used, such as in cleaning, resulting in serious and fatal accidents due to fire or explosion from spontaneous ignition. NEVER use oxygen to start engines, drive air tools etc.

e) DO NOT use oxygen or compressed air to dust off clothes: Clothes can become readily flammable and even self-igniting through oxygen enrichment.

f) DO NOT KINK pressure hosing: Kinking or nipping hose to interrupt gas flows or whilst changing torches is a very dangerous practice. Gas can still bleed through the system, or more seriously, escape rapidly should the operator lose his grip or the hose rupture.

5.2.3 Fuel gases

Each of the fuel gas-oxygen combinations warrants care in use, from handling of the gas supplies through to the point of intended ignition. There are greatly increased risks of fire and explosion in the case of leaks. Asphyxiation is also possible due to exclusion of air in leakage situations.

The precautions in Section 5.2.2 (b), (c) and (f) therefore apply equally to the use of all fuel gases. All fuel gases have special properties that warrant additional precautions.

5.2.3.1 Acetylene

Acetylene cylinder colour is claret. Industrial grade acetylene is a highly flammable, colourless, non-toxic, and slightly lighter than air gas, with garlic-like odour. It is an unstable gas at ambient temperature and pressure, and it becomes very unstable at elevated temperatures and pressures. To minimise risks, acetylene is dissolved in acetone in special cylinders (see 5.3.3.2). It must also be stored and used upright to prevent liquid withdrawal.

a) Chemistry — Acetylene has the chemical symbol C_2H_2 and is considered to be the simplest of all alkynes with just two carbon atoms and two hydrogen atoms being joined by a triple covalent bond.

   This triple bond is useful in that it stores substantial energy that can be released as heat during combustion. However, it is unstable, making acetylene very sensitive to excess pressure, excess temperature, static electricity, or mechanical shock.

b) Decomposition — Acetylene will decompose in the absence of air or oxygen into its constituent elements, carbon and hydrogen, with the evolution of large amounts of energy in the form of heat and light. Extreme heat and/or massive mechanical shock can initiate this decomposition.

   Acetylene can explode with extreme violence if the pressure of the gas exceeds about 200kPa as a gas. Thus, it is important to observe the maximum operating pressure of 150kPa downstream of an acetylene regulator (see AS 4839).

c) Combustion — Combustion of acetylene with oxygen produces a flame of over 3100°C; releasing 55.8MJ/m^3 of heat, Oxy-acetylene produces the highest temperature flame of the common fuel gases, enabling its unique use for welding.

   i) Flammability in Air — Acetylene is extremely flammable in air, forming flammable mixtures from 2.3% to 80%, the widest range of any fuel gas – refer to Table 5.1.

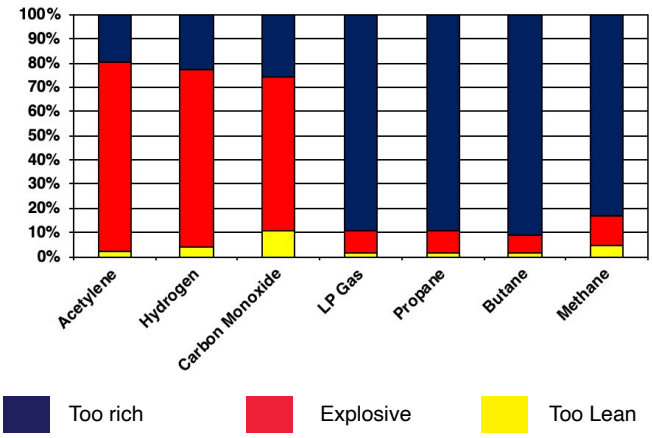


Figure 5.1 Fuel gas flammability concentration limits – in air

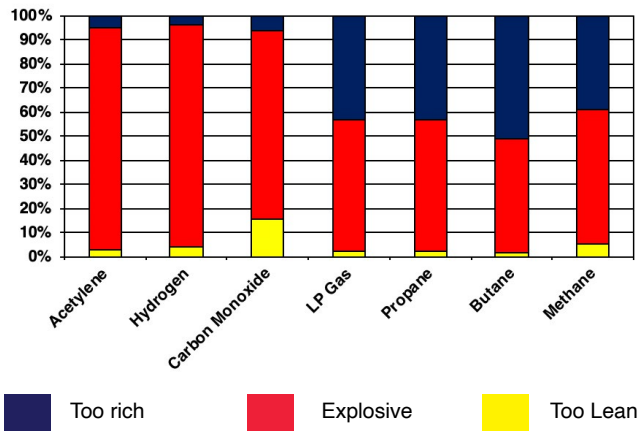


Figure 5.2 Fuel gas flammability concentration limits – in oxygen

Although acetylene is slightly lighter than air, for practical purposes, if it has leaked it will mix with the air and it is wise to assume it will be present in an explosive mixture.

Many references quote the flammability range of Acetylene in air as 2.3% to 100% as it can ignite by decomposition at pressures above 200kPa. Acetylene in air is flammable in a significantly wider range of concentrations than other common hydrocarbon gases mixed with oxygen.

ii) Flammability in Oxygen — Acetylene, in common with other flammable species, has a considerably wider flammable range in oxygen than in air – refer to Figures 5.1 and 5.2.

iii) Ignition Temperature — The auto ignition temperature for acetylene is very low at around 300°C (various sources range from 296°C to 325°C).

The energy required of a static spark capable of igniting acetylene is lower than for any other fuel gas except hydrogen. The ignition energy of acetylene in air is approximately seventeen times lower than that required for methane. The static charge developed by a person walking across a carpet floor on a dry day can be 1700 times greater than that needed to ignite acetylene. When acetylene is mixed with pure oxygen, the ignition energy is almost 100 times lower than it is in air.

A wide range of sources can ignite acetylene including:

- direct flame
- hot metal
- static discharge from a human finger or clothing
- sparks, e.g. from aluminium rubbing on rusty steel
- friction
- shock

iv) Rate of Combustion Reaction — As a consequence of its simple chemical makeup and sensitive triple bond, acetylene burns at a very fast rate. This very fast burning rate can accelerate the rate at which pressure is generated in an explosion beyond what would occur for other fuels. This, in turn, can make acetylene explosions more violent than for other fuels.

v) Flame Velocity — The oxyacetylene flame travels at 7.4 m/s. The velocity of the mixed gases flowing within the blowpipe must be greater than the flame velocity or flashback will occur.

d) Safe Use —Acetylene is slightly lighter than air and not likely to collect in ducts and drains, but could collect in roof spaces. It requires minimal energy to ignite in air or oxygen. A concentration of as little as 2.3% in the air can burn (or explode). Acetylene is a potential fire and explosion hazard. Adequate ventilation and leak free systems are required. Hot metallic particles or hot slag can cause ignition of leaks remote from the area where welding or cutting is taking place.
As this gas may decompose with explosive violence, it is supplied in special cylinders (Section 5.3.3). It must be used with dedicated regulators and hoses (see AS/NZS 1335[2]) specifically designed for acetylene.
To prevent flashback in welding, heating or cutting, flashback arrestors are essential, whether acetylene is supplied from gas cylinders or gas reticulation systems (Sections 5.6.1 and 5.4.7).
As acetylene can react with metals such as copper and silver to produce explosive acetylides, materials used for the construction of regulators, blowpipes, flashback arrestors and piping are restricted to copper alloys containing less than 70% copper or 43% silver.
Acetylene must be used at pressures not exceeding 150 kPa (see Sections 5.3.4.4 and 5.4.9.2).
The properties of acetylene are taken into account in systems developed for its storage and supply, and with adherence to safe procedures (Sections 5.3 to 5.5), dangerous situations will not arise.

> **NOTE***: Acetylene should not be stored in large volumes in reticulated piping systems and vessels, and care must be taken to prevent ignition sources including accidental heating of pipes and electrostatic sparks. Acetylene must not be vented to atmosphere.*

5.2.3.2 Liquefied Petroleum Gas (LPG):
LPG cylinder colour is silver grey or galvanised. LPG is usually supplied as a mixture of gases with propane as the main constituent.

a) Chemistry: Propane (formula C_3H_3) is a liquid at normal cylinder pressures but vaporises into the space above the liquid, therefore it is necessary to use the cylinder close to vertical to prevent liquid withdrawal. Standard LPG is odorised and has a fish-like smell. It is non-poisonous but may cause asphyxiation through depletion of oxygen.

b) Combustion: A flame temperature of about 2,800°C is produced when LPG burns with oxygen generating 95.8MJ/m³ of heat energy. It is denser (heavier) than air and will collect in low or confined spaces, e.g. ducts, drains, basements, boats, ships and closed tanks. A concentration of 2.3% to 9.5%

in the air can burn. It is a fire and explosion hazard, and, requires minimum energy to ignite when mixed with air or pure oxygen. LPG will ignite and burn instantly from a spark or piece of hot metal.

c) Safe use: LPG is denser (heavier) than air and will collect in low or confined spaces, e.g. ducts, drains, basements, boats, ships and tanks. Gas detectors are essential to prevent the risk of explosions in confined spaces.

LPG is usually used with oxygen for cutting applications and requires special cutting nozzles designed to handle the flame instability. Aspirated air torches are normally used for heating applications.

5.2.3.3 Natural Gas

Not normally supplied in cylinders for gas welding processes. It is available from gas reticulations systems at different supply pressures.

a) Chemistry: Natural gas is a mixture of gases and its main constituent is methane.

b) Combustion: A flame temperature of about 2,800°C is produced when methane burns with oxygen generating 37.7MJ/m³ of heat. It requires minimum energy to ignite in air or oxygen. A concentration of as little as 5% to 15% in the air can burn refer to Figures 5.1 and 5.2. Natural gas is a potential fire and explosion hazard.

c) Safe use – Natural gas is lighter than air and not likely to collect in ducts and drains, but could collect in roof spaces. Like LPG it is usually used with oxygen for cutting applications and requires special cutting nozzles designed to handle the flame instability. Aspirated air torches are normally used for heating applications.

5.2.3.4 Propylene

Propylene is supplied in disposable yellow cylinders. They are widely used by the plumbing and HVAC industry.

c) Chemistry: The chemical formula for propylene is C_3H_6

d) Combustion: The propylene/air flame temperature is about 2896°C generating 87MJ/m³ of heat. Propylene's lower explosive limit is 2% while its UEL is 11.1%.

e) Safe use: Propylene is denser (heavier) than air and will collect in low or confined spaces, e.g. ducts, drains, basements, boats, ships and tanks. Gas detectors are essential to prevent the risk of explosions in confined spaces.

Propylene is normally used with aspirated air torches for brazing applications.

5.2.3.5 Hydrogen

Cylinder colour is signal red. Hydrogen has no smell and is non-toxic.

a) Chemistry: Hydrogen (H_2) is much lighter (14x) than air so has a low risk of accumulation due to its propensity to readily float away.

b) Combustion: When hydrogen burns with oxygen the flame temperature is about 2,660°C generating 12.1MJ/m³ of heat. A concentration of 4% to 75.6% in air can burn. It is a fire and explosion hazard, and, has very low ignition energy – refer to Figures 5.1 and 5.2.

c) Safe use: The absence of a warning odour and its very low density combined with the possibility of explosion requires special attention in obtaining highly leak-tight distribution systems.

It burns with a very pale blue flame that is almost invisible and may be difficult to see under some working conditions.

Hydrogen cylinder valves should never be cracked open ("snifting"), as the gas may self-ignite in air on release from the cylinder valve.

5.2.4 Shielding Gases

These gases are used to shield particular arc welding processes or purging during welding of certain materials. They are non-flammable, non-toxic and usually inert and are stored in high pressure gas cylinders (see Table 5.1). Shielding gases may be pure argon and/or helium but in most cases are mixed with carbon dioxide and/or oxygen. Pure carbon dioxide may be used with some flux cored wires. Shielding gases are asphyxiants so care must be taken when used in confined spaces.



Figure 5.3 Colour coding of cylinders (see AS 4484)
Image courtesy CIGWELD

5.3 Gas Supply

5.3.1 General

Gases used in gas welding, cutting and allied processes are delivered to the point of use either from portable compressed gas cylinders colour coded to AS 4484[4] (Figure 5.3), supplying generally only one application, or from reticulation systems supplying an entire workshop.

> **Note***: Labels are the primary identification of the gas in a cylinder. The colour code is a secondary means of identification.*

Where cylinders are used it is important that at all times cylinders are secured to prevent toppling. Gas reticulation systems may be supplied from manifolded gas cylinders (packs), bulk gas vessels or from mains pressure supply (natural gas).

a) Cylinders (single or manifolded) are used in the majority of workshops (see Figure 5.3). Details of safe supply, usage, etc. are given in Sections 5.3.3, 5.3.4 and 5.3.6.

b) Bulk gas installations of liquid oxygen, argon, carbon dioxide and nitrogen in special insulated low temperature (cryogenic) storage vessels, or of liquefied petroleum gas in tanks (pressure vessels), are used in most large shops. General safety provisions are given in Sections 5.3.2 and 5.3.5.

c) Mains pressure supply of town or natural gas may be used where available in larger shops.

In all cases, gas supplies may be subject to statutory or regulatory provisions. Many Australian Standards cover the subject (see Appendix A for a listing). The location, separation, allowed quantities and signage of gas storage should be in accordance with the relevant statutory requirements and manufacturer's provisions.

5.3.2 Bulk Gas Supply

Bulk gas installations and acetylene generating plant safety provisions include:

a) Authorised personnel only are permitted to operate this plant.

b) Manufacturer's instructions must be available and followed.

c) Location must meet all statutory requirements and manufacturer's provisions. Particular mention is made of AS/NZS 1596[5].

d) Fire protection including firefighting systems, location of signs, and cleanliness of workplace and absence of ignition sources must comply with all statutory requirements and manufacturer's provisions.

e) Reporting of any abnormalities in the functioning of either a bulk installation or generating plant must be immediately reported to a responsible person. Emergency telephone numbers must be prominently displayed.

5.3.3 Cylinder Types and General Care

Cylinders used for oxygen, acetylene, LPG, hydrogen and all other gases, are in effect thin walled pressure vessels. Due to the presence of gases under pressure, full or partially filled cylinders can cause serious injury or damage should they rupture.

Cylinder design depends on the gas they contain. Compressed gases e.g. oxygen, nitrogen, argon, hydrogen and helium are stored at high pressures (up to 30,000kPa) and require high strength forged steel cylinders. Liquid gases such as LPG, propylene and methylacetylene-propadiene propane (MAPP) are stored at low pressures in thinner-walled welded steel cylinders.

Acetylene cylinders differ from those used for other gases in that they are filled with a porous substance saturated with acetone in which the acetylene is dissolved under pressure. Acetylene is unstable and highly reactive at high pressure. The porous substance or filler is therefore intended to quench heat of spontaneous decomposition and reduce the risk of explosion. Fusible safety plugs are fitted in the neck of the cylinder (or the cylinder valve) to permit the gas to escape, rather than have the cylinder explode in the event of overheating (see Section 5.6.5).

Many gases are available in disposable cylinders. Whilst propylene and MAPP have been available in Australia for decades, argon, oxygen and argon mixtures in disposable cylinders are recent additions. These oxygen and argon mixtures are stored at much lower pressures than standard industrial cylinders (typically up to 1,600kPa).

Cylinder valves are critical for the safe operation of all gas cylinders. Valve design depends on the gas and the cylinder pressure involved. Cylinder valves used in Australia must comply with AS 2473.2[6] (except for disposable cylinders) and incorporate a pressure relief (safety) device. These safety devices are designed to release gas if cylinder pressure exceeds the safe level to prevent the cylinder from exploding.

AS 2473.2[6] requires that cylinder valves have outlet connections specific to the gas involved. This is to prevent the risk of connecting the wrong regulator for a particular gas and cylinder pressure. Compressed non-flammable and non-toxic gases e.g. oxygen, argon, helium and argon based shielding gases have a Type 10 outlet (5/8” BSP RH internal 14TPI). Carbon dioxide



requires a Type 30 connection. Type 51 outlets are required for argon, helium and nitrogen in 30,000kPa cylinders.

Cylinder valves for flammable gases such as acetylene have Type 20 outlets while LPG, propane and propylene have Type 21 connections. Hydrogen cylinders are available in both a type 20 connectors for up to 20,000kPa, and type 22 connectors for pressures up to 30,000kPa. Where possible, if hydrogen cylinders are used in an environment that acetylene regulators may be available, the user should opt for a type 22 hydrogen regulator and type 22 connection hydrogen cylinder or cylinder pack to minimise the risk of inadvertent attempts to connect a low pressure regulator to a high pressure cylinder.

Because of these factors and the particular properties of the stored gases (Table 5.1), particular care is always required in the handling and usage of cylinders as follows:

a) Cylinders are generally obtained on loan or hire from gas suppliers. This enables the periodical testing specified in Australian Standards and statutory regulations to be carried out by the owner following and before refilling exchange.

b) Do not tamper with the markings or colour coding of cylinders. Do not use cylinders without labels/ colour code. If the labelling has been damaged or markings are illegible, do not guess contents – return any damaged cylinders to the supplier.

c) Refilling of cylinders must only be carried out by competent organisations with the correct gas and with the owner's approval. Refilling with any other gas is not permitted and is highly dangerous.

d) Gas should only be used for the particular intended purpose e.g. never use oxygen for cleaning (dusting), or to provide ventilation or to support breathing (see Section 5.2.2).

e) Gases should only be identified by their correct name so as to avoid dangerous mix-ups.

f) Never attempt to disguise or repair damage to a cylinder such as denting. Such cylinders must be returned to the gas supply company.

g) Care is required to ensure valve seats and outlets are protected by keeping all kinds of contamination away from cylinders, especially during connection and disconnection. Grit, loose fibres, hydrocarbons and other dirt may lodge in connectors and on valve seats causing leaks or may be picked up by high velocity gas streams, causing hot spots in regulators potentially resulting in ignition (Section 5.6.3). Organic matter such as oil, grease and hydrocarbon liquids that may ignite spontaneously in high-pressure oxygen is another hazard to regulators and other downstream equipment (Section 5.6.3). Any damage to valves or outlets should be reported.

h) Avoid flame impingement from the welding or cutting blowpipe. Keep cylinders away from all sources of heat (furnaces, boilers, radiators, flames). The fusible plugs at the top of an acetylene cylinder are particularly sensitive to heat and operation can lead to an extensive acetylene flame vertically from the top of the cylinder.

i) Do not be tamper with safety devices.

j) Return cylinders with the valve closed.

5.3.3.1 Oxygen Cylinders

a) Cylinder colour – black.

b) Filling pressure – up to 25,000kPa @ 15°C, (25,000kPa – 25.0MPa – 250 Bar).

c) Right hand thread.

d) Plain nuts on connectors.

e) Safety devices
   i) Plastic tag that indicates when the cylinder has been subjected to excessive temperature
   ii) Bursting disc that relieves pressure at approximately 1.5 x filling pressure.

f) Stored in a secure upright position.

g) Stored in a cool well-ventilated area.

Note*: At 65°C a full 200 Bar cylinder can reach pressures of up to 26,000 kPa. At 28,000 kPa the disc (safety device) bursts.*

h) Stored separately from flammable gases such as acetylene or LPG

i) When used in combination with fuel gases (Acetylene, LPG, Hydrogen) it is used for cutting, gouging, lancing, scarfing, brazing, welding, flame cleaning and heating.

j) High pressure compressed oxygen vigorously supports combustion of materials that would not normally burn in air.

5.3.3.2 Acetylene Cylinders

a) Cylinder colour – Claret (R55).

b) Acetylene gas is dissolved in acetone and stored within a porous mass (more stable).

Note*: Within a full acetylene cylinder (@ ~ 1,500 kPa) one volume of acetylene-saturated acetone dissolves up to 380 volumes of acetylene gas.*

c) Fill pressure – up to 1,500 kPa @ 15°C (1,500 kPa – 1.5 MPa – 15 Bar).

d) Left hand thread.

e) Notched nuts on connectors.

f) Safety devices
   i) Fusible plug or plugs in the neck that melts if the cylinder is exposed to 100°C temperature.
   ii) Vapour space in the neck to allow gravitational separation of acetylene and acetone before the acetylene enters the regulator.

g) Stored, transported and used in a secure upright position.

> **Note***: Acetone withdrawal from acetylene cylinders can occur during discharge if the cylinder is on its side during use, or has been on its side for a period of time prior to use, or gas flow is beyond the cylinder's maximum withdrawal rate.*

h) Colourless gas.

i) Pungent smell (sweet, garlic).

j) Slightly lighter than air and can accumulate in overhead cavities and enclosures.

> **Note***: Depending on the surrounds, leaking acetylene can accumulate in a cloud and explode without warning.*

k) Explosive in a wide range – 2.3% to 80% in air and 3% to 95% in O_2.

> **Note***: Due to the instability of acetylene and the propensity to decomposition (compression or auto-detonation) this value is often taken to be 100%.*

l) Use only correct fittings that must contain <70% copper content.

m) Discharge rate must not exceed 1/7th of contents/hour (see 5.5.1).

n) 'Empty' cylinders may still present an explosion hazard.

o) Stored in a cool well-ventilated area, away from oxidising gases.

5.3.3.3 LPG Cylinders

a) Cylinder colour – silver grey.

b) Left hand thread.

c) Notched nuts on connectors.

d) Safety devices – pressure relief valve incorporated in the valve body

e) LPG is a colourless, odourless gas. In order to detect releases of LPG from equipment and storage cylinders it has been given a distinctive odour by the addition of the chemical odorant ethyl mercaptan(ethanethiol), and most people describe the smell as either "rotten eggs" or "rotten cabbage".

f) LPG is pressurised to 700 kPa at which pressure it forms a liquid (0.7 MPa – 7 Bar).

g) 1 litre of LPG liquid will form 250 litres of gas when vaporised.

h) Stored in a secure upright position.

i) Stored in a cool well-ventilated area, away from oxidising gases.

j) Must be used in an upright position. Exception is LPG cylinders used for industrial vehicles such as forklift trucks, which are stored and used in the horizontal position.

k) 'Empty' cylinders may still present an explosion hazard.

l) Heavier than air and will tend to settle.

m) Narrower explosive range – 2% to 10% in air – 2% to 57% in O_2.

n) No limit on hourly discharge rate. Cylinders may freeze up if draw-off rates are too high.

o) 100% usage.

p) LPG has a lower flame temperature than acetylene – O_2 consumption is 4 times higher for LPG than for acetylene. Flame temperatures are ~2,800°C for Oxy/LPG vs ~3,200°C for Oxy/Acetylene.

5.3.3.4 Propylene cylinders (disposable)

a) Cylinder colour – yellow.

b) Right hand thread BOM fitting

c) Safety devices –

d) Propylene is a colourless gas with a slight petroleum odour.

e) Store in a secure upright position.

f) Store in a cool well-ventilated area away from oxidising gases.

g) Must be used in an upright position.

5.3.3.5 Hydrogen cylinders

a) Cylinder colour – red.

b) Left hand thread.

c) Notched nuts on connectors.

d) Safety device – pressure relief valve incorporated in the valve body.

e) Filling pressure – up to 30,000kPa (30.0MPa or 300 Bar) @15°C

f) Store in a secure upright position.

g) Store in a cool well-ventilated area, away from oxidising gases.

5.3.3.6 Shielding Gas Cylinders

a) Cylinder colour – depends on contents (see

AS 4484[4] – these gases are non-flammable and non-toxic so will be distinguished by hues of Brown, Green grey and Peacock Blue.

b) Filling pressure – typically up to 25,000kPa @ 15°C, (25,000 kPa – 25.0MPa – 200Bar).

Note*: Some cylinders and packs may be filled to much higher pressures, for example, up to 30,000 kPa @ 15 °C, (30,000 kPa – 30.0 MPa – 300 bar). These are usually fitted with pressure reducing valves that reduce the outlet pressure to well under 20,000 kPa so that existing cylinder regulators or connectors can be used, or Valves with Integrated Pressure Regulators (VIPRs) that can be connected directly to the hoses.*

c) Right hand thread.

d) Plain nuts on connectors.

e) Safety device – bursting disc in the valve.

f) Stored in a secure upright position.

g) Stored in a cool well-ventilated area.

h) Stored separately from flammable gases such as acetylene or LPG.

5.3.4 Cylinder Storage, Transport, Handling and Use

5.3.4.1 Storage

All storage areas must comply with statutory requirements. Australian Standard AS 4332[7] gives complete requirements and is referenced in State regulations and SafeWork Australia's Code of Practice *Managing risks of hazardous chemicals in the workplace*[8]. LP Gas storage should additionally meet the requirements of AS/NZS 1596[5].

Cylinder storage areas should be well ventilated and away from sources of heat. External storage is preferred. Protection from weather is desirable but not at the expense of ventilation. Other products should not be stored with cylinders, especially oil, paints or corrosive liquids. Oxygen cylinders must be separated from fuel gas cylinders by a distance greater than 3 metres or by a suitable fire wall at least 1m higher than the tallest cylinder.

LP Gas (LPG) cylinders should be stored in accordance with AS/NZS 1596[5]. LPG cylinders in excess of 50kg total capacity should not be stored within 3 metres of any other cylinders, including acetylene.

Cylinders should always be stored upright and restrained to prevent falling. Full cylinders should be segregated from empty ones and fuel gases from oxygen. "NO SMOKING OR NAKED LIGHTS" signs should be displayed where fuel gases are stored.

5.3.4.2 Transport – General

Take sensible precautions and ensure Australian Dangerous Goods Code (ADGC) and other regulatory requirements are met.

Use open vehicles wherever possible (Figure 5.4(c) and (d)). If closed vans or cars have to be used make sure they are properly ventilated at all times. Ensure all valves are fully closed and that there are no leaks. Secure cylinders against movement within the vehicle. Do not allow any part of the cylinder to protrude from vehicle (this prohibits cylinders being carried horizontally across forklift tines). Disconnect all equipment (e.g. pressure regulators) from cylinders. Do not use or transport cylinders in a closed vehicle or enclosed cabinet on a vehicle.



a) Two-cylinder trolley b) Cylinder trolley with lifting point c) Cylinder restraint brackets d) Transporting cylinders in cars

Figure 5.4 Handling of gas cylinders
Images courtesy BOC

Acetylene and LPG cylinders must be transported upright. This ensures that the safety device is in contact with vapour and not liquid.

5.3.4.3 Transport – Low Headroom

Where it is impractical to transport cylinders safely in the upright position, such as into mines, they should only be laid down for the minimum time practicable and the cylinder must be protected against shock. When the cylinders are in position they must be immediately placed in the upright position. Acetylene cylinders must be left standing before use for sufficient time to allow the acetone to settle and the vapour space to reform at the neck of the cylinder. Acetylene cylinders should be left standing before use for the same period of time as they were laid down during transport. OEM data may indicate shorter times are suitable.

5.3.4.4 Handling

Do not move cylinders with the cylinder valves open. Never lift a cylinder by the valve or with magnets, chains or a sling. Use a cradle when lifting cylinders by crane. Never roll a cylinder along the ground. This damages the identification labels, and may cause the valve to open. Use a trolley for manual handling (see Figure 5.4(a) and (b)). The trolley should incorporate a heat shield because of the proximity of the fuel gas to the oxygen cylinder.

5.3.4.5 Cylinder Use

The manufacturer's instructions and recommendations should always be followed. Factors that warrant mention in addition to the safe procedures given in Table 5.4 are:

a) Never open (“crack” or “snift”) a fuel gas or oxygen cylinder valve. Uncontrolled release of fuel gases or oxygen can result in fires and explosion.

b) Damaged valves or regulators or those suspected to be damaged should not be used until checked by a competent organisation or person.

c) Cylinders must never be used as rollers to assist moving other objects.

d) Acetylene, LPG and liquid gas cylinders must always be in the vertical or near vertical position when in use.

e) Acetylene can only be used to a maximum pressure of 150kPa (gauge). With increasing pressure explosion may occur due to instability of this gas.

f) Opening of cylinder valves should only be carried out with approved keys or hand wheels. Do not use excessive force or extension key to open or close cylinder valves.

g) Acetylene valves should not be opened more than about one and a half turns; one turn is preferable to allow for quick closing in an emergency.

h) Empty cylinders should have the valves closed, any protective caps fitted and be suitably identified e.g. "MT" in chalk.

i) Always leave cylinders with the valve closed.

5.3.4.6 Connection of Regulators and Hoses

Keep the cylinder valve clean, especially its outlet connection. No grit, dirt, oil or dirty water should be present. Particles of dirt and residual moisture may be removed by blowing out, by wiping with a clean dry cloth or blowing out with clean dry compressed air. The old practice of “cracking” open the valve momentarily and then closing it (also known as “snifting”) has led to a number of incidents and is now a prohibited practice on many worksites.

Make sure the pressure regulator is suitable for the gas and pressure in the cylinder and that its inlet connection is the same thread as that in the cylinder valve. Fuel gas connections have left handed threads. Never force any connection that does not fit.
Open the cylinder valve slowly (anti-clockwise) using its hand wheel or a suitable key for key-operated cylinder valves. An opened valve should never be left against the backstop (i.e. fully opened until resistance is encountered), but should be turned back at least half a turn to avoid seizure in an open position. This can occur if a valve is left open for long periods of time. If the valve spindle is too stiff to turn with the hand wheel or the correct key, do not increase the leverage on the spindle and return the cylinder to the gas supplier. Close the valve (clockwise) after use. Do not over tighten the spindle when shutting off the valve as this will destroy the soft seating material in the valve.

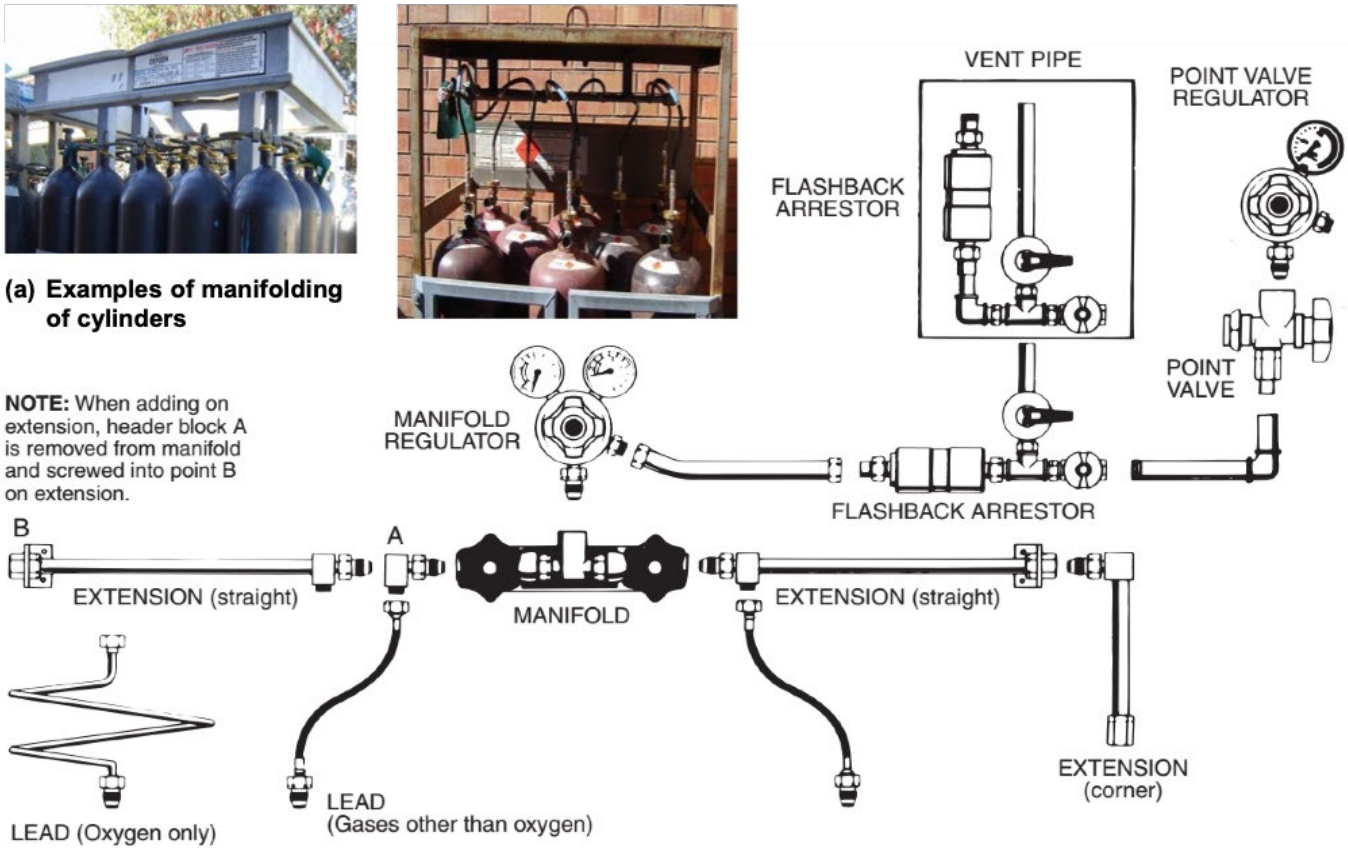
5.3.5 Piping and Manifolds

Where gas requirements exceed the delivery achievable from a single cylinder or uninterrupted supply is required, or cylinder handling is to be avoided, manifolding of cylinders (Figure 5.5) and piping gas to the point of use is widely adopted. Manifolds are also used for connecting multiple cylinder packs and/or bulk gas tanks to gas reticulation systems (pipelines)

AS 4289 applies to oxygen-acetylene systems and AS/NZS 1596[5] to LPG systems. Regulatory requirements may also apply.

Care is required in design, choice of materials, location of piping etc. as outlined in the following:

a) Design of systems must only be carried out by qualified persons and in accordance with appropriate design rules and regulations. The gas supply organisation will generally be responsible for this.



Notes

1. All leads should conform to EN ISO 14113 as there is currently no applicable Australian standard
2. The fitting of oxygen manifold flashback arresters is common practice in Europe and advised, but not currently required, in Australia
3. Oxygen flexible leads must have a heat sink and anti-whip cable
4. Leads direct to cylinder packs should be 1800 mm or longer

Figure 5.5 Manifold of cylinders

b) Manifolds should be located in environments free of oil, grease and dust and should be compatible with the filling pressures of the cylinders to be connected, especially in the case of oxygen.

c) Components such as regulators, pressure gauges and connections should comply with AS 4267[9] and be of a satisfactory type for the gas type and operating pressure.

d) Materials must be of a suitable type and have adequate resistance to the chemical action of the gas under operating conditions. Attention is drawn to the fact that alloys of a higher copper content (greater than 70% copper) cannot be used in applications involving acetylene due to the possibility of formation of explosive copper acetylide. Acetylene piping is usually of the seamless steel or stainless-steel type.

e) Location should be chosen to avoid damage to piping and allow ease of repair (e.g. use ducting) and be remote or insulated from electrical cables.

f) Piping must be clearly labelled at inlet and outlet ends and along the length to identify the contents. Marking should be in accordance with AS 1345[10].

g) Piping must never be used as an earth for electrical equipment or as a work return path for welding due to the risk of explosion, fire or corrosion damage to the pipe.

h) Operating instructions must be available and safety-warning notices prominently displayed.

i) Installation must only be carried out by qualified persons experienced in the requirements for oxygen and fuel gas pipelines. Internal surfaces of piping and fittings must be free of foreign matter and the completed system should be fully tested prior to commissioning.

j) Outlet points for use with oxygen-fuel systems should comply with AS 4289[11] e.g. incorporate a shut-off valve and a flashback arrester as a minimum.

k) Regulators used on manifold systems must be capable of matching the flow and pressure requirements.

Note*: Pipeline outlet regulators which are designed for use on lower (regulated) pressures should be used on pipeline outlets. Standard regulators designed to operate at the high cylinder pressures should not be used on pipeline outlets.*

l) The requirements a) to i) above are also applicable to portable outlet headers.

5.3.6 Portable and Mobile Cylinder Supply

Portable and mobile cylinders should be set up in accordance with the requirements of AS 4839[12]. Portable and mobile cylinder trolleys should be of a design that enables the cylinders to be returned to the upright position when in use (Figure 5.4).

5.3.6.1 Storage

The general provisions given under 5.3.4.1 Cylinder Storage apply equally for these applications except see 5.4.8 for cylinder trolleys.

5.4 Equipment Specifications and Assembly

5.4.1 General

All equipment and assemblies of equipment should be properly designed, manufactured, maintained and used in conformance with appropriate Australian Standards where these exist, or other alternative National or International Standards if not available. In particular, full consideration should be given to the hazards inherent to the use of oxy-fuel gas mixtures detailed particularly in Sections 5.1, 5.2, 5.3 and 5.6.

5.4.2 Pressure Regulators and Gauges

Applications should never be supplied directly from compressed gas cylinders. A pressure regulator must be connected to the gas cylinder to control the pressure of the gas at the end application e.g. a welding or cutting blowpipe (see Figure 5.6). Regulators are usually fitted with two pressure gauges to allow monitoring of the cylinder contents and the delivery pressure to the end application. Australian Standards AS 4267[9] and AS 4840[13] give requirements for regulators for each gas and cylinder filling or reticulation pressure.

Although accidents rarely occur as a direct result of regulator failure, care must be continuously exercised because the potential hazards are severe. This is particularly true of oxygen regulators where ignition and explosion is possible under adverse conditions (see Section 5.6.3). It must be noted that fill pressures for oxygen cylinders have increased over time, and older regulators may not be suitable for the newer cylinders due to hazard from ignition. AS 4839 requires that regulators are overhauled or replaced after 5 years.

The following recommendations should be observed in order to ensure continued safe operations:

a) Regulators should be used only with the gas and maximum cylinder pressure for which they are designed and labelled (see AS 4267[9] and AS 4840[13]).

b) The maximum outlet pressure of the regulator should never exceed the rated pressure of any downstream equipment

c) Acetylene and LPG regulators should only be used with the gas for which they are designed. Use of an LPG regulator on acetylene cylinders could result in exceeding the maximum safe use pressure of acetylene.

d) Regulators having damaged pressure gauges or inlet and outlet connections etc. should never be used. Inlet and outlet connections should never be changed from the original manufacturing specification.

Recommended pressures for acetylene tips (i.e. cutting tips and welding blowpipes) used in general fabrication and maintenance are typically in the range of 50kPa (welding tips) to 100kPa (majority of cutting, gouging and heating tips). There are exceptions to this generalisation where pressures lower than 50kPa are recommended for certain tips but they are not commonly used in general fabrication. Weld Australia is not aware of any tips designed to operate at any acetylene pressure greater than 100kPa.

An acetylene pressure regulator complying with AS 4267 is limited by a stop on the adjusting screw that prevents the regulator being set to a pressure higher than 150kPa. Most tips found in maintenance workshops are designed to operate at an acetylene pressure of 100kPa.

Acetylene at a pressure of 250kPa or greater is prone to auto detonation (compression).

It is not practical or indeed safe to increase acetylene pressures to compensate for pressure drops over long hose lengths.

5.4.2.1 Static Increment

AS 4839:2001 Clause 7.3 specifies that the static increment or “gauge creep” shall not exceed 30%



Figure 5.6 Acetylene and LPG regulators and gauges, and regulator point valve set to AS 4840[12]
(Images Courtesy BOC and TeSuCo)

of the pressure indicated under operational flow conditions, (sometimes referred to as the dynamic pressure).

If we consider an acetylene regulator set to an operational flow (dynamic) pressure of 100kPa. This means that during operation the regulator gauge would indicate a regulated pressure of 100kPa with gas flowing. The static increment, or increase in indicated pressure, when the gas is turned off, should not rise above 130kPa, an increase of 30kPa, in this example.

5.4.2.2 Gauge Indication at Zero Pressure

Gauges on pressure regulators are covered by AS 1349[14]. Pressure regulators and their gauges can be easily damaged by incorrect start-up and shutdown procedures resulting in shock loading of the regulator seat and damaging the bourdon tube or mechanism of the gauge. A gauge that does not return to zero when the system is depressurised indicates damage.

Gauges that indicate a pressure other than zero (within 3% of maximum range) at atmospheric pressure do not comply with AS 1349[14].

5.4.3 Hoses and Fittings

5.4.3.1 Requirements

Hose and fittings for use in gas welding, cutting and allied processes should meet the requirements, including colour coding, specified in AS/NZS 1335[2] and the additional requirements of AS 1869[15] for LPG. For safety reasons the hose should present the minimum practicable flow restriction, i.e. be of the largest diameter and shortest length possible to minimise pressure drop and gas starvation at the tip or nozzle with potential of flashback.

5.4.3.2 Colour Coding

It should be noted that AS/NZS 1335[2] specifies different test methods and cover colours for acetylene hose (red) and LPG hose (orange). These hoses are constructed of different materials in accordance with the respective properties of acetylene and LPG and should never be interchanged. AS/NZS 1335[2] also specifies the colours for oxygen (blue) and air, nitrogen, carbon dioxide and argon (black) – see Table 5.1.

5.4.3.3 Location

Hoses should be located and protected from heat, mechanical damage, traffic, sparks, slag and oil so that accidental damage such as piercing or burning cannot occur. Location of hoses over sharp edges or manifolds or under sparks or hot slag from welding or cutting should be avoided.

5.4.3.4 Fittings

These must be as specified in AS/NZS 1335[2], with dimensions as specified in AS 4267[9] *Pressure regulators for use with industrial compressed gas cylinders*, be of an appropriate type, with connections securely made and leak tight. Wire should never be used to fasten hose to fittings. Oxygen and shielding gas fittings have right hand threaded nuts, fuel gases left hand threaded nuts.

5.4.3.5 Length and Diameter

Hose should be of a diameter suitable for the flows required by the intended application. Hoses should be of the minimum practicable length to avoid excessive pressure drop, kinks, accidental damage etc.

It is recommended that the maximum hose length

should not exceed fifteen (15) metres for each gas, or such distance that will allow the operator of hand-held equipment to be in sight of all the supply gas cylinders, whichever is the smaller. Hoses should be single length, but where extended lengths are required, lengths of hose should only be joined using fittings that comply with AS/NZS 1335[2]. If twin hose is not used, single oxygen and fuel gas hoses should be clipped together at about two metre intervals using special clips available from the hose supplier.

AS/NZS 1335[2] defines a range of hose sizes (i.e. nominal internal diameter) from 4.0 to 50.0mm, including 5.0, 6.3, 8.0, 10.0, 12.5, 16.0 and 20.0. AS 4839[12] specifies that the maximum length of hose shall be 15 metres.

The standard outlines two reasons for this:

a) To maintain the supply cylinders (this obviously includes pressure regulators and regulator end safety devices) within view of the operator.

b) Ensure flow rates at the tip are adequate to ensure the gas flow rate is matched to the flame velocity.

The second point is referred to in Clause 7.4 of AS 4839. Insufficient gas flow or velocity in the tip is the prime reason for the flame to move back into the mixer of the blowpipe during a back-fire or flashback. If flow velocity is too low the flame can "chase" the mixed gases back to the mixer. Maintaining a minimum velocity of the gas mixture as it leaves the tip is critical for stable operation and depends on the pressures of the fuel and oxygen set at the regulators, the length and diameter of the hoses and the cumulative flow restrictions in the system. Restrictions can develop in operation due to blocked or damaged tip orifices, accumulation of particles (build-up of soot) in safety devices, or kinked and pinched hoses.

If hoses longer than 15 metres are required in particular circumstances, pressure losses can be overcome by increasing the hose diameter. A 10 mm diameter hose, for example, carries four times the volume and therefore has a much lower pressure drop per unit distance at a given flow rate than a standard 5 mm diameter hose. It is recommended that larger diameter hoses be considered where the 15-metre restriction is impractical.

Equipment manufacturers advice should be sought to ensure the correct high flow safety devices are matched to higher capacity hoses.
Where published data or advice cannot be obtained from the manufacturer or manufacturers of components used in a system, AS 4839 requires the user to ensure that the "*assembled system is safe to use and complies with this Standard*." Refer AS 4839:2001 Clause 7.1.

Where it is necessary to use hose lengths greater than allowed by AS 4839 or OEM data, substitution of LPG for acetylene should be considered. LPG draw-off rates can be much higher than acetylene draw-off rates. There are no immediate safety concerns with use of high draw-off rates from LPG cylinders, however at very high rates the cylinders may "freeze", limiting the available gas.

5.4.4 Blowpipes and Mixers

Blowpipes perform the gas control and mixing function with the aid of a gas mixer that may be integral to the blowpipe or a separate, compatible attachment. In any case, blowpipe and mixer must perform the mixing of oxygen and fuel gas with due consideration to potential backflow of gases and flashback.

5.4.4.1 Requirements for Blowpipes

a) The inlet connections should be suitable for the welding hose fittings (see 5.4.3.4).

b) The control valves should be clearly marked 'oxygen' and 'fuel' (e.g. by the full names or by the abbreviations 'O' and 'F'), and colour coded blue for oxygen and red for fuel gas.

c) Only suitable mixers and other attachments should be fitted to a blowpipe.

d) The blowpipe and mixer should be operated in accordance with the manufacturer's instructions.

e) Particular attention should be paid to the recommended maximum and minimum operating pressures and flows for the blowpipe-mixer tip or nozzle combination. These should always be respected.

5.4.5 Tips, Nozzles and their Attachment Fittings

a) Tips and nozzles should be well identified and carry information relating to their use.

b) Tips and cutting nozzles appropriate to the particular fuel gas should be used. Sizes should be selected from the supplier's operating data or Weld Australia's Technical Note 5, Flame Cutting of Steels.

c) It should be noted that tips and nozzles operate safely and efficiently over a limited range of flows.

Below a minimum flow the flame will recede into the tip or mixer with potential hazard of flashback. Manufacturer's recommendations for correct operating pressures and flows should be followed.

d) Recommended operating pressures for tips and nozzles should take into account the pressure drop introduced by long lengths or small diameters of hoses and any added safety devices.

5.4.6 Safety Devices

5.4.6.1 Requirements

It is recommended that safety devices should always be used in oxygen-fuel systems. AS 4839 specifies safety devices shall be used in all portable or mobile oxy-fuel systems. Safety devices should comply with AS 4603. Regulatory requirements may apply. For example, in Western Australia, the use of flashback arresters on both ends of the gas delivery hoses is mandated.

Flashback is the sustained retrogression of the flame into the upstream gas passages of the blowpipe, and possibly into the hoses and regulators, with the risk of a subsequent explosion. If the flashback goes to the mixing chamber there is a squealing sound and a characteristic smoky, sharp-pointed flame. If the gases are not promptly turned off, it is likely that the blowpipe will melt (often in a heating barrel).

As a minimum one non-return valve and flame arrester for each gas line should be used. Flashback arresters that comply with AS 4603 must include a non-return valve and flame arrester. Additional devices should be fitted where practicable. Optimum protection is provided when a flashback arrester for each gas is fitted at the blowpipe end, and a flashback arrester with a temperature activated cut-off valve for each line is fitted at the regulator end (see Figure 5.7).

> **Note**: *The use of safety devices like non-return valves or flashback arresters does not reduce the need to follow correct and safe operating procedures (see Table 5.4).*

Due consideration should be given to the pressure drop introduced by the safety devices, and it should be ensured that the total system is capable of supplying the required pressures and flows to the end application (tip or nozzle) as recommended by the manufacturer. If pressure drop is excessive, flame instability will result, and once this point is reached additional safety devices may reduce, rather than increase, the safety level due to the lower flow capacity. Higher flow flashback arresters should be fitted to minimise the pressure drop.

5.4.6.2 Non-return Valve

A non-return valve is a device designed to prevent the passage of gas in the direction opposite to normal flow. When fitted to the blowpipe end of the hose, as long as it is in good condition, it reduces the possibility of oxygen and fuel gas mixing within one hose by preventing back flow of gases. Non-return valves do not respond quickly enough to stop a flashback reaching the hose, regulator, pipeline or cylinder. Only a correctly designed flashback arrester can stop flashbacks.

5.4.6.3 Flame Arrester

Flame arresters are devices that incorporate a dense sintered element to quench a flame front (flashback or decomposition).



Figure 5.7 **Pressure regulator connected to the gas cylinder to control the pressure of the gas at the end application (generally a Welding or cutting Blowpipe)**
(Image Courtesy BOC)

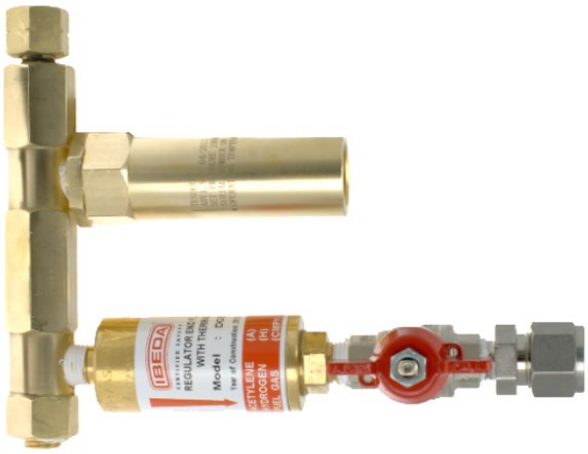


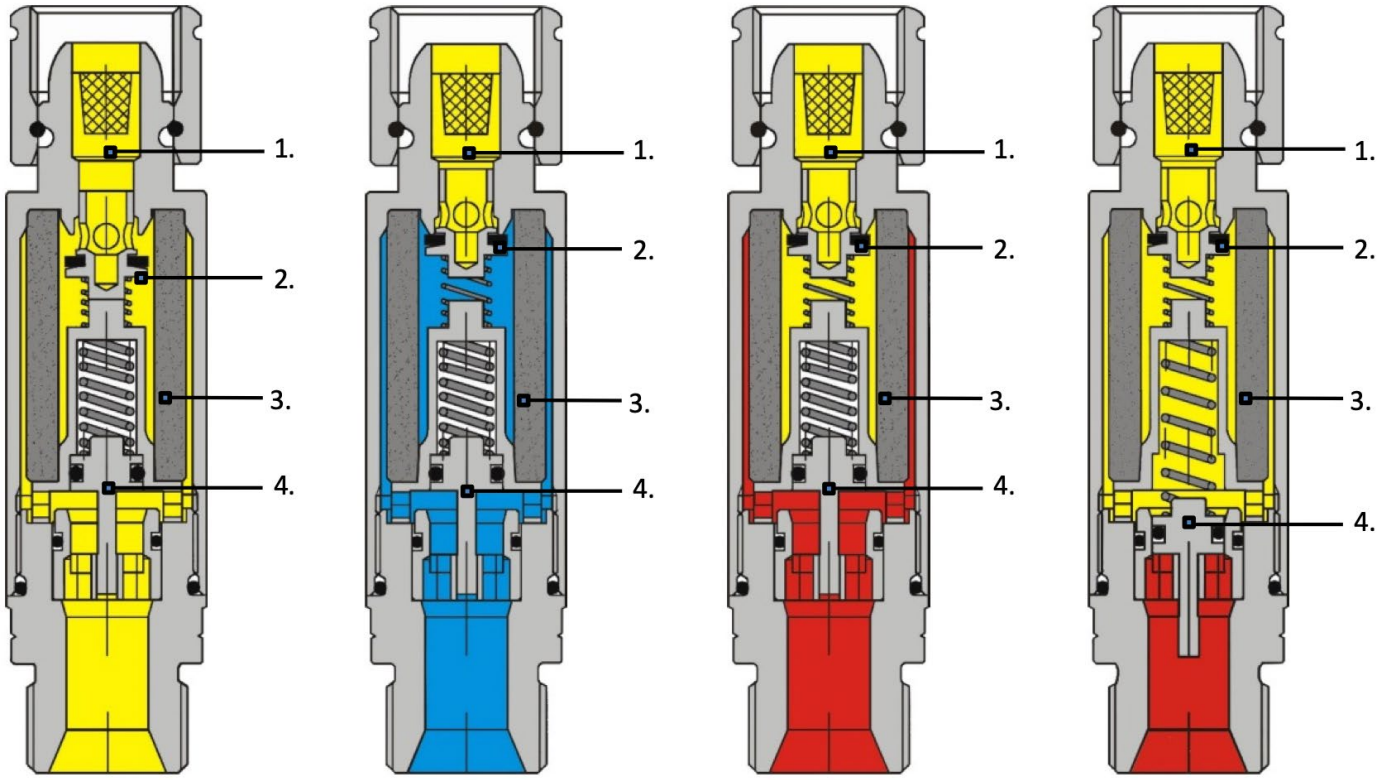
Figure 5.8 **Safety relief valve system (acetylene) with integrated flashback arrester**
(Image Courtesy TeSuCo)

5.4.6.4 Flashback Arrester

A flashback arrester is a safety device designed to stop a flashback and is for use on equipment where fuel gas and oxygen/compressed air are being used in combination. A flashback arrester is designed to prevent a flashback reaching the hoses, regulator, pipeline or cylinder and includes a non-return valve and flame-arrester.

Flashback arresters (see Figure 5.9) incorporate one or more of the following:

- Flame arrester – a device that quenches a flame front (flashback or decomposition). Depending on design, devices are effective in one or both directions. The good thermal conductivity, high porosity and small pore size of the sintered element leads to flame quenching.
- Non-return valve – a device that prevents passage of gas in the direction opposite normal flow. It is held open by energy in the gas stream and closes when downstream pressure is approximately equal to, or greater than, that in normal direction of flow.
- Temperature-sensitive cut-off valve – a device that closes preventing passage of gas when a predetermined temperature has been reached.
- Excess flow cut-off valve – a device that closes in the event of flow exceeding a predetermined value.
- Pressure-relief valve – a device, which automatically vents gas to the atmosphere when the pressure exceeds some, predetermined value and seals again when the pressure returns to within specified limits of that value (see Figure 5.8).
- Pressure-sensitive cut-off valve – a device that closes in the event of a backpressure wave from the downstream side of the cut-off valve.



Notes
1. Dust filter
2. Non-return valve open
3. Flame arrester
4. Temperature-sensitive cut-off valve open

a) Normal flow

Notes
1. Dust filter
2. Non-return valve closed
3. Flame arrester
4. Temperature-sensitive cut-off valve open

b) Reverse flow of oxygen of fuel gas

Notes
1. Dust filter
2. Non-return valve closed
3. Flame arrester
4. Temperature-sensitive cut-off valve open

c) Flashback

Notes
1. Dust filter
2. Non-return valve closed
3. Flame arrester
4. Temperature-sensitive cut-off valve open

d) Burnback

Figure 5.9 Flashback arrester – modes of operation
(Image and Diagrams Courtesy Ibeda)

5.4.6.5 Fitment of Safety Devices

AS 4839 specifies safety devices shall be used in all oxy-fuel systems. As a minimum, one non-return valve and flashback arrestor per gas line must be used with due consideration to the pressure drops experienced in all components of the assembled system at the rated flow capacity of the tip or nozzle in use.

> **Note**: *For high flow applications (such as heating) the operator is to ensure higher flow flashback arrestors are used.*

Flashback arrestors shall comply with AS 4603[16]. Additional devices shall be fitted whenever practicable. The minimum recommended configurations are listed below in order of preference.

1. Flashback arrestors at both hose ends (optimum protection). Optimum protection is provided when at the blowpipe end a flame arrestor and a non-return valve for each gas line are fitted, and at the regulator end a flame arrestor, a non-return valve and a temperature activated cut-off valve for each line is fitted. Pressure activated cut-off valves at the regulator end are optional. The options in 2. and 3. below provide lower levels of protection and should be used only when it is not otherwise possible to achieve the rated flows of the end heat output device through the lack of outlet pressure from the pressure regulator.
2. Flashback arrestors at the blowpipe hose ends only. A flame arrestor and a non-return valve shall be fitted to each blowpipe inlet connection.
3. Flashback arrestors at the regulator hose ends and non-return valves at the blowpipe ends. At the blowpipe end, non-return valves shall be fitted on each gas line. At the regulator end, a flame arrestor, non-return valve and a temperature activated cut-off valve shall be fitted to each gas line. A pressure activated cut-off valve may also be fitted at the regulator end of each gas line.

5.4.6.6 Flow Capacity and Operating Pressure

After the final assembly has been chosen, the user should verify the operating pressure and flow of each gas recommended by the manufacturer for the tip or nozzle in use. The user should ensure that all pressure drops through the whole of downstream equipment have been considered.

5.4.6.7 Maintenance of Safety Devices

Continued performance of safety devices is essential to safety performance. Safety devices should be included in any routine inspection and maintenance schedule and tested in accordance with manufacturers' recommendations and requirements of relevant standards e.g. AS 4839[12].

5.4.7 Personal Protective Equipment (PPE)

Operators of oxy-fuel gas equipment should use appropriate personal protective equipment. Full details are given in Chapter 19.

5.4.8 Cylinder Trolleys

Cylinder trolleys should provide a suitable platform with secure non-flammable restraints for operation and transport. Trolleys should enable safe and stable transport of cylinders to the work location. A maximum of one each of oxygen and fuel should be used on a trolley. Acetylene cylinders must always be upright in operation. A heat shield between the cylinders is recommended.

Cylinders should be located on the trolley such that outlets are directed away from the other cylinder in the event of a possible release from a cylinder safety device to allow unimpeded release of gas. The maximum size of cylinder allowed by the design should be stated on a permanent label on the trolley.

5.4.9 System Assembly

5.4.9.1 General Compatibility

Any gas welding, cutting and allied processes application comprises many components, from gas cylinder or supply vessel to tip or nozzle. In the general case, many manufacturers and suppliers will provide these components separately. Even where one vendor supplies all the system components, the possible permutations are many. The user will decide the complete combination selected for any particular application; hence it is vital that not only the selected equipment complies individually with the specifications given above, but that the components are compatible with each other.

Significant factors to be considered and avoided include insufficient pressure gas flow at the regulator outlet, especially in the case of acetylene, welding hose too small in diameter or too long and insufficient flow capacity due to the flow capacity of hoses and safety devices downstream.

Where a manufacturer provides this information in the form of a table indicating suitable combinations of regulator outlet pressure, appropriate lengths and diameters of hose and type and position of safety devices, only those combinations should be used. An example of such a table is shown for guidance in Table 5.2.

Each size and type of tip (nozzle) has a recommended ideal operating pressure for both the oxygen and fuel gas, and these pressures should be marked on the tip.

Each size and type of tip also has a characteristic flow rate at the recommended pressure. Flow rate information is available from manufacturers' data.

A common mistake is to set up an oxy-acetylene system based on experience rather than equipment manufacturers' recommendations. This often puts the operating parameters well outside those recommended for safe use by the equipment manufacturers and exposes operators and other personnel to potentially hazardous situations. Equipment manufacturers publish data on maximum recommended hose lengths for a given hose diameter, safety devices, tip type and tip size. Equipment must be matched for safe operation.

5.4.9.2 Fuel Gas

The choice of fuel gas uniquely determines several of the system operating parameters, especially equipment and operating pressures. Only equipment specified by the manufacturer for use with that particular fuel gas should be used.

Acetylene systems should not be used at flowing pressures exceeding 150kPa downstream of the outlet of the pressure regulator (see AS 4267[9]). LPG equipment, including especially regulators and hose, should never be used in acetylene systems. It should be noted that gas suppliers recommend that the maximum acetylene gas draw-off rate should not exceed 1/7th of the cylinder contents per hour, which for the common large acetylene cylinder (G Size) of 7 m^3 dissolved gas capacity limits the maximum flow to 1m^3/hr. or 16.67l/min. Systems requiring larger flows should be supplied from portable manifolds, manifold packs of cylinders, reticulated systems or in consultation with the gas suppliers.

LPG systems should comprise only equipment especially designated for LPG except for multi-fuel gas components where the manufacturer specifically nominates LPG amongst the recommended fuels. LPG systems are not subject to maximum outlet pressure limitations except that at low temperatures the vapour pressure in the cylinders for some mixtures may prevent high system pressures. 400 kPa is a commonly used upper limit.

Hydrogen systems may operate at higher pressures than acetylene and LPG and only regulators specially designated for Hydrogen should be used. Care must be taken in not exceeding the maximum rating of hydrogen safety devices that may be in the range 400 to 600kPa.

Natural gas systems generally may use LPG equipment depending on the natural gas supply pressure. However, it must be distinguished between reticulated natural gas, which may have a very low supply pressure unsuitable for some equipment, and cylinder-supplied natural gas, which has a much higher contents pressure that must be regulated down to common LPG supply pressures.

5.4.9.3 Flow Capacity

The tip or nozzle in use determines the required system pressures and flows and hence the pressure regulator outlet pressure settings. Particular care must be taken in allowing for pressure drops, especially through long lengths of small diameter hose and multiple safety devices. Manufacturer's instructions should be carefully followed. A system that has excessive pressure drops may become unstable resulting in possible retreat of the flame into the tip leading to overheating, backfire or flashback. Pressure drop is particularly important in acetylene systems because of the limitation in maximum operating pressure to only 150kPa maximum.

Although propylene is used in large cylinders in some countries, in Australia it is normally supplied in disposable yellow cylinders that require unique torches or burners that are connected direct to the cylinder. They are widely used for brazing and soldering by the plumbing and HVAC industry.

Table 5.2 Assembled Component Listing — Example Table

	Cylinder Type and Size	Tip Model and Size	Regulator Model and Outlet Pressure	Regulator Mounted Safety Device Model	Hose min. Diameter	Hose max. Length	Blowpipe Mounted Safety Device Model
Fuel							
Oxygen							

5.5 Setting Up Plant Safely

5.5.1 Acetylene Draw-off Rates

Exceeding the maximum recommended safe draw-off rate of the acetylene supply (one-seventh of the capacity of the cylinder or pack) is a common occurrence leading to solvent entrapment in the gas. Solvent entrapment damages regulators and release of dissolved gas from the solvent downstream of the regulator causes rapid fluctuations in gas pressure and flow, promoting flashbacks. A typical full G size cylinder contains 7,000 litres of acetylene dissolved in just 26 litres of acetone, therefore one volume of solvent drawn from a full cylinder has the potential to release up to 360 volumes of acetylene.

Equipment manufacturers publish data on acetylene flow rates but gas manufacturers label cylinders in total cubic metres contained and draw-off rates as $1/7^{th}$ of contents per hour. For example, a typical G size cylinder contains 7.0 m^3 cubic metres of dissolved acetylene so the maximum draw-off rate is 1.0 cubic metres/hour. Maximum withdrawal rates for other cylinder sizes are shown in Table 5.3. The maximum safe draw-off rate from a single G size cylinder is 16.6722 litres/minute.

In order to comply with AS 4839, a tip with a recommended flow rate exceeding 16.67 litres/minute must be supplied with manifolded cylinders with a combined draw-off rate equal to or exceeding the tip flow rate.

Examples of exceeding the acetylene draw off rate:

Example 1:

> *A size 15 cutting tip on a standard cutting attachment requires 7l/min acetylene gas to sustain flame continuity. If the cutting attachment is connected to a "D" size cylinder, the 2.38l/min acetylene delivery is sufficient to supply the requirements of a size 15 cutting nozzle. The flame will burn faster than the gas delivered and can cause a flashback.*

Example 2:

> *The use of an 8 x 12 heating tip (8 holes at 1.2mm each) requires 55 litres per minute acetylene to sustain the flame. Whilst single "D" size , "E" size or "G" size cylinders cannot deliver 55 l/min on their own, a manifold pack of 4 acetylene cylinders (typically 6 or 9 cylinders) is more than capable of safely delivering the flow required.*
>
> **WARNING**: *Whilst running a heating tip on an acetylene "G size" cylinder by setting the oxygen pressure very high and winding the acetylene pressure regulator flat out can provide the appearance of a "stabilized" flame on the heating tip, the operator may not be aware that the high pressure oxygen flowing past the hand piece mixer causes a cavitation effect, creating a vacuum within the acetylene cylinder which then draws acetone out of the cylinder damaging the regulator, blocking the flash back arrestor and initiating flash-backs.*

5.5.2 Safe Equipment

Only equipment complying with the general specifications given in Section 5.4 and obtained from a reputable supplier should be used. Equipment should be used only for the purpose and with the gas for which it was designed. An example of a component combination chart is given in Table 5.2. This includes cylinders, cylinder valves, regulators, flashback arrestors (regulator outlet and blowpipe inlet), and correct hose diameter and length for the attached device.

5.5.2.1 Safety Devices

Gas equipment should never be used unless it has been set up with all the safety devices in place and in good order.

5.5.2.2 Cylinders

Cylinders in use should be placed in a purpose-built trolley or secured against toppling. Acetylene and LPG cylinders should be in an upright position.

5.5.2.3 Location of Cylinders

Wherever possible cylinders should be located in a well-ventilated area, well away from any sources of ignition.

Cylinders should not be taken on board ships or into any enclosed areas unless a complete risk assessment has been carried out and precautions implemented.

5.5.3 Training

Only persons who have been trained in the safe and effective use of these processes should be permitted to use the equipment.

5.5.4 Rules and Instructions

All instructions for operation and maintenance, supplied by the manufacturers, must be available to all operators.

5.5.5 System Operation

Detailed procedures for setting up, using and closing

down the typical oxy-fuel application are given in Table 5.4. Some of the more important steps are:

5.5.5.1 Leak Testing

Prior to initial use of gas equipment, all breakable connections, glands and valves should be checked for leakages, e.g. by a pressure drop method (see Table 5.4) or by means of a suitable non-flammable leak detecting fluid. Smell should not be relied upon as many persons have a poor sense of smell. NEVER test for leaks with a flame.

Leak testing should be carried out using a suitable non-flammable liquid that forms visible bubbles at the leak site as there is a risk of fire or explosion with some hydrocarbon-based detergents that may be used to make up test media.

5.5.5.2 Purging

It is strongly recommended to purge oxygen and fuel gas hoses prior to usage at the start of the day and after the blowpipe has been shut down for a substantial period of time such as lunch periods or overnight. This must not be done in confined spaces or in the presence of any ignition source (see Table 5.4). Always refer to operating instructions for the correct purging procedures.

5.5.5.3 Lighting up (Igniting the Flame)

Flint lighters or stationary pilot flames should be used for ignition of flames. Blowpipes must not be lit or re-lit by hot metal, matches, cigarette lighters, hot electrodes or welding arc. When lighting, ensure that the flame cannot touch either nearby personnel or any combustible material (see Table 5.4). Always refer to operating instructions for the correct lighting procedures.

5.5.5.4 Work Interruption

When blowpipes are not in use, the oxygen and fuel gas should be closed off at the supply and hoses blown down to prevent possible leakage and gauge failure. Blowpipes and hoses should be safely placed so accidents or damage cannot occur. Fuel gas leaks have resulted in fatalities in Australian workplaces.

5.5.6 Equipment Inspection and Maintenance

5.5.6.1 Inspection

Inspection should be carried out on a routine basis for all items of equipment considered in Sections 5.3 and 5.4. Guidance on inspection and maintenance for gas equipment described in Section 5.4 is given in Table 5.4 and AS 4839[12].

5.5.6.2 Maintenance

Maintenance operations should be carried out according to manufacturer's instructions and the suggested guidance on inspection and maintenance intervals in Table 5.4. It is advisable to arrange for servicing of equipment by either the manufacturer or its accredited repairers or by organisations that specialise in maintenance of such equipment. Larger workshops may support a maintenance group capable of carrying out this work.

5.5.6.3 Detailed Inspection and Maintenance

Some useful guidance on inspection and maintenance for specific equipment follows:

a) Checks for gas leakage should be carried out on

Table 5.3 Acetylene Draw-Off Rates

Acetylene Cylinder Size	Cylinder Aggregate Water Capacity, Litres	Cylinder Contents Cubic Metres (m^3)	Maximum Safe Draw-Off Rate (1/7th contents/hour)	
			Cylinder Contents Cubic Metres/Hour (m^3/hr)	Litres/Min (l/min)
D	7	1.0	0.14	2.38
E	25	4.1	0.59	9.8
G	50	7.0	1.0	16.7
GX (see note)	54.5	8.7	1.24	20.7
MDA8	436	69.6	9.9	166

Note: This example is based on a cylinder with a capacity of 8.7m^3.



all hoses, connections, regulators, valves and cylinders regularly and at least each time the equipment is set up.

b) Repair and maintenance of regulators must only be carried out by approved persons or organisation, e.g. repairers accredited by manufacturers or suppliers.

c) If a regulator shows excessive delivery pressure "creep", it should be replaced immediately and the defective regulator repaired.

> **Note***: To check for "creep" (pressure build-up when the blowpipe valves are closed), close the welding or cutting blowpipe valves whilst the regulator is open and check for continuing increase in pressure beyond the pressure that has been set. Refer to manufacturer's operating manual for the acceptable figure.*

d) If pressure gauges or indicators do not return to the stop when pressure is released, replacement and repair is required.

e) Checks of regulator pressure indicator accuracy should be carried out at least annually.

f) Damaged hoses should be discarded and not repaired. Rubber hose should never be repaired with adhesive tape. When flashback has occurred all hoses should be discarded as internal damage has probably resulted (see Section 5.6.1).

g) All blowpipes, welding tips and cutting nozzles should be handled carefully, cleaned regularly and protected from damage. Blowpipes must not be left burning unattended.

h) Regular inspection and cleaning of blowpipes is recommended. See Table 5.4 for recommended inspection intervals.

i) Cutting nozzles and welding tips should be cleaned only by methods that have been recommended by the manufacturer. Drills should not be used for this purpose as any damage may promote the occurrence of flashback. Nozzles and tips should be stored in such a way as to minimise damage to the seating area, e.g. by use of rubber caps or storage blocks.

j) Flashback arrestors should be inspected strictly according to the requirements in AS 4603 (see Table 5.4)

k) O-rings used on regulator inlet connections, mixer attachments etc. should be replaced regularly or where they show signs of damage. Use only oxygen compatible replacements.

l) Only oxygen-compatible PTFE tape should be used in making up threaded connections.

5.5.7 Flame Cutting and Ancillary Equipment

A wide range of mechanised equipment and aids to hand flame cutting are available and often used. Malfunction can result in damage that could eventually lead to injury or damage to other equipment. Basic procedures that should be adopted include the following:

a) Maintenance: Adopt a regular inspection and maintenance program for all mechanical or electrical equipment.

b) Frequency: The frequency of the above will depend largely on the complexity of the equipment and extent of usage.

c) Location: Equipment should be located in the safest and cleanest possible environment.

d) Work table: Supports should be carefully designed so as to minimise risks to personnel.

5.6 Emergencies and Incidents

5.6.1 Backfires and Flashback

Instability of the flame in a tip or nozzle is a common cause of emergencies and incidents in Oxygen-fuel gas systems. These emergencies can occur during lighting up or during operation.

Incorrect lighting up procedures (especially neglecting to purge hoses – see Table 5.4), low fuel gas flow rates at the tip or nozzle resulting from inadequate gas supply, damaged or poorly maintained equipment or a combination of all these are usually the cause. Often this is due to under-size or partly full acetylene cylinders used to supply large cutting or heating nozzles.

The problems show up as:

a) **Backfire** is the return of the flame into the blowpipe with a popping sound, the flame being either extinguished or re-ignited at the nozzle.

b) **Sustained backfire** is the return of the flame into the blowpipe with continued burning within the neck or handpiece. This is accompanied by an initial popping sound followed by a hissing sound from the continued burning within the blowpipe. In this case, immediately turn off gases at the blowpipe, oxygen first, and check nozzle or tip condition, gas pressure and connections to torch and cylinder.

c) **Flashback** is the return of flame through the blowpipe into the hoses and even the regulators. Unless flashback arrestors are in place, it may also reach the fuel gas cylinder, causing heating, fire or explosion.

If any of these events occurs, especially flashback, immediately close the oxygen blowpipe valve followed by

the fuel gas blowpipe valve. Close cylinder valves and if cylinders heat up, cool as described in 5.6.4 and 5.6.5.

Check operating conditions and equipment faults and leak test before restarting. Discard any gas hose when flashback into the hose has occurred. In the event of a sustained back-fire or a flash-back, the flash-back arrestors should be withdrawn from service and tested for functionality prior to reuse (see AS 4603).

5.6.2 Gas Leaks

Leaking gas is a potential hazard wherever it occurs and whichever the gas. Fuel gases present the greatest hazard since all can ignite even when in low concentrations in air and require minimum energy to do so, i.e. any spark or source of high temperature is sufficient to start a fire or an explosion.

Oxygen makes all materials more readily combustible and will increase the intensity and severity of any fire. Inert gases displace oxygen and can cause unnoticed loss of alertness and then asphyxiation.

The sources of gas leaks include:

a) Cylinder fittings (valves, regulators and safety devices) damaged or in poor condition.

b) Valves not closed off when equipment is not in use.

c) Breakable connections improperly made up or in poor condition (scored or dirty nipples, conical seatings, O-rings). The typical oxygen-fuel gas plant has many connections points in the cylinder valves, regulators, hoses, blowpipe and tips and nozzles. Each of these is a potential leak point if not in good condition.

d) Hoses in poor condition. Whenever a gas leak is suspected or detected, operations should cease, the leak rectified immediately if possible, heat sources removed or switched off and the area cleared until gas has dispersed.

5.6.3 Ignition of Regulators, Hoses and Other High-Pressure Equipment

Although accidents of this type are rare, when they do occur the results may include serious injury, a major fire or even fatality. Care in use and maintenance of oxygen regulators and other equipment is therefore extremely important.

If a fire occurs at the cylinder, it is important to be able to distinguish between a regulator or hose fire and a cylinder fire. A cylinder fire will be much larger with the root of the flames at the cylinder safety valve or fusible plug. If the fire is at the regulator or hose, the root of the flame will project from the gas leak or hose failure.

Ignition may occur due to:

a) A leaking acetylene regulator, flashback arrestor, hose or hose connection can ignite causing a regulator fire. Generally, these fires will not cause the cylinder to overheat or catch fire and can be extinguished by closing the cylinder valve. Do so as soon as the fire is detected and assessed.

b) Spontaneous ignition of oil, grease or hydrocarbon liquids in high-pressure oxygen. Keep oil and grease away from regulators and other equipment, do not use oil or grease as a lubricant for tight threads etc. and do not use oily rags, tools or operate with oily hands (see 5.2.2).

c) Use of equipment (e.g. pressure regulators, manifolds, high pressure hoses) not clearly designated as suitable for high' pressure oxygen and rated for the same pressure as the cylinders in use. Use only equipment clearly marked for oxygen, of a suitable pressure rating, clean and in good operation condition.

d) Particles entrained in high-velocity gas streams (e.g. piping, valve connections) causing ignition in cylinder valve or regulator seats and seals. Cleanliness and generally good housekeeping practice are required. Always clean seats of cylinder valves (see Table 5.4 and AS 4839) before fitting equipment. The old practice "snifting" or "cracking" the cylinder valve has led to many incidents and is not allowed on many worksites.

e) Rapid opening of the oxygen cylinder valve causing a high temperature at the regulator seat and seals. The cylinder valve must be opened slowly.

5.6.4 Cylinders in Fires

The most common incidents are those involving ignitions of fuel leakages from regulator and hose connections near the cylinder. If this occurs, the cylinder valve should be closed using a gloved hand, and the fire extinguished as soon as possible. Otherwise, use of a dry powder or CO_2 fire extinguisher should be followed by closing of the cylinder valve to prevent re-ignition.

If it is not possible to extinguish quickly fires of any type with a fire extinguisher, no further attempts should be made.

In the case of a fire emanating from a fuel gas cylinder:

a) The area should be evacuated (100 metres minimum).

b) The fire brigade should be called.

c) If attempts are made to fight the fire, they should

be done only from a protected position and using copious quantities of water.

d) Cylinders not involved in the fire and that have not become heated should be moved away as quickly as possible, provided this can be done without risk. Cylinder valves should be closed. Cylinders that have been heated can explode even after the fire has been extinguished, particularly acetylene cylinders.

e) When the fire brigade arrives, they should be notified of the location and number of cylinders involved in the fire, and the name of the gases they contain.

f) Inform the gas supplier as soon as possible.

g) If the cylinder contents are unknown, the actions taken should be those for acetylene cylinders (see Section 5.6.5).

5.6.5 Acetylene Cylinder Overheating

Acetylene cylinders may become hot either through flashback or due to accidental heating (e.g. contact with hot objects, fires). To prevent serious accidents, the following procedure should be carried out immediately overheating is noted:

a) Shut cylinder valve quickly and have the supplier notified as soon as practicable. If the cylinder is on fire, call the fire brigade.

b) Clear all personnel from the area.

c) Cool the cylinder with a plentiful supply of water, preferably from a fire hydrant and with the person behind a suitable protective barrier.

d) If the cylinder safety device functions and issuing gas ignites, cool as above, but do not extinguish the flames. Where gas does not ignite, all sources of ignition must be removed from the area if this can be done safely.

e) Continue cooling but with stops at intervals to check if the cooling water dries off the cylinder or if it remains wet.

f) When the cylinder remains wet on removal of the water, the cylinder should be removed to an open space away from any ignition source and left to cool.

g) Continue cooling for 24 hours or as advised by the gas supplier or a competent authority.

5.6.6 Oxygen Cylinder Explosions

Accidents have been reported that involve explosion of an oxygen cylinder due to direct flame impingement from an adjacent acetylene cylinder. Such accidents can arise when there is a leaking acetylene hose at the regulator, the escaping gas ignites, and the flame impinges on the oxygen cylinder. This causes softening, bulging and bursting of the oxygen cylinder without appreciable increase in its internal pressure, i.e. without causing the bursting disc to rupture.

Where oxygen and acetylene cylinders in use are adjacent to each other, consideration should be given to protecting the oxygen cylinder by placing a non-flammable shield e.g. a 2-3 mm sheet of steel or refractory fibre between the cylinders. The shield should extend at least from the shoulder of the acetylene cylinder to the top of the oxygen cylinder regulator.

5.7 References

1. Standards Australia, AS/NZS 80079.20.1, *Explosive atmospheres, Part 20.1: Material character-istics for gas and vapour classification — Test methods and data (ISO/IEC 80079-20-1:2017, (ED. 1.0)/COR1:2018, MOD)*
2. Standards Australia, AS/NZS 1335, *Gas welding equipment - Rubber hoses for welding, cutting and allied processes (ISO 3821:2019 IDT)*
3. Health and Safety Executive, UK, *Fire and Explosions Due to Misuse of Oxygen,* London, 1975
4. Standards Australia, AS 4484, *Gas cylinders for industrial, scientific, medical and refrigerant use - Labelling and colour coding*
5. Standards Australia, AS/NZS 1596, *Storage and handling of LP Gas*
6. Standards Australia, AS 2473.2, *Valves for compressed gas cylinders Part 2: Outlet connections (threaded) and stem (inlet) threads*
7. Standards Australia, AS 4332, *The storage and handling of gases in cylinders*
8. Safe Work Australia, *Model Code of Practice, Managing risks of hazardous chemicals in the workplace*
9. Standards Australia, AS 4267, *Pressure regulators for use with industrial compressed gas cylinders*
10. Standards Australia, AS 1345, *Identification of the contents of pipes, conduits and ducts*
11. Standards Australia, AS 4289, *Oxygen and acetylene reticulation systems*
12. Standards Australia, AS 4839, *The safe use of portable and mobile oxy-fuel gas systems for welding, cutting and allied processes*
13. Standards Australia, AS 4840, *Low pressure regulators for use in industrial compressed gas reticulation systems*
14. Standards Australia, AS 1349, *Bourdon tube pressure and vacuum gauges*
15. Standards Australia, AS 1869 (series), *Hose and hose assemblies for liquefied petroleum gases (LP Gas), natural gas and town gas*
16. Standards Australia, AS 4603, *Flashback Arresters – Safety devices for use with fuel gases and oxygen or compressed air*

Table 5.4 Safe Procedures for Setting Up and Closing Down Gas Welding, Heating and Cutting Equipment (based on AS 4839)

Step	Action	Comment
1. Setting Up		
1.1 Equipment Connection	1. Check that all equipment, equipment connections and especially both valve outlets and regulator inlets are clean and free from oil, grease, coal gas and flammable residues.	
	2. Remove the protective cover and check the cylinder valve outlet. Clean with a dry cloth if necessary. Do not “Crack” (briefly open and close) the cylinder valves. This practice has led to many incidents and is a prohibited practice on many sites.	This is to remove any contaminants from the valve outlet. Always ensure outlets are clean and dry.
	3. Screw regulators into cylinder valves, using an appropriate spanner where applicable. Make sure the regulators adjusting knobs are completely off (anti-clockwise).	Note that all oxygen connections have right hand nuts and fuel gas connections have left hand nuts.
	4. Fit flashback arresters and hoses to the regulator outlets, using an appropriate spanner. Do not over tighten connections.	All components should be identified by marking according to the appropriate standard. Regulators and hoses should be colour coded blue for oxygen, red for acetylene and orange for LPG. Safety devices are blue for oxygen and red for fuel gases.
	5. Slowly open the oxygen cylinder valve, then the acetylene cylinder valve.	Open slowly enough to observe the rise in the cylinder pressure gauge on the regulator. Sudden opening of the cylinder valve can cause damage to the regulator seat and lead to fire and explosion on an oxygen regulator.
	6. Adjust the oxygen regulator to allow a small flow through the hose and then release the control knob fully. Repeat for the fuel gas regulator.	
	7. Connect the blowpipe to the other hose ends, including flashback arresters.	Flashback arresters at the blowpipe end should always be used. Blowpipe inlet connections and control valves should be marked O for oxygen, F for fuel gas.
	8. Connect any required attachments, tips or nozzles to the blowpipe.	Ensure blowpipe, attachment and tips and nozzles are compatible.
1.2 Pressure Setting and Leak Test	1. Check that the blowpipe valves are closed and adjust the oxygen regulator to the required pressure.	Set the pressure recommended by the manufacturer of the equipment.
	2. Close the oxygen cylinder valve and check for pressure drop on the regulator gauges.	Any drop indicates a leak between the cylinder valve (including gland) and the blowpipe valve. Leaks through the blowpipe valve will show at tip or nozzle.
	3. Check also for leaks at the top of the cylinder, particularly at the safety device, gland nut and regulator inlet and outlet connections using an ammonia free solution of leak detecting fluid like Teepol HB7.	These will not show as a pressure drop. Any leak on the cylinder and its fittings must be referred to the gas supplier.
	4. Once all leaks have been corrected, re-open cylinder valve slowly.	
	5. Repeat the procedure (1.2.1 – 1.2.4 for the fuel gas.	
	6. If the valve is not hand wheel operated, leave the cylinder key in the fuel gas cylinder valve.	This will allow quick shut-down in an emergency.



Table 5.4 Safe Procedures for Setting Up and Closing Down Gas Welding, Heating and Cutting Equipment (based on AS 4839) (continued)

Step	Action	Comment
2. Use		
2.1 Purge	1. Open, then close, each blowpipe valve in turn for 2 seconds for every 5 metres of hose.	Make certain that no source of ignition is nearby. Purging will eliminate mixed gases in hose – a cause of flashback at lighting up.
2.2 Lighting Up	1. Open the blowpipe fuel gas about ¼ turn.	Some manufacturers may recommend the oxygen valve be opened prior to the fuel gas for specific injector-type blowpipes
	2. Light the gas at the tip or nozzle using only a spark lighter or a pilot flame.	
	3. Increase the fuel gas flow until the flame no longer produces soot.	Soot is only produced by acetylene flames.
	4. Open the blowpipe oxygen valve and adjust the flame to that required by the process.	
	5. Check the regulator set pressures and readjust if necessary.	
2.3 Shutting Off Blowpipe	1. Close blowpipe fuel gas valve.	This cuts off fuel supply to the flame.
	2. Close blowpipe oxygen valve.	This procedure is satisfactory for temporary halts not involving leaving the equipment unattended.
	3. IN CASE OF SUSTAINED BACKFIRE, CLOSE IMMEDIATELY BLOWPIPE OXYGEN VALVE FIRST	This cuts off oxygen supply to the internal flame and should extinguish it immediately.
3. Closing Down		
	1. Shut off blowpipe as in 2.3 above.	This procedure should be performed whenever the equipment is left unattended or whenever cylinders are being changed.
	2. Close both cylinder valves.	
	3. Open the blowpipe oxygen valve to allow the gas to drain out.	This will release all pressure in the regulator, hose and blowpipe.
	4. Unscrew the oxygen regulator control knob once the contents pressure gauge reads zero.	
	5. Repeat the procedure (3.1 – 3.4) for the fuel gas valve and regulator.	

Table 5.5 Guidance on Equipment Maintenance (based on AS 4839[12])

	Maintenance		
Equipment	**Weekly (Note 1)**	**As Nominated (Note 2)**	**Refurbishment or Replacement Intervals (Note 3)**
1. REGULATORS	Visual examination to determine suitability for service (e.g. gas, pressure rating, damage), condition of threads and sealing surfaces, oil or grease contamination. Leak test all joints at working pressure.	Six monthly: Functional tests to ensure the correct operation of internal components.	Manufacturer or supplier recommendation, but not exceeding 5 years[4].
2. FLASHBACK ARRESTORS and other safety devices (including non-return valves)	Visual examination to determine suitability for service (e.g. gas, pressure rating, damage), condition of threads and sealing surfaces, oil, greaseor soot contamination. Leak test all joints at working pressure.	Yearly as detailed in AS 4603 or following a flashback: Proper functioning of the non-return valves and flashback arresters. For non-return valves, check there is no flow in the normal direction with the valve tripped.	Manufacturer or supplier recommendation, but not exceeding 5 years[4].
3. HOSE ASSEMBLIES	Visual examination to determine suitability for service (e.g. gas, pressure rating, damage), condition of cover, threads and sealing surfaces of the end fittings. Leak test all joints at working pressure.	Six monthly: Check for absence of cuts and excessive wear by bending the hose in a tight radius, to ensure reinforcement is not visible.	Determined by the hose assembly condition.
4. BLOWPIPES, MIXERS AND ATTACHMENTS	Visual examination for damage of the threads and sealing surfaces of the hose connections and the attachment connections and Operchlo-rings. Leak test all joints at working pressure.	Six monthly: Test control valve function. Blank the attachment connection and leak test for internal malfunction.	Manufacturer or supplier recommendation, but not exceeding 5 years (Note 4).

NOTES:
1. If in constant use or BEFORE EVERY USE (to be performed by the operator according to manufacturer's instructions.
2. To be carried out by a technically competent person.
3. Equipment condition determines whether refurbishment or replacement is required.
4. Regulator elastomers and seals will wear and deteriorate in service or on the shelf. Items stored for 1 year or over without use, should receive inspection as per the annual maintenance inspection.

Recommended Oxy-Fuel Gas Daily Inspection and Pre-Start Check List	
Item	**Description of Inspections to be Carried Out**
Gas Cylinders	Check cylinders are secured against falling over and in an upright position before making any connections. Check cylinder labelling. Check there is no mechanical damage.
Cylinder Valve	Inspect the valve for damage. If the valve appears to be damaged DO NOT OPEN. You may not be able to close it again. Do not crack cylinder valve – uncontrolled discharge of gas can be hazardous. Remove dust protection cap manually. Clean seat with a clean dry cloth prior to fitting gauges. USE NO OIL!
Regulators	Check type, rating and condition. When fitting regulators to cylinders ensure they are not contaminated with oil, grease or coal dust. Face the front of the gauges and ensure the rears of the gauges are directed away from others when opening the cylinder valve. Use only oxygen compatible o–rings and thread tape.
Flash Back Arrestors	FBAs should be fitted at both the regulator and blowpipe ends of hoses and be suitable for the gas flow requirements. Check current inspection tag or sticker.
Hoses	Check correct type hoses are fitted. Oxygen – BLUE. Acetylene – RED. LPG – ORANGE. Check hoses for damage particularly at junctions to fittings where mechanical fatigue damage occurs. Maximum length of standard hoses is 15 metres. Use larger diameter hoses for increased length or high draw rate attachments e.g. heating torches. Refer to and follow recommendations of equipment manufacturers.
Blowpipe	Ensure the blowpipe is in good condition, the body is true, valves open and close fully, threads and seats are in good condition. Use only oxygen compatible o–rings and thread tape.
Tip	Check the tip condition, seats are in good condition, face is flat and clean, holes are open and free of contamination, tip is the right size and type for the job in hand. Set regulator pressures to suit tip and plate thickness. Ensure the required flow rate of acetylene tips is within the safe draw rate of the acetylene cylinder/s (1/7th/hr).
Purging and Pressurising	• Ensure blowpipe valves are closed and regulator pressure adjusting knobs are wound all the way out (anti-clockwise). • Slowly open cylinder valves (one full turn only on fuel gas). • Wind regulator adjusting knobs in until required line pressure is indicated. • Individually open the blowpipe valves and allow gas to run through the line, readjust pressure to achieve correct pressure when gas is flowing, then close the blowpipe valve before opening the other one.
Pressure Test	• With the system purged and pressurised and blowpipe valves closed, close the cylinder valves. • Observe the regulator valves for one minute. Note any anti-clockwise movement of the cylinder pressure or regulated outlet pressure gauges. • Open the cylinder valves. Note any clockwise movement of the cylinder pressure or regulated pressure gauges. • A change in the cylinder pressure gauge or regulated pressure gauge indicates a leak. • Find and eliminate all leaks. Use a soapy water technique to find leaks
Lighting up	• Use approved lighting flint (not matches or cigarette lighter). • Light fuel gas with medium flow. If the flame is burning off the tip, reduce the fuel gas flow until the flame is coming off the tip. • Open oxy feed blowpipe valve to achieve the required flame.
Shutting down	• Shut down fuel feed blowpipe valve. • Shut down oxy feed blowpipe valve. • Close cylinder valves and depressurise the hoses and blowpipe. • Wind regulator adjusting knobs all the way out (anti-clockwise)
Storage	• Store in approved storage areas only. • Keep different gas types separated and empty and full cylinders segregated. • Be aware of mandatory requirements for storing gas cylinders.
Transport	• Transport in secure upright position. • Be aware of mandatory requirements for transporting gas cylinders.
Inspection Tag	Check that a current inspection tag, traceable to your equipment maintenance register, is attached to the equipment.

Notes

- If on completion of this pre-start checklist you are unsure of the safety of any part of this equipment - DO NOT USE. Isolate the equipment and notify your supervisor immediately, in order that remedial action can be taken.
- Fumes are generated by hot work. Take adequate precautions to limit exposure to fumes from cutting, brazing, welding consumables or surface coatings and contaminants.
- Oils, greases and other organic compounds including their residues may become highly flammable or explosive in the presence of pressurised oxygen. Ensure all fittings are clean and dry before assembly. Ensure there is no opportunity for contamination of parts.
- Ensure that you have all necessary Personal Protective Equipment in place, in good order and dry, before turning on the oxy-fuel gas equipment.

6. Plasma Arc Welding and Cutting

6.1 Introduction

Plasma arc processes have found relatively widespread applications in cutting, metal spraying (Chapter 11) and welding operations. A number of features of the process require treatment of health and safety aspects separately from conventional arc and gas welding and cutting processes. Plasma cutting equipment is relatively inexpensive and economic, because it only requires compressed air for the plasma gas. These features have made the process popular in many small workshops.

6.2 Process Features

The two main plasma systems used in welding and cutting operations are:

a) *Transferred arc systems*: Plasma is transferred from torch to workpiece (Figure 6.1(a)).

b) *Non-transferred arc systems*: The arc is struck between cathode and anode within the torch and plasma only issues from the torch (Figure 6.1(b)).

The units for both systems are designed to run on a range of shielding gases, i.e. argon, nitrogen, air and oxygen. Hydrogen is also mixed with argon and nitrogen to improve performance.

Variants on these systems are based on external use of water:

i) *Water-shroud attachments*: The plasma jet and shielding gas are surrounded by a concentric, tubular curtain of water that reduces noise and radiation. A dye may be used in the water to further reduce radiation to safe levels (see Section 6.6.1 and Figure 6.1(c)).

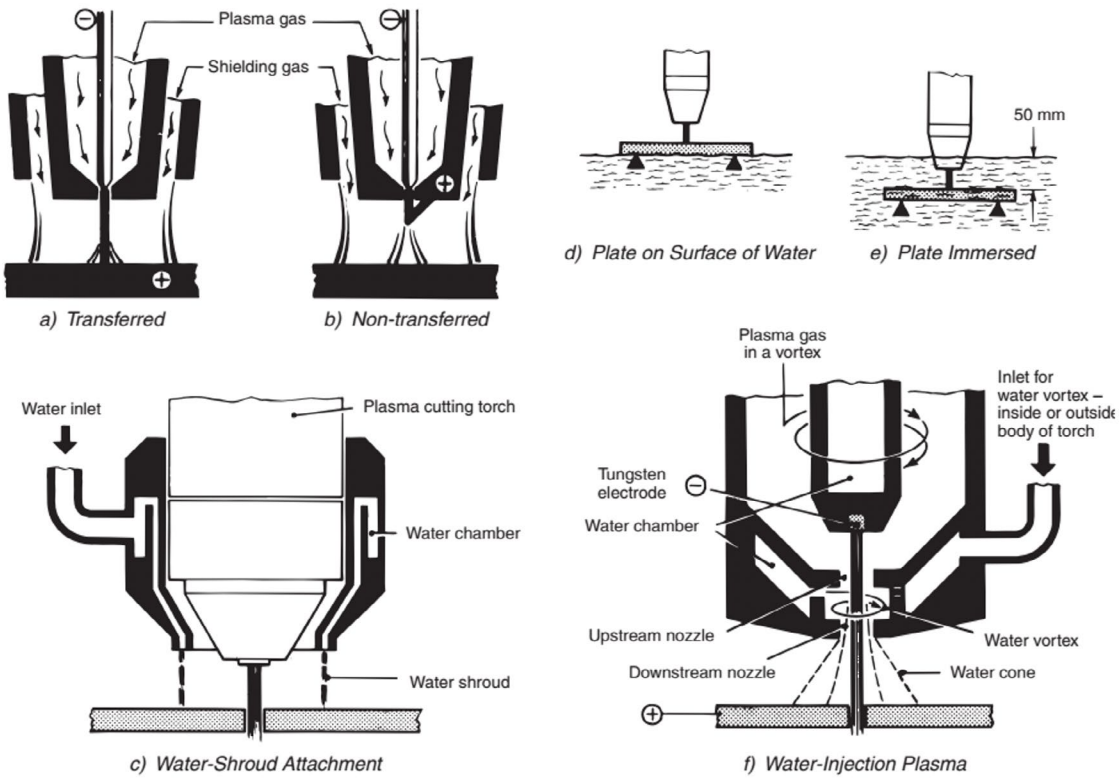


Figure 6.1 Plasma arc welding and cutting

ii) *Water tables*: The work to be plasma cut is supported horizontally in a tank with the water level set at half the thickness of the plate or slightly above the upper surface of the plate, depending on the material being cut. Apart from technological advantages in the cleanliness of the cut, this procedure reduces noise and eliminates fume from the process (see Section 6.6.2 and Figure 6.1(d)).

iii) *Underwater plasma*: A water table is used, and the water level is set 50 mm above the plate surface. This eliminates the need for a water-shroud attachment (see Figure 6.1(e)). When cutting on a water table there is potential for pockets of hydrogen to form under the cutting table. This hydrogen formed by water dissociation from the high voltage and temperature of the plasma can increase in volume and be detonated by the heat generated. The risk can be reduced by stirring the water under the table to avoid pockets of gas forming at the plate/water interface.

iv) *Water injection plasma*: A radial flow of water, directed at the plasma, constricts the arc and cools the workpiece. The noise emission is comparable with a dry plasma gun while the fume and radiations are less, but not as low as from a water-shroud attachment (see Figure 6.1(f)).

Plasma systems require special precautions to be taken in the design, manufacture and operation of equipment to ensure safe working. The main hazards are:

1. **Electric shock** – Operating voltages can be in excess of 700V (see Chapter 14).
2. **Toxic gases** – Generation of ozone, nitrogen dioxide and decomposition of certain degreasing agents can occur.
3. **Fume** – High levels of fume may result from oxidation of the workpiece or decomposition of a coating on it.
4. **Noise** – Noise levels usually exceed those generated by other cutting and welding processes.
5. **Radiation** – Intense visible, infrared and ultraviolet radiations are emitted (comparable to TIG welding at high current levels) (see Chapter 15).

6.3 Electric Shock

Open circuit voltages of up to 700V are possible, and high frequency current at high voltage is used to initiate the arc. Torch design is such that operators cannot simultaneously touch both electrodes. Additionally, protective devices and warning signs are attached to all possible areas of contact. Although the risks involved in operation of plasma equipment are minimised by design and manufacture standards, the following basic precautions are essential:

a) Educate operators in respect of hazards to minimise the possibility of unauthorised tampering or foolish practice.

b) Do not operate dry plasma equipment in damp or wet environments unless specifically designed to do so safely i.e. without causing electrical shock (see Chapter 14).

c) Regularly maintain and inspect equipment to ensure that hazardous situations do not exist.

d) Torches and electrodes are generally water-cooled. Care should be exercised to ensure that excessively hard water is not used as this could lead to scaling and blocking of waterways and burning out of the torch.

The conductivity of the water is also important because it could cause an electrical leak to earth. Plasma torch manufacturers require that the electrical resistivity of the cooling water to exceed 0.1 MΩ/cm.

Note: Ω/cm = Ohms/cm

6.4 Noise

Noise levels during plasma cutting can cause hearing loss both for the operator and nearby personnel. Table 6.1 gives an indication of the noise levels attainable in plasma cutting. It should be noted that noise level increases with the thickness of the material being cut. Operators and all personnel in the vicinity of the plasma torch should be provided with adequate hearing protection (Chapter 18). AS/NZS 1269[1] prescribes a suitable hearing conservation program.

6.5 Arc Radiation (Non-ionising)

The level of arc radiation (visible, ultraviolet and infrared) emitted in dry plasma cutting and welding is similar to that given off by high current GTAW (TIG) welding. To avoid damage to skin or eyes, the provisions given in Chapter 15 and Chapter 19 should be adhered to.

6.6 Toxic Gases

6.6.1 Production of Gases

As with other high-power gas shielded arc processes, potential dangers arise from the formation of toxic gases by the effect of ultraviolet radiation on the ambient atmosphere. The main gases to be considered are:

a) Ozone — Is produced by the action of ultraviolet radiation on oxygen in the air.

b) Oxides of nitrogen – Are produced by the combination of nitrogen and oxygen in the presence of ultraviolet radiation.

c) Phosgene and other gases arising from solvents—Ultraviolet radiation and heat will cause a breakdown of chlorinated hydrocarbon solvents such as perchloroethylene and trichlorethylene that are sometimes used as degreasing agents.

Note*: Water-shrouded torches (operating with dyed water to absorb ultraviolet radiation) generate little or none of these gases.*

6.6.2 Recommended Controls

The following recommendations are based on AWS C5.2[2]:

a) Local exhaust ventilation should be provided except where for cutting using water tables or underwater plasma. When cutting or welding in confined spaces appropriate ventilation and protection is required (Chapter 17).

b) When using degreasing agents guard against the formation of toxic phosgene. The recommendations of Section 10.3 should be observed. This will prevent chlorinated hydrocarbons reaching the weld zone.

6.7 Fume

The amount of fume (and toxic gas – Section 6.6.1) given off during plasma cutting or welding is, as with other processes, largely dependent upon current and material thickness, and in general is similar to that encountered in high current GMAW (*MIG*) welding. The type (constituents) of fume depends mainly on the material being cut or welded with oxides of nitrogen being significant in the gaseous components. Ventilation requirements are similar to those that apply to other welding processes (see Chapter 17).
In cutting processes most of the fume is given off underneath the material being cut and it is preferable to provide fume extraction from underneath the workpiece (Section 17.6).

Use of a water table (Figures 6.1 (d) and (e)) in plasma cutting, traps fume and is recommended for automated installations. Cutting of aluminium in a water bath may however generate hydrogen bubbles under the workpiece which can cause explosions. To avoid this, the water should be circulated (see Clause 6.2 item iii) and maintained in a clean condition.

6.8 Dusts

See fire and explosion hazards of dusts in Sections 11.4 and 16.3.

6.9 Spring-Back

Sudden movement of a section of a structure (e.g. spring-back) or movement of the structure itself can occur without warning and with considerable force when plasma cutting or gouging existing structures or removing welds during maintenance activities. Consideration must be given to the presence of this 'stored energy' and the need to enable a controlled release of the energy to prevent injuries[41]. See also Section 4.1.2.

6.10 References

1. Standards Australia, AS/NZS 1269 (series), *Occupational noise management*
2. American welding Society, AWS C5.2 *Recommended practices for plasma arc cutting and gouging*
3. Department of Mines and Mineral Resources, Mines and Energy (Queensland), *Report into a fatality at Goonyella Riverside Mine on 5 August 2017*, 2019

Table 6.1 Typical Noise Level During Plasma Cutting of Stainless Steel (see AWS C5.2[2])

Plate Thickness mm	Cutting Power kW (Note 1)	Overall Noise dB (2 m from torch) (Note 2)
12	55	98
25	55	104
51	110	103-106
102	165	108-111
180	220	112

NOTES:
1. Plasma gas not specified.
2. Noise reductions relative to a "dry" gun are generally achievable as follows:
   a. Water shroud without water table or without water contacting lower surface of plate ..... -6dB
   b. Water shroud and water table, water in contact with plate ..... -10dB
   c. Underwater cutting (40-50mm water over plate) ..... -30dB



7. Resistance Welding

7.1 Introduction

Resistance welding processes have widespread industrial usage in high production operations involving sheet metals, in the automotive industry and fabrication of domestic appliances, rail carriages, aircraft etc. These processes include projection, spot, seam and flash butt welding in a wide range of welding power source types.

The main hazards that may arise with these processes are:

a) Electric shock due to contact with live primary terminals or uninsulated parts.

b) Ejection of small particles of molten metal during the welding.

c) Crushing of some part of the body between electrodes and other parts in power operated welding power sources, both on closing and opening strokes.

d) Toxic fumes and gases as a result of welding coated or contaminated materials (see Chapter 17). For fixed equipment strategically placed fume extraction can minimise the effects.

7.2 Manufacture and Installation of Resistance Welding Equipment

7.2.1 Electrical Safety

Resistance welding equipment is designed and manufactured to avoid accidental contact with parts of the system that are electrically hazardous. All electrical equipment including control panels must be manufactured and installed in accordance with the safety requirements of electricity authorities and appropriate national Standards. High voltage parts must be suitably insulated and protected by complete enclosures with access doors and panels interlocked to electrically isolate the welding power source. Doors and access panels and other live electrical equipment accessible at production floor level must be kept locked or interlocked to prevent access by unauthorised persons to live portions of the equipment (see AS 2799[1]).

All electrical equipment must be suitably earthed and the transformer secondary may be earthed or provided with equivalent protection. External weld-initiating control circuits must operate at low voltage and not over 32V for portable equipment.

7.2.2 Mechanical safety

Resistance welding equipment should be designed to avoid crushing of hands and other parts of the body. This may be achieved by:

a) Arranging initiating controls such as push buttons and foot switches etc. to prevent the operator from inadvertently operating them.

b) Guarding the operator of multi-gun welding machines or large platen-type machines where fingers may pass under the point of operation, by the use of two hand controls, barriers, electronic eye safety circuits or similar devices to those required for punch presses.

c) Providing one or more emergency buttons for each operator of multi-gun welding power sources.

d) Designing the moving holder or portable resistance welding power sources so that the fingers placed on the operating handles cannot be crushed, e.g. by suitably remote two-hand controls.

7.3 Location of Equipment

Care must be taken in choosing a safe location for resistance welding equipment to minimise risks to nearby personnel, equipment and materials. This is particularly so for flash butt welding where a large number of hot or molten particles are ejected for considerable distances during welding. These can cause fire, eye injuries or superficial burns. Guards or screens on fixed flash butt welding equipment reduces

the ejection distance of the ejected molten particles. Some close shielding may also be possible with portable/mobile equipment.

There is also high level of visible radiation associated with flash butt welding. Guards or screens may be necessary adjacent to flash butt welding equipment.

7.4 Personal Protective Equipment

As with other welding operations, the personal protective equipment required is dependent upon the particular application. Chapter 19 gives details of various items of safety equipment, and the following indicates equipment needed for resistance welding:

a) Eye protection in the form of eye or face shield or hardened lens goggles is recommended (face shields are preferred). For flash butt welding, goggles incorporating a number 2 or 3 filter shade are recommended to minimise discomfort due to visible radiation (see Chapter 19).

b) Skin protection should be provided by the wearing of non-flammable clothing with long sleeves and long pants / trousers, with the minimum number of pockets and cuffs in which hot or molten particles can lodge, and leather gloves. For flash butt welding, the use of flame-resistant aprons, spats, gauntlets, cap etc. provides increased protection and is advisable.

c) Protective footwear in good condition must be worn i.e. with the steel toecap not exposed.

d) Respiratory protection may be required (see Section 19.6).

e) Appropriate measures should be taken to protect adjacent workers near the equipment whilst in use. This may be achieved by screening of the equipment with suitable guards.

7.5 Electromagnetic Radiation Exposure

Due to the very high currents used in resistance welding, operators of resistance welding equipment can be exposed to stronger electromagnetic fields (EMF) than those arising in general arc welding. The European Electromagnetic Fields (EMF) Directive 2013/35/EU which came into force on 1 July 2016 sets out to limit workers exposure to EMF from industrial processes, and it is known that resistance welding produces high levels of EMF. In particular, equipment that is hand-held or processes in which components are held close to the electrodes may be significantly affected.

Whilst this Directive is not applicable within Australia, operators of resistance welding equipment can minimise their exposure to adverse levels of EMF through the use of mechanisation and automation of resistance welding processes, and keeping the body and limbs as far from the electrodes as is reasonably practical. Guidance on the measurement and minimisation of exposure to EMF can be found in IIW document VIII-2235-16[2].

7.6 References

1. Standards Australia, AS 2799, *Resistance welding equipment – Single-phase A.C. transformer type*
2. International Institute of Welding, Document VIII-2235-16, *Electromagnetic fields (EMF) from resistance welding processes and the implications of the European EMF Directive*, 2016

8. Special Welding, Cutting and Gouging Processes

8.1 Aluminothermic Welding

8.1.1 Process

The basis of the aluminothermic welding process, also known as the Thermit process, is the exothermic chemical reaction between powdered forms of aluminium and iron oxide. An ignition powder, usually aluminium powder with a peroxide, chromate or chloride is ignited to initiate a reaction between the components of the aluminothermic mix. This results in the liberation of intense heat and forms steel at a temperature in the order of 2500°C. Alloying elements such as manganese, carbon, chromium and others can be added in the proportions required to the aluminothermic mix. Figure 8.1 illustrates the essential components and principles of aluminothermic welding.

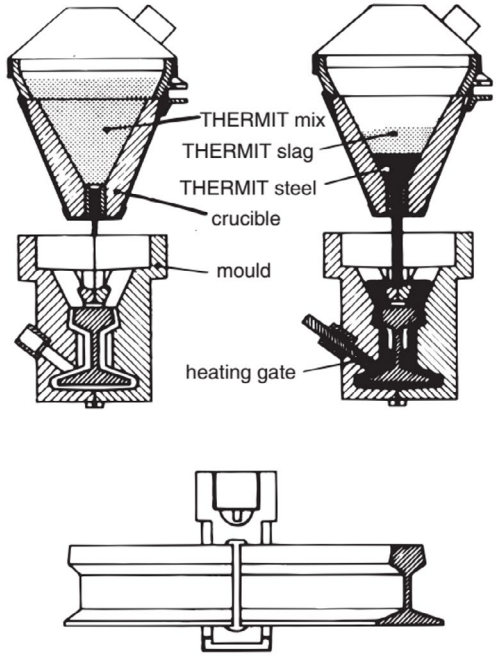


Figure 8.1 Aluminothermic welding of rail steels

The process is most often used on high carbon rail steels that are inherently difficult to weld, even when high preheat temperatures are used. Preheating with flames is also required to dry any moisture from the components used and to assist in preventing chilling of the molten metal when it contacts the surfaces to be welded.

8.1.2 Applications

The aluminothermic process finds its major application in welding of rail steels and is mostly employed in field welding operations. However, it is also used in workshop situations for a variety of applications, examples being repair of large broken steel castings and welding of complex shapes for which moulds can be prepared.

8.1.3 Precautions

a) *Moisture*: The presence of moisture, either in the aluminothermic mix, within the moulds or crucible or on components to be welded, can lead to rapid formation of steam and ejection of molten metal during the process. Hence:
   i) Follow the recommended preheating procedures.
   ii) Do not use aluminothermic powders that have become moist.
   iii) Do not use the process in wet weather or workplaces that are wet unless steps can be taken to prevent any moisture from entering the system either before, during or within about thirty minutes after welding.

b) *Welding Site*: The process generally results in ejection of many small molten and hot particles in the vicinity of the operation. These constitute a hazard to personnel and risk of fire within approximately three metres. Heavy fume is given off, and respiratory protection may be required by personnel in close proximity to the process (see Chapter 17, and Tables 17.1 and 17.2.
   i) Work areas should be chosen to minimise the

risk of combustible materials such as wooden structures, paper, wood products or fabrics being ignited by either hot particles or radiant heat.

ii) Buildings in which the process is used should be well ventilated to prevent the build-up of a high level of fume (see Section 17.8.8).

c) *Personal Protective Equipment*: Protection against heat and molten or hot particles is required for those working within about three metres of the process.
   i) Full-face shields or equivalent are required. Protective filters to shade 2 or 3 are recommended to avoid excessive exposure to intense visible radiation (Chapter 19).
   ii) Boots that prevent molten or hot metal entering should be worn. Boots with protective toecaps are also advisable in view of the weight of crucibles used.
   iii) Leather spats should be worn.
   iv) Clothes should be such that hot particles will not cause skin burns or lodge in cuffs, pockets etc. (Chapter 19).

d) *Storage*: To avoid the presence of moisture in aluminothermic or igniter mixes and to minimise fire or explosion risks, the following precautions are required:
   i) Dry conditions for storage of aluminothermic and igniter mixes.
   ii) Separate storage of the aluminothermic mix and igniters.

e) *Preheating*: Generally, oxygen-fuel gas flames or preheat flames from other sources are used to dry and heat moulds, crucibles and components. Precautions applicable to oxygen-gas systems (Chapter 5) and heat treatment processes (Chapter 12) apply. If the ventilation is sufficient to disperse heavy fume, problems should not eventuate with noxious or toxic gases due to incomplete combustion or emission of waste gas.

8.2 Laser Welding, Cutting and Cleaning

8.2.1 General

The laser process involves focusing of high intensity light beams containing ultraviolet (<400nm), visible (400nm-700nm) or infrared (>700nm) wavelengths to a small spot size with very high energy (see Chapter 15). Hand-held laser welders have an energy density in the order of MW/cm^2 which is sufficient to vaporise most materials that come into direct contact with the beam.

Operators of laser systems are required to be suitably qualified in accordance with AS/NZS IEC 60825.1[1] and AS/NZS IEC 60825.14[2].

The eye is most vulnerable to injury by laser energy, particularly the retina for laser wavelengths within the retinal hazard range (400nm-1400nm). This is because of the ability of the cornea (the transparent section) of the eye and lens, to focus parallel laser beams on a small spot on the retina. Lasers generating in the ultraviolet and far infrared regions of the spectrum can also cause lens and corneal damage (e.g. cataracts), since at these wavelengths the energy absorbed at the cornea is not transmitted through the lens to the retina.

Detailed safe installation and operating procedures are required by safety standards to be provided by equipment suppliers and must be strictly adhered to.

High intensity visible and ultraviolet radiation from the plasma at the welding or cutting point requires the use of special goggles and face shields (as for welding protection - see Section 19.3.5.1), and must also be designed to meet the protection requirements for the particular laser beam wavelength (see AS/NZS IEC 60825.14[2] and AS/NZS ISO 19818.1[3]). Exposure to the direct laser beam is a concern when at the end of welding runs or directed off the intended target and additionally, laser radiation may be reflected and scattered from the work surface or surrounding fixtures. Care must be taken to shield both operators and other workers in the vicinity from reflected radiation. Refer also to Weld Australia's Technical Guidance Note TGN SW02 – Laser Safety.

> **NOTE**: *Whilst AS/NZS ISO 19818.1 has superseded AS/NZS 1337.4 [2], AS/NZS 1337.4 (identical to EN 207) is likely to remain in use for some time until protective eyewear compliant with AS/NZS ISO 19818.1 can be manufactured.*

Users of lasers should also be aware that the interaction of the laser beam with the material being welded or cut for example, can cause a plasma in the interaction zone. This plasma can generate secondary radiation and expose the operator and personnel in the vicinity of the process to this radiation. The spectral distribution of the radiation will vary but typically includes visible radiation, infrared radiation and ultraviolet radiation.

Fume will also be generated when laser welding, cleaning or cutting and the ventilation recommendations of AS/NZS IEC 60825.14[2] should be followed (see also Chapter 17).

8.2.2 Precautions

Laser welders (including hand-held laser welders), laser cleaning systems and laser cutting systems are Class 4 devices, and are capable of inflicting serious



and permanent injuries including permanent eye damage and (instant) blindness.

Fire, thermally induced aberrations in optical components and the melting or vaporisation of solid targets designed to contain the laser beam, are all potential hazards induced by the radiation of Class 4 lasers. A suitable beam stop should be provided. Materials which may be degraded by the beam must be avoided.

Class 4 laser radiation is defined as a fire hazard and can be a source of ignition at ranges beyond the intended surface to be processed, and particular care must be taken in explosive or oxygen enriched atmospheres.

The following engineering controls are essential to minimise laser hazards including:

(a) Hand-held laser welders must not be operable when not in contact with the workpiece.

NOTE: *Hand-held laser welders are typically fitted with a work piece lead which is attached directly to the workpiece. Some machines also incorporate additional protective measures to prevent activation should contact with the workpiece be compromised e.g. plasma detection.*

(b) Locking out laser systems when not in use to protect against unauthorised access/activation. Options include removal of the key from a key-controlled activation switch, use of lockout isolation systems etc.

(c) Backstop/shielding and/or beam-stops that are suitably robust (see AS/NZS IEC 60825.4 for laser guarding), opaque and fire resistant should used to control any stray beams or reflections.

(d) Fitment of an emergency stop (E-stop) switch to deactivate the laser within close proximity to the operator (see ISO 11553-2).

(e) Fitment/use of a remote interlock switch that deactivates the laser when a person attempts to enter the laser-controlled area e.g. a door switch.

(f) Good general ventilation and fume capture (see Chapter 17) is required in enclosed areas to prevent fume build-up and exposure to hazardous fumes. Great care should be taken to avoid laser generated air-contaminants for laser welding or cutting processes and particularly in cleaning applications, as they can contain sub-micron particulates, noxious chemicals and even potentially hazardous biological material.

In addition, the following general precautions are also recommended when using laser welders, cleaners and cutting systems:

(i) All laser equipment should be confirmed as compliant with a recognised laser product safety standard e.g. AS/NZS IEC 60825.1[1] (or equivalent IEC or EN standards).

(ii) Appointing a trained laser safety officer (see AS/NZS IEC 60825.14[2] and Weld Australia's Technical Guidance Note TGN-SW02 *Laser safety*) to manage the safe the use of the laser device.

(iii) The laser (including hand-held lasers) should only be operated in a laser-controlled area. The entrances to areas should be secured from unauthorised entry, light-tight and posted with a standard laser warning sign as specified in AS/NZS IEC 60825.14[2]. The installation of a "Laser on" warning light or signal is also recommended. This allows suitable precautions to be taken to prevent direct and indirect (including diffuse reflections) laser radiation impacting the laser operator and any person including those outside of the laser-controlled area.

(iv) Laser booths:
A. Lasers should be operated in a laser booth to prevent the beam and reflections travelling beyond the laser-controlled area. For laser cleaning systems which are typically operated in situ, a local temporary laser-controlled area should be established, e.g. using laser-safe screening (see EN 12254[7] or AS/NZS IEC 60825.4[5]) should be used to prevent reflected radiation travelling beyond the laser-controlled area.
B. Special precautions may be required to prevent unwanted reflections, especially for infrared laser radiation, and the beam and target area should be surrounded by a material opaque to the laser wavelength. Polished or glossy surfaces are particularly hazardous as they produce specular (mirror like) reflections Even dull metal surfaces can produce highly specular reflections at the longer wavelength used by CO_2 (e.g. 10,600 nm or 10.6 µm) and produce diffuse reflection hazards solid-state, diode-based or fibre lasers (e.g.~1064nm).

(v) PPE:
A. Limiting access to the laser-controlled area to authorised persons trained in the safe use of the laser, and, wearing proper laser protective eyewear (see AS/NZS ISO 19818.1[3] and AS/NZS 1337.4[4]). Good room illumination is important in areas where laser eye protection is worn. Light-coloured diffuse wall surfaces help to achieve this condition.
B. Suitable protective clothing and gloves being worn (by the operator and personnel potentially exposed to the beam) to protect the skin from

direct and/or indirect beam contact and collateral radiation from the process being carried out.

Additional guidance on the safe use of hand-held laser devices can be found in ISO 11553-2[6] and AS/NZS IEC 60825.14[2].

Where required, locations with restricted laser access to allow monitoring of the activity or untrained personnel such as observers, can be provided through the use of filtered partially transparent laser-safe viewing windows (see EN 12254[7]) in the laser-controlled access location. However, a camera and viewing screen is a better and safer solution where process monitoring is required.

8.3 Electron Beam Welding

8.3.1 Process

The electron beam process is used in the automotive industries and in other specialised areas, particularly aircraft and aerospace. Its capabilities for welding heavy wall material, has led to its application in pressure and containment vessels.

The essential parts of an electron-beam welding machine are:

a) A dynamically evacuated work chamber, in which the work to be welded is enclosed;

b) An electron gun, with a means of traversing the workpiece or to follow the contour of the weld;

c) A power pack that supplies the low and high voltages to generate, accelerate and focus the electron beam.

Typically, voltages of 30-200kV are used in the process, filler metals are not normally used, and the process is operated in the key-hole mode. The potential hazards of the process are:

a) Electric shock;

b) Radiation;

c) Fumes and gases; and,

d) Physical.

8.3.2 Precautions

a) **Electric shock** The safety of the equipment or the exterior of the equipment is largely the responsibility of the designer and manufacturer. The owner and operators of the equipment must ensure all protective equipment is maintained in excellent working order. This especially applies to interlocking safety devices for the protection of operators working inside the chamber for cleaning and loading of the workpieces (these units can be quite large, permitting the entry of personnel).

A system of interlocks must be designed to prevent accidental locking of personnel in the unit. Internal systems should also be available to personnel working inside to prevent operation of the unit (e.g. Castell trapped key system).

The whole of the high-tension (or high voltage) supply, should be in an earthed metal enclosure. Before entry into the chamber, a system of interlocks should ensure the equipment is electrically isolated. A grounding rod should be used to discharge any static electricity that builds up on the electron gun.

b) **Radiation** An electron beam system is capable of generating X-rays. If electron beam equipment is inadequately shielded it could result in personnel being exposed to hazardous levels of radiation.

The design of the machine should prevent a radiation hazard by the thickness of the chamber walls and the lead glass viewing areas. The material being welded and the maximum operating currents are the main factors associated with the level of radiation. Equipment should be test rated for maximum radiation levels.

Where lead (Pb) is employed as a radiation barrier it should be mechanically supported and properly protected to avoid accidental damage. Regular checking of shielding protection by properly trained personnel should be carried out to ensure that deterioration is not occurring. The regular checks should be recorded for reference, to assess deterioration with time.

Non-vacuum and partial vacuum electron beam systems need to have X-ray protection screens employing moving or tunnel type shielding.

Other Radiation Electron beams produce a high degree of infrared, visible and ultraviolet energies. The viewing panels of lead glass should provide adequate protection against this form of radiation. Where electron beam welding is done in a non-vacuum, adequate eye protection is required.

c) **Fumes and Gases** (Toxic Hazard): Toxic fumes and gases may be generated by electron beam equipment – specifically ozone (O_3) and various oxides of nitrogen (NO and NO_2) in particular). The material being welded could also produce toxic fume, e.g. beryllium, copper.

Environmental measures are necessary for external venting and filtering. The material deposited on the walls of the vacuum chamber can be readily air borne and hence there is a risk of inhalation.

Before entry into the work chamber the toxic gases and fume must be reduced to a safe level. Exhausting fumes must be safely discharged where personnel cannot breathe them.

Non-vacuum and medium-vacuum electron beam machines have the potential to form toxic fumes and gases in the atmosphere surrounding the arc. These types of electron beam machines must have adequate ventilation.

High vacuum systems are unlikely to produce ozone and oxides of nitrogen as there is insufficient air available. The non-vacuum and partial vacuum types are able to produce quantities of these gases.

d) **Physical Hazards** It should be borne in mind that materials welded in vacuum do not cool as quickly as in air. Hence, care should be taken to avoid burns.

8.4 Electroslag Welding and Consumable Guide Welding

8.4.1 Process

Figure 8.2 illustrates the essential features of this welding process. The illustration shows a single wire and single guide, however, where heavy wall sections are welded, there are multiple wires and guides employed. The welding operation is similar to a casting process with moulds constructed of copper or aluminium. Flux to provide a slag cover for the weld pool is added by the operator, or may be combined with the consumable nozzle in the form of flux ferrules. Because the welds are carried out vertically the structures have to be erected, and, depending on the length of the joint, scaffolding may have to be also erected. Due attention has to be made to the stability of the structure and safety of the personnel working on scaffolding. The fixtures for holding the cooling shoes should take into consideration the safety of personnel working in the location.

8.4.2 Precautions

Electrical safety precautions, as outlined in Chapters 4 and 14, apply here because of exposed consumables. Whilst the operating voltages (typically 38-55 volts) are above the normal welding voltage range, they are not above values for open circuit voltage.

a) **Eye Protection**. Protection is required for the following reasons:
   i) UV radiation is not emitted. Filters of shade 3 are sufficient to protect against other radiation if viewing the weld pool.
   ii) Hot particles may be ejected from the weld pool if insufficient slag is present.
   iii) On removal of moulds, hard slag particles often require considerable force to detach and hence goggles with hardened lenses should be worn.

b) **Dust**. The flux added to the weld can produce quite high dust loads and care should be exercised in adding the material. Care should also be exercised in handling the material to avoid the formation of dust.

c) **Gases**. Nitrogen dioxide, carbon monoxide and ozone are formed in the welding process and adequate ventilation should be provided.

d) **Heat Radiation**. Ambient temperature rises in the vicinity of the weld and adequate protection must be provided for operators. The operation of removing cooling shoes subjects the operator to considerable radiant heat. The effect is increased with the thickness of the material being welded.

e) **Fume** Consists mainly of fluorides, manganese, silicon, iron, titanium and other elements. The fume load is low, however, in confined areas consideration to local extraction or ventilation should be given.

f) **Physical Hazards** With incorrectly fitted moulds or incorrect welding conditions excess penetration can cause run out of slag and weld metal. Protective gloves, aprons, spats and boots are highly recommended.

g) **Water Supply** Adequate supply with continuous flow is required to prevent overheating or melting

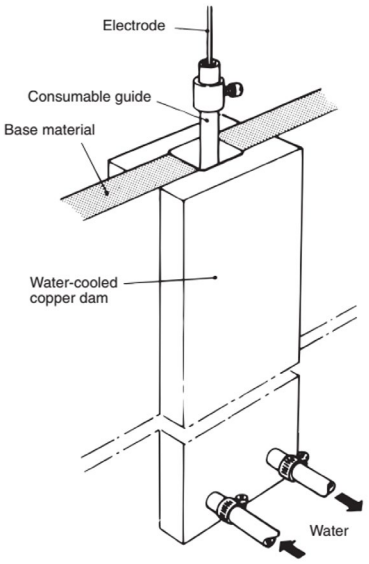


Figure 8.2 Consumable guide electroslag welding

of moulds. Contact of the weld pool with water is dangerous as the sudden formation of steam will cause an explosion. Ensure water cannot enter the weld region during or immediately after welding. Plastic hoses should not be used because hot water can soften them, causing displacement and leakage.

8.5 Explosive Welding

This process is highly specialised and must comply fully with the requirement of the explosive supplier and statutory authorities. Proven procedures and qualified personnel must be used.

The process is normally used for cladding plate and is supplied by specialist manufacturers.
Variants of the process may be used for tube/tube plate welding in normal fabrication shops. In such cases personnel must be adequately trained and special requirements relating to the use and handling of explosives must be observed.

8.6 Friction Welding

8.6.1 General

Friction welding may be divided into two modes, the conventional moving workpiece mode and the rotating tool mode known as friction stir. In the conventional friction welding mode, the two parts to be joined are oscillated or rotated in contact to generate friction heating prior to forging. In the friction stir welding process, a rotating tool is moved along the seam to be joined. In both cases, the operation involves machines with moving parts and relatively high applied force.

Such equipment must be adequately guarded and the operators fully trained in the process. Appropriate protective clothing and safety glasses should be worn. Loose clothing that may be caught in the rotating parts of the machine should be avoided and long hair should be tied back or covered with appropriate headgear. These processes often generate noise and hearing protection should be provided.

8.6.2 Friction Stir Welding

The equipment required is large and robust with high stiffness requirements and high clamping forces utilised in jigs and fixtures to maintain alignment of components. The main safety concerns are related to manual handling and mechanical hazards. The welding tool rotates and either the component is moved, or the tool is moved along the weld joint. Prevention of contact with moving parts e.g. by guarding or light screens may be required.

As with other friction welding processes there is no UV-radiation, welding fume or spatter. Whilst there is significant heat generated at the tool, there is no hazard to the operator.

8.7 Thermal Lancing

8.7.1 General

Thermal lancing (or oxy-lancing) is a powerful cutting and piercing method that uses an iron or steel tube packed with metal rods (e.g. steel, magnesium, or aluminium), through which oxygen is fed. The tube is held at one end and fed with oxygen from a cylinder or cylinder pack, with the other end ignited by an oxyacetylene torch, creating temperatures well in excess of 3,000°C, capable of melting or cutting most materials including steel slabs, refractories and concrete.

It is mainly used in applications where alternative cutting methods are unsuitable including tapping steel-making and other furnaces.

Similar to flame cutting, the process works with the steel and metallic rods burning in the oxygen stream and the remnant oxygen flow blowing away swarf and fume. The exothermic reaction generates intense heat capable of melting and cutting most materials.

8.7.2 Hazards

As with any industrial process, WHS regulations require the hazards to health and safety to be identified and managed.

The process utilises high pressure oxygen and all hazards and controls associated with its use (see Section 5) remain applicable.

In addition, aside from intense heat, the process generates copious sparks, molten particulates and fume at high temperatures that can travel long distances. It also produces extreme noise >> 130 dBA (see 18.8.1).

It is recommended that a task-based risk assessment be conducted prior to commencement of the lanc-ing operation to identify the hazards present and controls required to manage the hazards.

8.7.3 Controls

Due to the nature of the process, applicable controls required to protect the user are limited to adminis-trative controls (i.e. operator training) and the use of specialist personal protective equipment (PPE) that provides full body protection. Recommended PPE



includes the steelmaking teeming coats, thermal lancing trousers, thick fire-retardant gloves and boots, spats, hearing protection and respiratory protection.

When the use of thermal lancing is being considered, hot-work controls conforming with the recommendations of AS 1674.1[8] should be implemented noting that the high energy particulates generated can travel long distances. Considerations should include:

(a) protection of the surrounding area from the molten material produced during this process;

(b) the use of a firewatcher trained in the hazards of thermal lancing.

8.8 References

1. Standards Australia, AS/NZS IEC 60825.1, *Safety of laser products Part 1: Equipment classification and requirements*
2. Standards Australia, AS/NZS IEC 60825.14, *Safety of laser products Part 14: A user's guide*
3. Standards Australia, AS/NZS ISO 19818.1, *Eye and face protection — Protection against laser radiation Part 1: Requirements and test methods*
4. Standards Australia, AS/NZS 1337.4, *Personal eye-protection Part 4: Filters and eye-protectors against laser radiation (laser eye-protectors)*
5. Standards Australia, AS/NZS IEC 60825.4, *Safety of laser products Part 4: Laser guards*
6. International Standards Organisation, ISO 11553-2, *Safety of machinery — Laser processing machines Part 2: Safety requirements for hand-held laser processing devices*
7. European standard EN 12254, *Laser safety screens for workplaces*
8. Standards Australia, AS 1674.1, *Safety in welding and allied processes Part 1: Fire precautions*

9. Brazing and Soldering

9.1 Brazing and Soldering Processes

Although these groups of processes differ in operating principles and techniques, they have sufficient in common to warrant joint consideration in respect of health and safety consideration.

Unlike welding processes, neither of these processes involve the melting of parent (base) metal, however they are differentiated by the melting temperature of their filler materials. For soldering, by definition (see AS 2812), fillers melt at temperatures less than 450°C, and for brazing, fillers melt at temperatures of at least 450°C.

They can be conveniently sub-divided in respect of their joining temperature and heating source as this largely determines the safety precautions required. Other factors include the consumable type (flux and filler), aspects of pre- and post- joining cleaning, and proximity to work.

Table 9.1 gives joining temperatures and Table 9.2 lists the processes, their heat source and particular risks.

9.2 Brazing Hazards

The amount and toxicity of fume is dependent largely upon the process and the type of filler metal and flux used. Accordingly, ventilation requirements are in turn largely determined by these factors. It should be noted that fluxes, fillers, salt baths etc. are designed with optimum temperature ranges. Heating to temperatures above the range will always substantially increase the amount of fume generated.

In addition to fume, the welder needs to avoid direct contact with certain salts etc. Particular safety aspects of fluxes, filler metals and process details are discussed below.

9.2.1 Fluxes

a) **Low temperature silver brazing fluxes**: The fume given off by these fluxes may contain small quantities of hydrofluoric acid and boron trifluoride. They have an irritating effect on the eyes, nose and respiratory tract and can cause dermatitis if there is skin contact with fume or the flux.

Local exhaust ventilation is required for all but intermittent work and must be used in dip brazing operations.

Barrier type cream should be used for protection of skin on the face, hands and forearms. However, care should be taken to prevent contamination of

Table 9.1 Brazing and Soldering Temperatures

Process	Main Filler	Joining Temperature
Soldering (Note)	silver, tin or lead	< 400°C
Aluminium Brazing	zinc or aluminium	450-600°C
Silver Brazing	silver and copper and/or cadmium	650-800°C
Copper – Phosphorus Brazing	copper, silver, phosphorus	650-800°C
Brazing of Copper, Gold, high temperature metals, reactive and refractory metals	copper, gold, nickel, and/or special metals	520-3000°C
NOTE: Also called soft soldering		

surfaces to be brazed with protective cream as this may affect brazing performance.

Abrasions or skin cuts require immediate cleaning and protection by waterproof adhesive dressing.

Thorough washing of hands (including nail cleaning) and other exposed skin is required after work and before eating, drinking or smoking. Foodstuffs and drinks are to be separated from the working area at all times.

b) **High temperature boric acid fluxes**: No significant ill effects have been observed with these fluxes.

c) **Sodium carbonate and nitrate salt baths**: These processes are chiefly used for aluminium brazing. No significant fume hazards have been observed. However, as the precise constituents of the baths may not be known, it is wise to adhere to recommended practices.

Temperature of salt baths should be maintained within the recommended operating range.

d) **Cyanide salt baths**: Due to the highly toxic nature of cyanide fumes, protection with respect to breathing or absorption through skin or ingestion is required. Additionally, storage facilities for cyanide salts and acids must be such that no possibility of accidental formation of hydrogen cyanide gas exists.

Exhaust ventilation must ensure hazardous concentrations of fume do not occur.

Protective clothing that prevents contact of fume or salts is required as absorption through skin may result in poisoning or dermatitis.

Meals and refreshments must not be taken in the immediate workplace.

Burns due to splashes from cyanide baths must receive immediate first aid. Immediately flood the affected area with water. A buffered phosphate solution that can neutralise both acids and alkalis should be available.

Special first aid facilities must be readily available for cyanide poisoning. The nearest hospital should be alerted to the fact that cyanide salts are in use.

9.2.2 Filler Metals

The toxicity of brazing fume is also increased by the following constituents:

a) **Cadmium**: Some filler metals e.g. some copper-silver-zinc types, contain cadmium that is extremely dangerous in fume and dust form. The amount of cadmium fume increases rapidly as the heating temperature increases in excess of the optimum heating range. Correct brazing conditions greatly reduce the hazard. Deaths have occurred due to cadmium poisoning. Cadmium free filler metals (e.g. cadmium-free silver solder) are available.

The following precautions are required for brazing where either the filler contains cadmium or components are cadmium plated:

i) Local fume extraction is necessary.
ii) Confined situations require the use of a half face airline respirator (Figure 19.5) even where local exhaust systems are used.
iii) Observation for 48 hours after suspected exposure is necessary because there may be a latent period without symptoms prior to a severe reaction.

b) **Zinc**: In brazing, some zinc fume will be produced where zinc is present in the filler metal, parent metal or coating. Good natural ventilation and welding practice should be used. In poor ventilation conditions more positive ventilation is needed. Medical attention is advised after significant exposure.

c) **Beryllium**: This element may be present in some brazing alloys and is also present in some copper alloys. Although the welding of beryllium containing alloy is known to be hazardous, the situation with respect to brazing is not clear. It is strongly recommended however, that the following precautions be applied:

i) Local exhaust ventilation should be used in all circumstances. Filters are required to prevent discharge to either the workshop or outside atmosphere.
ii) Regular analysis of breathing zone and background (workshop) air is advised. Consultation with statutory authorities should be taken before handling beryllium in any form to determine appropriate requirements for personal protection and hygiene.

d) **Other metals**: May be present but constitute a lesser hazard.

In all cases, consider the use of respiratory protection (see AS/NZS 1715[1]) if fume exposure levels are above the exposure limit.

9.2.3 Explosion and Fire

9.2.3.1 Possible Sources

In addition to the gases used for flame or gas heating the sources of possible explosion and/or fire are furnace brazing atmospheres, and nitrate or nitrite salt baths.

9.2.3.2 Flame and Gas Heating

See Chapter 5 for precautions.

9.2.3.3 Brazing Atmospheres

a) Purging of air from furnaces is required prior to heating as some brazing atmospheres are explosive or flammable in the presence of air.

b) Pilot lights that ignite protective flames in some brazing furnaces should always be maintained.

c) Exhaust and safely discharge all explosive or toxic gases that arise from purging operations or brazing operations.

9.2.3.4 Nitrate and Nitrite Salt Baths

a) Salts must be dry before being added to the bath, to prevent steam explosions.

b) Aluminium must not be heated in the nitrate salt baths used for dip brazing steel because of possible explosive reaction between aluminium and nitrates.

c) Aluminium brazing can be safely carried out in nitrite salt baths.

d) Oils, tars, plastics, their residues and other carbonaceous materials also explode in contact with molten nitrate salts. Such a blast can propel droplets of molten flux into the workplace.

e) Handling of nitrate salts, especially when dry, requires great care because of risk of forming explosive mixtures. Procedures approved by the appropriate authority (Appendix B) must be employed.

9.3 Soldering Hazards

9.3.1 Toxic Fume and Salts

a) *Active (zinc chloride) soldering fluxes*: Zinc chloride is toxic if taken internally (e.g. ingestion from contact with contaminated hands) and can cause eye or skin irritation. Irritation resulting in the formation of ulcers in nasal passages is also possible. Considerable care is required in the handling of active fluxes.

b) *Rosin-based (safety) fluxes*: The principal constituents are colophony (pine resin), and in many fluxes, a volatile solvent such as isopropyl alcohol. Fluxes and fumes can cause skin disorders (e.g. dermatitis) or unpleasant irritation to nasal passages or cause symptoms such as nausea or sleepiness. Asthma sufferers often experience irritation and an asthma reaction sometimes occurs in others. People who exhibit such sensitivity should be given work in an area free of fume from this flux.

c) *Phosphoric acid based (stainless steel) fluxes*: Phosphoric acid is not volatile, but spray may be generated. Causes severe skin burns and eye damage, and contact with skin and eyes must be avoided.

Note: *Refer to the manufacturer's SDS for further information.*

9.3.2 Safety Precaution for Fluxes

a) Local exhaust ventilation is required when large quantities of active flux are handled e.g. dip soldering.

b) Safety goggles or screens are required where splashing of flux occurs or where fume is present.

c) Barrier creams should be applied to hands and forearms.

d) Protective gloves are discouraged. Once contaminated by zinc chloride, cleaning is extremely difficult and they can then promote dermatitis.

e) Cleaning of hands cannot be carried out with ordinary soaps, and the use of solvents must be avoided. Obtain safe and effective hand cleansers.

Note: *Refer to the manufacturer's SDS for further information.*

9.3.3 Toxic Fume from Solder

Tin and tin fumes (tin oxide) are of low toxicity. The main problem arises from lead, a constituent of most soft solders. Because of the relatively low vapour pressure of lead at normal soldering temperatures, lead fume is not usually regarded as a problem.

Note: *Specific federal, state and territory regulations may apply to lead-risk work including soldering.*

Where solder baths are used, however, substantial

quantities of dross containing fine lead oxide dust are produced and this may be dispersed by mechanical action as the bath is used, so that an extraction hood is recommended. Dross removal must be carried out in such a way as to avoid dispersing lead oxide dusts. In can soldering lines, where a high lead solder is used, solder droplets and lead oxides are mechanically propelled into a large area surrounding the line and local exhaust ventilation is required.

Cadmium is used in low melting point (tin-based) and higher melting point (lead-based) solders. In the low melting point solders, fume is not a problem but precautions against inhaling fume from the higher melting point solders are necessary.

9.3.4 Fire Hazard – Rosin Based (Safety) Fluxes

These soldering fluxes contain flammable solvents. Although the risk of fire or explosion is not high, basic precautions should be applied. Rosin based solders have also been cited as a possible cause of industrial asthma and suitable local ventilation must be provided for the operator.

a) Store all supplies in closed containers.

b) Naked lights or other ignition sources must be kept away from open flux baths.

c) Extinguish any flux bath fires by exclusion of oxygen e.g. cover containers with metal sheets or flameproof sheeting.

9.4 Electrical Hazards

The possibility of electric shock arises in processes such as resistance or induction methods and other processes using electric power as a heat source. The usual requirements in respect of installation and maintenance, use of procedures and protective clothing devices apply. These are similar to those in Chapter 4 (see also Chapter 14).

a) Avoid contact with work coils in induction processes as slow healing deep skin burns can occur.

b) Cabinets must not be opened until power is disconnected. Safety switches preferably of the fail-safe type are recommended.

9.5 Eye Injuries

These may result from radiation in flame processes or from hot liquid metals or fluxes.

a) Goggles with suitable protective filters are required for flame (torch) blazing or soldering (Chapter 19).

b) Full Face Shields are required for operations involving salt baths or solder baths (Chapter 19).

9.6 Cleaning Hazards

See *Metal preparation*, Section 10.3.1 *Chemical treatments*.

9.7 Burns to Body

In addition to burns to the eye, various parts of the body, particularly the hands and arms may suffer burns due to hot metal or parts. Good equipment, work procedures and protection should be used.

Salt and solder baths and pots must be designed so that, when heated from cold, the top melts first. In this way the possibility of ejection of molten solder through a solid crust is prevented.

9.8 References

1. Standards Australia, AS/NZS 1715, *Selection, use and maintenance of respiratory protective equipment*
2. Standards Australia, SA/SNZ IS ISO 16975 (series), *Respiratory protective devices — Selection, use and maintenance*



Table 9.2 Brazing and Soldering Process Hazards

Process	Hazard							
	Heat Source	Flux Fume & Toxic Salts (Sect. 9.2.1)	Metal Fume (Sect. 9.2.2 & 9.3.3)	Explosion or Fire (Sect.9.4)	Electric Shock (Sect.9.5)	Eye, Nose, Throat Injury (Sect.9.5)	Cleaning Agents (Sect. 9.6)	Body Burns (Sect. 9.7)
Brazing								
Torch/blowpipe brazing and braze welding	Flame	X	X	X	–	X	X	X
Induction brazing	Electrical	X	X	–	X	–	X	X
Resistance brazing	Electrical	X	X	–	X	–	X	X
Furnace brazing	Gas, Electrical	X X	X X	X –	– X	– –	X X	X X
Salt and Flux Bath Brazing	Gas, Electrical	X X	X X	X –	– X	X X	X X	X X
Soldering								
Blowpipe soldering	Flame	X	–	X	–	X	–	X
Soldering iron	Electrical	X	–	–	X	–	X	X
Mass soldering (see NOTE)	Gas, Electrical	X X	– –	X –	– X	X X	X X	X X
Hot plate soldering	Electrical	X	–	–	X	X	X	X
Induction soldering	Electrical	X	–	–	X	–	X	X
Resistance soldering	Electrical	X	–	–	X	–	X	X
Furnace soldering	Gas, Electrical	X X	– –	X –	– X	– –	X X	X X

NOTE: Dip, drag, jet and wave soldering



10. Metal Preparation Processes

10.1 The Need for Metal Preparation

Metal surfaces need to be cleaned prior to welding to remove materials that may lead to an inferior weld and/or adversely affect the working conditions and health of the welder.

Metal surfaces may be covered with a variety of materials such as rust and scale, paints and surface coatings, plastics, greases and oils, and galvanising. Metal preparation not only involves checking visible surfaces but also:

a) What is behind the metal work surface.

b) What may be in or has been in a pipe or duct.

c) What may be adjacent to or in the vicinity of the welding operation.

A thorough hazard identification and risk assessment is recommended before carrying out any metal preparation processes to determine:

i) The nature of the coating.

ii) Whether the coating would be affected by the hot work process.

iii) Whether the coating has to be removed to eliminate the hazards associated with reactions resulting from hot work.

iv) Whether the coating removal process or products of the process create new hazards.

Note*: SDSs for surface coating products do not usually address the possible outcomes of hot work that involve intense heat sources and high temperatures in many cutting and welding processes.*

10.2 Metal Cleaning Processes

Metal surfaces and edges may be cleaned, treated or finished using either physical or chemical processes. Some of these processes or operations are:

a) Chemical
   i) Chemical plate de-scaling.
   ii) Degreasing.
   iii) Surface coating or paint removal.

b) Physical
   i) Abrasive de-scaling.
   ii) Mechanical edge preparation; shearing, guillotining, nibbling, machining, arc gouging (see Chapter 4), flame cutting (see Chapter 5), and plasma cutting (see Chapter 6).
   iii) Grinding of plate and final welds.
   iv) De-slagging, Chipping.
   v) Chiselling.
   vi) Peening.
   vii) Flame cleaning.

These processes introduce mechanical, chemical and heat hazards that necessitate suitable precautions.

10.3 Precautions with Preparation Processes

Welding personnel will be involved or closely associated with a number of the above processes but may encounter some on only rare occasions. The following are the main precautions that should be observed with the above processes.

> **WARNING***: Wherever possible, the use of chemical cleaners (especially those containing hydrofluoric acid) should be avoided. Contact or exposure with any of these chemicals, especially hydrofluoric acid (chemical formula HF), requires immediate medical attention. Calcium gluconate should be available on site where hydrofluoric acid is used.*

10.3.1 Chemical Treatments

If in the immediate vicinity of the process, observe all the applicable precautions specified for handling corrosive materials and solvents. Safety Data Sheets (SDS's) should be obtained for all the chemicals being used in the process. In turn, these Sheets should be used to develop safe working procedures.

10.3.1.1 Caustic Solution Cleaning

This process is often used to clean off paints and surface coatings as well as to clean brazed assemblies especially in aluminium. Caustic cleaning solutions, especially if hot and/or concentrated, will give off corrosive and strongly irritant fumes. Caustic solutions cause burns to skin and eyes. When in contact with many metals, especially aluminium, they can cause hydrogen gas to be evolved. This means precautions against fire and explosion must be taken. Such processes require:

a) Use of local ventilation (that must be fire and spark proof if hydrogen is being evolved).

b) Full protective clothing and footwear.

c) Use chemical resistant gloves that extend past the elbow.

d) Use of full-face shield. Caustic burns to the eye can cause severe and irreparable damage.

e) Use of barrier creams for exposed skin.

f) Maintenance of adequate emergency facilities (showers and eye washes) and first aid facilities with caustic burns in mind.

g) Proper safety procedures for handling corrosive chemicals should be followed.

10.3.1.2 Acid Solution Cleaning

Again, the major hazards are skin/eye contact and fumes. The hazard is increased when hot and/or concentrated solutions are used. The precautions are similar to those for caustic solutions above. Neutralising materials such as sodium bicarbonate should be available in case of spillage. Acid burns need to be treated immediately with running water, not neutralising solution. Particular care needs to be exercised if nitric acid or hydrofluoric acid is being used. Nitric acid on contact with organic materials such as cotton, sawdust and so on will form flammable and potentially explosive compounds. Hydrofluoric acid, especially if dilute, does not give immediately obvious burns but penetrates the skin to do severe damage to tissue and bone underneath. Hydrofluoric acid should not be used except with specific safety procedures. Precautions to be taken include:

a) Use local ventilation.

b) Use full protective clothing and footwear.

c) Use chemical resistant gloves that extend past the elbow.

d) Use full-face shield. Acid can cause severe eye damage.

e) Use barrier creams for exposed skin.

f) Maintain adequate emergency showers and eyewashes.

g) Where hydrofluoric acid is used, calcium gluconate should be available on site.

h) Proper safety procedures for handling acids should be followed. Reference should be made to the Safety Data Sheet (SDS) supplied by the chemical's manufacturer.

10.3.1.3 Pickling and Passivation Pastes

Pickling and passivation pastes used for the cleaning of stainless steels after welding often contain strong alkalis or acids including nitric acid and/or hydrofluoric acid. The paste manufacturer's Safety Data Sheet (SDS) should always be consulted prior to the use of such pastes and any instructions for safe use complied with, including recommended safety precautions. This is particularly critical for pastes containing hydrofluoric acid, as even small concentrations (as low as 2% HF) are capable of inflicting very serious burns.

Contact with hydrofluoric acid requires immediate medical attention. Calcium gluconate should be available on site where hydrofluoric acid is used.

A specific plan for hydrofluoric acid use should be developed and discussed with First Responders prior to consideration for use.

10.3.1.4 Degreasing Chemicals

Where solvents are being used, precautions to limit worker exposure and the risk of fire (with hydrocarbon solvents) are required. In general, degreasing solvents fall into three categories: water based, hydrocarbon and halogenated hydrocarbon solvents.

Water based degreasers generally contain detergents and surfactants. They are the least hazardous but have a number of technical deficiencies.

Hydrocarbon solvents are flammable and sometimes form toxic gases when burnt.

Halogenated solvents (usually chlorinated hydrocarbons) are not flammable but decompose on exposure to heat or ultraviolet radiation to form toxic gases including phosgene. Even halogenated solvent fumes drawn through a cigarette may produce toxic decomposition products. In addition, chlorinated hydrocarbons can form potentially explosive compounds with aluminium.

Regardless of type, the degreaser will remove skin oils from exposed skin. This will initially cause dry skin and irritation but may also lead to dermatitis. The use of degreasers in confined spaces is particularly



hazardous, not only from higher toxic fume levels but also from simple asphyxiation.

The following precautions are necessary with degreasing processes:

a) Great care is required if gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) or plasma processes are used.

b) Degreasing of large areas should be carried out in special areas remote from the welding operation (refer AS 1627.1[1] for details).

c) Welding must not commence until the degreasing solvent is completely removed from the surface and from the area.

d) Where degreasers are expected to evaporate, welding must not commence until the surface is dry and ventilation has removed any fumes.

e) Degreasing solvents must be stored well away from welding operations.

f) These measures are necessary because many chlorinated hydrocarbon degreasers are heavier than air and the vapour may travel a considerable distance from the area in which it is being used.

g) Manufacturer's Safety Data Sheet requirements and recommendations must be adhered to in the handling all degreasing solvents.

10.3.1.5 Solvent Paint Strippers and Removers

These are usually strong caustic solutions or products based on halogenated hydrocarbons - see 10.3.1.4 items a) and c), and always refer to manufacturer's Safety Data Sheets.

10.3.2 Physical Treatments

The main hazards with these processes are the physical hazards of high velocity particles, noise, vibration, the moving parts of machinery and tools, and the creation of dusts. Protection against high velocity particles involves putting barriers between the source of such particles and workers. Such barriers may be a blasting cabinet/room, or personal protection (see Chapter 19). Adequate eye protection is critical. Noise and vibration are discussed in Chapter 18.

Of particular concern is noise in confined areas and excessively vibrating tools. Equipment must be properly guarded and adequately maintained to minimise risks to personal safety. Dust can present both a health and fire/explosion hazard. The dust comes both from the abrasive grit and the surface being treated.

The health hazards of dust can be controlled by:

a) Using less hazardous processes or materials.

b) Ventilation of fumes, dusts, etc. (see Chapter 17).

c) Personal protection (see Chapter 19).

The residues from blasting may themselves be, or form with other materials, a significant dust fire and explosion hazard (see Section 11.4).

All hand tools and other equipment must be maintained to optimise their operation and minimise the risks to users. Operators must be adequately trained and supervised in the use and day-to-day maintenance of equipment.

Blasting and other operations must comply with state regulations. Such regulations can be ascertained by contacting offices of the responsible government department.

10.3.2.1 Abrasive Plate Descaling and Cleaning

This process uses abrasive blasting to remove surface coatings or to clean up the surface. The process may use metallic shot grit, chopped wire and the safer non-metallic grits. High velocity particles and air blast are the main hazards. The relevant safety procedures pertaining to the particular equipment and abrasive compound must be observed (refer AS 1627.4[2]).

10.3.2.2 Mechanical Edge Preparation

Shearing, guillotining, nibbling and machining operations should be carried out using equipment and procedures that meet relevant safety standards. In addition, persons suitably trained in the safe use of such equipment should carry out the work.

10.3.2.3 Grinding and Abrasive Disc Cutting

Grinding and abrasive disc cutting present similar hazards to abrasive plate descaling. However, since they are typically a manual operation the hazard level can be significantly higher. Special care is required with abrasive cutting and grinding discs to avoid rupture.

The disc must have a speed rating at least as high as the maximum spindle speed of the tool. Care must be exercised to ensure the disc is not overloaded or shock loaded. Abrasive cutting discs are often used incorrectly e.g. for grinding operations, resulting in greater than intended stress and a possibility of disc failure.

Guarding must always be in place, correctly positioned and adjusted. Handles must be fitted and used. Incorrectly fitted or missing guards and operators not holding the grinding tool correctly with both hands are the cause of many injuries.

Use of incorrect disc support washers also results in excessive stress on the disc and can lead to failure. There is high kinetic energy in a high-speed angle grinder. Due to the high incidence of serious injuries related to the use of larger angle grinders (230 mm or 9 inch), many companies in Australia have introduced strict controls on the use of angle grinders, particularly the larger types.

A double layer of eye protection is recommended for all grinding activities e.g. safety glasses worn under a full-face shield complying with AS/NZS 1337.1[3].

Welding helmets that comply with Chapter 4 of AS/NZS 1337.1 are only required to meet medium impact requirements and are therefore considered to be inadequate for face and eye protection while using grinding tools.

> **Note***: European standards use the same velocities as listed in AS/NZS 1337 but use a 6.0mm steel ball instead of a 6.35mm steel ball, so conformances to European impact resistance classifications are not directly equivalent since the kinetic energy of the impact for the European tests are only 84% of the kinetic energy applied by the Australian/New Zealand tests*

10.3.2.4 De-slagging, Chipping, Chiselling and Peening

The major hazard is from eye injury (refer Chapter 19).

10.3.2.5 Flame Cleaning

The major hazard is eye injury (refer to Chapters 5 and 19).

10.4 Coated Metals

Coated metals may require special precautions that are dealt with in Section 17.11.

10.5 Contaminated Surfaces

In maintenance or repair work, the surfaces to be welded etc. may be contaminated with various materials. Unless materials are known to be non-hazardous, they should be treated as above and in Sections 17.1, 17.11 and also Chapter 21 on working in or on containers and pipes.

10.6 Metal Preparation in Special Locations

Special hazards arise in metal preparation operations in the following specific locations:

a) In confined spaces (refer Chapter 20);

b) In or on containers (refer Chapter 21);

c) On pressurised equipment (refer Chapter 22);

d) In refineries and chemical plants (refer Chapter 24);

e) At heights or underneath construction (refer Chapter 25).

See also Section 16.3.2 regarding use of non-sparking tools to avoid an explosion.

10.7 References

1. Standards Australia, AS 1627.1, *Metal finishing – Preparation and pretreatment of surfaces, Part 1: Removal of oil, grease and related contamination*
2. Standards Australia, AS 1627.4, *Metal finishing – Preparation and pretreatment of surfaces, Part 4: Abrasive blast cleaning of steel*
3. Standards Australia, AS/NZS 1337.1, *Personal eye-protection Part 1: Eye and face protectors for occupational applications*

11. Thermal Spraying

11.1 Introduction

Thermal spraying is used to deposit a variety of metals, non-metals and ceramics as an overlay on components. It is used both in mechanised and manually operated forms. Figure 11.1 illustrates the spraying processes.

11.1.1 Basic Compounds

The basic components of thermal spraying equipment are:

a) Source of heat, for example:
   i) Oxygen-fuel gas torch (Chapter 5) – see Figure 11.1(a).
   ii) Wire-arc gun – see Figure 11.1(b).
   iii) Plasma gun (Chapter 6) – see Figure 11.1(c).

b) Wire or powder feed to supply the overlay material into the flame or arc.

c) Compressed air to project molten particles onto the surface of the component being overlaid (wire-arc and oxygen/fuel gas processes only).

11.1.2 Hazards to Health

Hazards to health and safety that are more likely to arise in metal spraying processes than in other welding or allied processes (see AWS C2.1) are:

a) Fire and explosions of gas (Chapter 16).

b) Dust fires (Section 16.3).

c) Poisoning or respiratory difficulties due to dust.

d) Skin disorders due to dust.

e) Radiation – eye and skin hazards (Chapter 15).

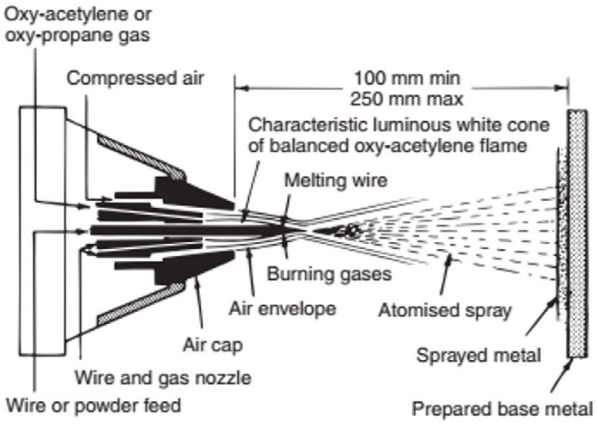
f) Electric shock (Chapter 14).

g) Noise (Chapter 18).

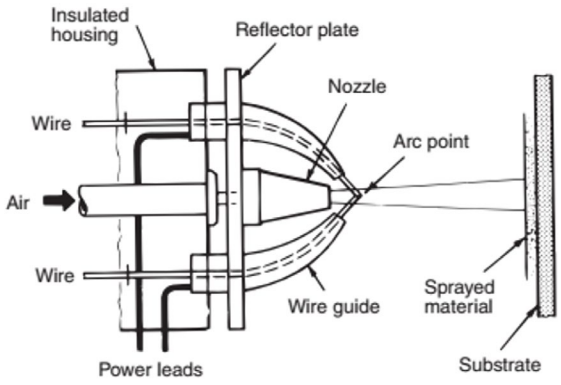
h) Burns.

i) Fume/particulates.

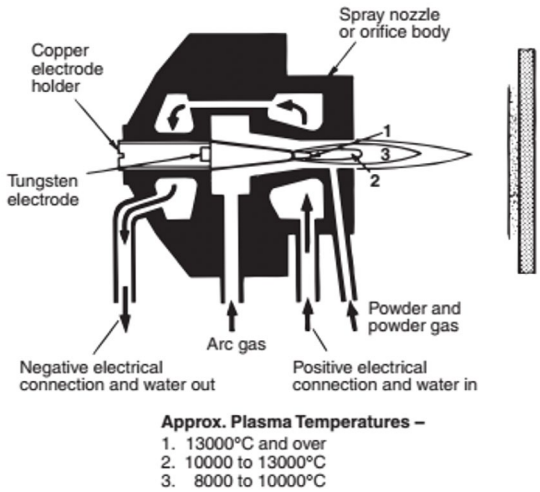
The precautions required in respect of these hazards are discussed below.



a) Oxygen — fuel-gas



b) Wire — arc
The arc is struck between two consumable wires



c) Wire — arc

Figure 11.1 Thermal spraying equipment

11.2 Surface Preparation

Abrasive blasting is a commonly used method of surface preparation for metal spraying as it provides a good surface for adhesion.

Special precautions and restrictions apply to abrasive blasting – see Section 10.3.2.1.

11.3 Gas Fire and Explosion

As with any process that uses oxygen-fuel gas systems, care is required to ensure that malfunctions or dangerous practices do not arise. These are:

a) *Precautions with gases*: The requirements for safe handling of gas supply and distribution outlined in Chapter 5 should be adhered to.

b) *Spraying guns*: It is advisable to use guns of modern design that minimise the possibility of obtaining a mixture of oxygen and fuel gas in the gun i.e. guns having individual diaphragm valves for oxygen, fuel gas and compressed air. Guns should be maintained in accordance with the manufacturer's instructions.

c) *Nozzle backfire*: Wire pistols have a slight tendency to backfire due to heat conduction back through the wire. For pistols that operate at critical pressures, safety devices are incorporated to prevent flashback into pressure hose. When backfire occurs, nozzles should be replaced.

d) *Gas leakage*: Care is required to ensure leakage does not occur from valves, regulators, and nozzles or from gas supplies left on without lighting them. Explosive gas mixtures can build up very quickly especially in small working areas.

11.4 Dust Fire and Explosion

11.4.1 Need for Precaution

Accumulated metal dusts are, under certain circumstances, capable of burning or exploding. Although this situation is likely to arise only very rarely, the possible results are such that stringent precautions are required. These are given below.

11.4.2 Flammable Metal Dusts

The reactive metals that, when finely divided (in the form of dust) may burn in air are:

a) Aluminium;

b) Zinc;

c) Magnesium; and,

d) Titanium.

Spraying or grinding these metals often produces the dust.

Metallic dust fires are slow moving and difficult to extinguish. Ignition may be brought about by:

i) Hot (molten) spatter;

ii) Electric short circuits from cable with damaged insulation.

Explosion may result if burning dust is stirred up into a cloud, providing oxygen access to a large surface area of hot metal.

Fight metal dust fires with procedures tailored to these special characteristics as described in Section 16.3.4.

11.4.3 Self-burning Dust Mixtures

Many metal oxides may provide the oxygen necessary for the combustion of the reactive metals listed in 11.4.2 without the need for any other air or oxygen. This aluminothermic reaction rapidly generates high temperatures (white heat) and showers of sparks. It is the type of reaction used in the aluminothermic welding process (Section 8.1).

The most common metal oxides that can so combine with the metals listed in 11.4.2 are:

a) Iron oxide from blasting, grinding, cutting etc;

b) Copper oxide;

c) Tin oxide;

d) Lead oxide.

Firefighting procedures are given in Section 16.3.4.

11.4.4 Collection of Metal Dusts

Metal dusts rapidly accumulate if not appropriately managed. Options include:

a) Vacuum cleaners of flameproof design should be used to keep dust accumulation to a minimum.

b) Workshops designed for metal spraying should have smooth walls and a minimum of ledges or obstructions on which dust accumulations are possible.

c) Metal spraying and blasting should, wherever possible, be carried out in completely separate rooms.

d) Metal dusts should not be freely discharged to air.

e) Water wall spraying booths (Figure 11.2) collect metal dust at the source by flooding it with water, allowing safe disposal.

f) Wet scrubbers are preferable to dry dust collectors.

g) Bag or filter type collectors should be sited outside the workrooms and fitted with explosion relief doors.

h) Cyclones should be protected against the entry of moisture as reactive metal dusts (11.4.2) are capable of spontaneous combustion in humid conditions or when partially wetted.

i) Ventilation ducting should be designed and operated as recommended in Section 16.3.3.

11.4.5 Prevention of Dust Fire and Explosion

The evidence currently available indicates that the particle size of dusts formed in metal spraying is rather larger than that which would constitute any appreciable risk. Nevertheless, this risk must be assumed to be present and appropriate precautions taken.

Prevent dust fire and explosion by observing the recommendation of Section 16.3.

11.5 Health of Operators

Metallic dusts generated in metal spraying may result in a variety of health problems in workers ranging from quite short-term effects to a serious deterioration in health. Adoption of efficient ventilation facilities and, in severe situation, a positive airflow respirator will obviate these problems. In modern metal spraying, deterioration in health due to exposure of dusts is very rare. It is as well, however, to be aware of the possible consequences of excessive exposure.

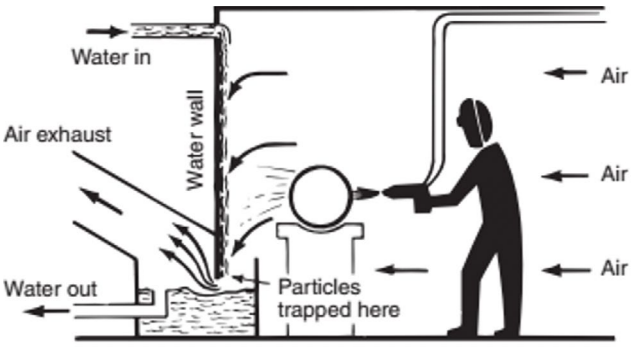


Figure 11.2 Water wall spraying booth

a) *Larger particles*: Nose and throat irritations are the major hazards resulting from particles of size greater than about 5µm. Discomfort is likely, but such particles are generally not dangerous.

b) *Small particles*: Lung deterioration can be associated with particles of a size of less than 5µm, and particularly if less than about 1.5µm, which may become trapped in the lungs. Dependent upon the type of dust an impairment of lung functions and long-term deterioration can occur.

c) *Zinc spraying*: Zinc spraying can result in operators being affected by metal fume fever. Although symptoms vary, it is in many ways similar to mild influenza. There appears to be no long-term effects and recovery generally occurs about eight hours after removal from fume exposure.

d) *Lead spraying*: Lead is a cumulative poison and can have very serious consequences. Stringent statutory regulations apply to conditions of work, and medical examinations are required (e.g. routine blood tests) in industries where lead poisoning or absorption can occur. Such regulations must be adhered to and strict supervision of workers must also be practised.

e) *Cadmium spraying*: Cadmium fumes may also cause poisoning that can be fatal in acute cases. Good ventilation must be ensured and strict adherence to statutory provisions is required (see Appendix A).

f) *Other metal powders*: Alloys that contain manganese, cobalt, vanadium, nickel or chromium should be treated with great care. Reference should be made to the relevant exposure limits[1,2].

g) *Skin disorders*: Dermatitis can affect some people. Barrier creams may be effective in prevention but in any case, a doctor should be consulted. Where chronic dermatitis occurs, a change in occupation may be required.

11.6 Personal Protective Equipment

a) Goggles are required to provide protection against infrared and ultraviolet radiation, and from flying, sometimes molten particles. Filter selection depends upon the process being used (see Chapter 19 – note that due to the high arc energies involved, stronger filters may be required to reduce ultraviolet radiation).

b) Hearing protection is required with some metal

spraying guns that are excessively noisy e.g. arc and plasma (see Chapter 18 – earplugs and earmuffs are commonly used in combination.)

c) Work clothing and footwear should be chosen to minimise the possibility of burns or injury due to molten particles.

d) Respiratory protection devices are determined by the nature, type and magnitude of the fume and gas exposure (see Chapter 17 and Section 19.6).

11.7 Spray Guns

It is important to recognise the potential hazards with defective guns that use compressed air, oxygen and a fuel gas (see Chapter 5).

a) Flashback or unexplained blowouts require the cause of failure to be found and eliminated before re-lighting.

b) Oil should not be allowed to enter gas passages or mixing chambers. Only those lubricants recommended by the manufacturer can be used.

c) Acetylene gas can only be used in guns specially designed for this gas. High issuing velocities that are not achievable in other gun types are required to prevent the flame from burning back into the mixer.

11.8 Spray Booths

The operation should be carried out at a negative pressure to prevent fume affecting nearby personnel. A manometer can be used to ensure a visual indication during operation.

11.9 References

1. Weld Australian, Technical Guidance Note TGN-SW01, *Fume minimisation guidelines*
2. Safe Work Australia, *Workplace exposure limits for airborne contaminants*

12. Heat Treatment Processes

12.1 Type of Process

Heat treatment in various forms is extensively used in welding applications. Examples are found in preheating of weldments and post weld heat treatment such as stress relief or occasionally normalising and solution heat treatment.

Salt bath heat treatment is not normally applied to weldments, but appropriate precautions are given in Sections 9.2, 9.5 and 9.7.

12.2 Hazards

Hazards arise through heat treatment. A thorough hazard identification and risk assessment should be carried out before commencing any heat treatment activity. Important features for consideration are:

a) **Location**: Where possible, post-weld heat treatment (PWHT) should be carried out where personnel cannot touch the workpiece. Care needs to be exercised in preventing contact with workpieces either during heat treatment or during subsequent cooling.

b) **Insulation**: To prevent skin contact with heated surfaces, suitable thermal insulating materials should be provided. Insulating materials can also create hazards, particularly when they break down to form airborne particles after repeated use or high temperature exposure.

> **Note***: Fibreglass, rock wool and aluminosilicate, for example, may shed fine airborne particles and for respiratory protection it is recommended that exposures be limited by use of a suitable dust mask.*

c) **Warning signs and barriers**: These will be required in working areas where safe relocation of the workpiece cannot be carried out.

d) **Protective clothing**: Heat resistant protective gloves and clothing will be required where preheat temperatures are such that they give rise to risks of burns (See Chapter 19). Respiratory protection is required where there is exposure to airborne particles.

e) **Burns**: No matter how minor, all burns should receive first aid. Burns constitute the principle hazard that can arise from heat treatment but there are also specific hazards that are related essentially to the heating process used (see below).

f) **Heat stress**: Heat stress can be severe in confined areas (see Chapter 23).

g) **Fire and explosion**: There are many issues to consider in preventing fire and explosion during heat treatment processes. They can arise from:
   i) The component or its contents being flammable;
   ii) The heating process if it involves combustion of fuels; or,
   iii) The effect of the activity on the surrounding environment e.g. supports or other neighbouring items that are heated by the process.

h) **Ventilation of closed spaces**: Closed spaces must be identified and vented before heat is applied. Failure to adequately vent can lead to pressure build up, ruptures and explosions.

12.3 Flame Heating

Oxygen-fuel gas systems are frequently used for both pre- and post-weld heating. Precautions common to all oxygen-fuel gas systems must be adopted (see Chapter 5). Particular considerations include the following:

a) **Fire and explosion**: Exercise care in handling of all equipment, take precautions to avoid leakage and build-up of oxygen or fuel gases (see also Chapter 16).

b) **Ventilation**: In confined spaces, build-up of fuel gases, carbon dioxide or carbon monoxide can occur. Care is required to ensure gas supply systems are leak-tight (Chapter 5) and that appropriate ventilation is provided (Chapter 17). The requirements of AS/NZS 2865[1] should be met.

12.4 Electrical Heating

Electrical resistance heating is commonly used and in many situations electrical power is obtained from welding plant or other appropriate generators or transformers. To ensure safety in respect of electrical safety and operation of equipment, the following considerations apply:

a) Electric plant (refer Chapter 4); and,

b) Electric shock protection (refer Chapter 14).

12.4.1 Resistance Heating Elements

Resistance heating elements can reach temperatures in the order of 1000°C when in operation. The power sources have an AC output and operate at similar voltages to MMAW power sources so there is a similar electrical hazard. It is therefore critical that measures are in place to prevent contact with any uninsulated conductive parts.

12.4.2 Induction Heating

Induction heating uses electromagnetic induction to create eddy currents that generate heat within an object rather than using an external heat source via heat conduction.

Additional hazards, including use of a coolant, typically water, electromagnetic radiation and magnetic fields may be present when using coils for induction heating. Therefore, additional safety measures and checks should be applied if using this technology. These include checks for damaged equipment, shielding or distancing from EMF and magnetic fields. Anyone with a cochlear implant, pacemaker or metal implants should consult their doctor prior to exposure (see Section 15.6).

12.5 Thermal Distortion

In any heat treatment activity, the effects of thermal expansion must be predicted and managed. Thermal expansion is an inevitable consequence of heating and care must be exercised to ensure that any differential expansion or restrained expansion does not create hazardous situations or potential damage to the component being heat-treated.

12.6 References

1. Standards Australia, AS/NZS 2865, *Confined spaces*



13. Materials and Process Hazards

13.1 Introduction

In addition to the various hazards associated with each welding process, problems can arise with a variety of materials during welding or flame cutting if suitable precautions are not taken.

Table 13.1 cross references the hazards that may arise from welding or cutting on particular materials or through the use of particular consumables.

Refer also to the manufacturer's Safety Data Sheets for additional information and Safe Work Australia's Workplace exposure limits for airborne contaminants[1].

Table 13.1 Materials and Process Hazards

Material	Containment (Notes 7,8)	Hazards To Be Dealt With	Remarks
Aluminium spray powder and wires flake paint	 Al Al	 *fume *dust fire and explosion *fume *radiation	 see also plastics
Aluminium and its alloys plate extrusions and castings welding consumables Aluminium bronze	 Al (Mg, Mn, Cr) ozone Al (Mg, Mn, Cr, Be) ozone Cu Al	 *fume *radiation *fume *radiation	
Basic (hydrogen controlled) manual electrodes and flux-cored wires	flourides	*fume	
Blasting Residue	iron, copper oxides, Silica	*dust fire and explosion	Note 1
Brass and Bronze	Cu, Zn, (Sn) Mn, Ni, Pb	*fume	
Brazing baths – see Heat Treatment			
Brazing fillers Cadmium-free Cadmium-bearing	 Cu, Ag, Zn, Ni (Sn) Cd, (Cu, Ag, Zn, Ni)	 *fume 9.2.2 *fume 9.2.2	
Brazing fluxes	fluorides	*fume 9.2.1	
Casting, iron welding electrodes for Nickel or Nickel-iron type Bronze type	 Ni Cu, Zn (Al)	 *fume *fume	
Coatings, metal, on steel etc. See also metal spraying, plated steel, surfacing, lead	 Zn, Pb, Cr, Cd, Ni, Cu, Sn	 *fume	See also Metal spray Note 2
Coatings, plastic, on steel etc	organic fume	fume 17.10	See also Metal Spray
Copper and its alloys Copper, brass and bronze Copper-beryllium alloy	 Cu, Zn, (Sn), Mn, Ni, Pb, Al Be (Cu)	 *fume *fume	 See also Brass and Bronze
Degreasing agents, chlorinated hydrocarbons – decomposition products	 phosgene	skin and eye irritation – fire – narcosis intoxication and addiction vapours *fume 17.11 and 10.3	

Table 13.1 Materials and Process Hazards (continued)

Material	Containment (Notes 7,8)	Hazards To Be Dealt With	Remarks
Dissimilar metal joints, welding electrodes for High alloy stainless type Nickel alloy type	 Cr, Ni, (Fe) Ni, Cr, (Fe)	 *fume	Note 3
Galvanised steel Hot dipped zinc, zinc plated zincalume	 Zn (Fe) Zn (Al, Fe)	 *fume *radiation *fume *radiation	 See also coatings metal on steel
Heat treatment/dip brazing molten salt baths molten cyanide salt baths	 nitrates, nitrites cyanides barium and alkali	 explosion 9.2.3.4 steam explosion as in 9.2.3.4, poisoning, skin disease 9.2.1	
Lead, lead-coated steels, terne plate Leaded free machining copper aloys	Pb Pb oxide	-*fume, dusts 9.3.3 *dust fire and explosion	
Magnesium and its alloys plate extrusions and castings dusts	 Mg, Zn	 *fume *radiation *dust fire and explosion	
Metal spraying see also surfacing	 Al, Zn, Pb, Mo	 *fume *dust fire and explosion	
Nickel and its alloys Monel Incoloy, Inconel Hastelloy	 Ni, Cu Ni, Cr, Fe Ni, Cr, Co	 *fume *radiation *fume *radiation *fume *radiation	
Paint coatings on steel etc. Weld-through primers - Zinc silicate type Epoxy type	 Zn, Cd	 *fume *radiation see plastics	
Other metals in paint Aluminium flake Zinc Chromate Red lead see also Plastics	 Al Zn, Cr Pb	 *fume *radiation *fume *fume	
Other paints – see Plastics			
Plastics, decompose on excessive heating	organic fume filler materials	fume 17.10..1, 10.3.1.4 fire and explosion 21.3.2	
Plated steel etc. Zinc – see Galvanised steel Cadmium Chromium Nickel	 Cd Cr, Cu Ni	 *fume 9.2.2 *radiation *fume *radiation	 Notes 2, 4
Solders tin-lead	Pb	fume 9.3.3	
Soldering flux safety stainless steel active	 colophony phosphoric acid zinc chloride	 fume 9.3.1. Fire 9.3.4 fume 9.3.1 fume, skin irritation 9.3.1	



Table 13.1 Materials and Process Hazards (continued)

Material	Containment (Notes 7,8)	Hazards To Be Dealt With	Remarks
Steel types			
all	Fe	*fume	Note 5, 6
austenitic manganese	Mn	*fume	Note 5, 6
wear resistant	Mn, Ni, Cr, Mo	*fume	Note 5, 6
cryogenic steels (9% Ni)	Ni	*fume	
leaded steels	Pb	*fume *dust fire and explosion	
maraging steels	Ni, Co	*fume *radiation	
stainless steels – 400 series	Cr, Mo	*fume *radiation	
stainless steels – other	Cr, Ni, Mo	*fume	
tool steels (> 5% Cr)	Cr, W, V	*fume	
Submerged arc fluxes	silicates	dust	Note 11
Surface contaminants	organic fume etc.	fume 17.11 fire and explosion 21.3.2	
Surface treatments		mists & vapours	
acid (pickling, paste) solutions	products of	fume, 10.3.1.2	
caustic solutions	decomposition	*fume, skin irritation 9.6	
paint remover	- methylene chloride	fume 17.10..1,10.3.1.4 skin disease 17.11	
see also Degreasing	- phosgene	fume 17.11	
see also Blasting			
Surfacing (hardfacing) consumables Weld Australia Group (refer to Technical Note 4)			
1. Steels	Fe, Mn, Cr, Ni	*fume	Note 5, 6
2. Carbide and complex carbide irons	Cr, Co, W, Mo	*fume	Note 7
3. Tungsten carbide composites	Co, Cr etc.	*fume	
4. Cobalt alloys (Stellites)	Ni, Cr, Cu etc.	*fume	
5. Nickel alloys	Cu, Ni etc.	*fume	
6. Copper alloys			
Titanium plate and sheet	Ti	*radiation	
Titanium powder	Ti	*dust, fire and explosion	

* Key to frequently referenced information:

* fume hazard: see ventilation in Table 17.1 and **Appendix B**
* radiation hazard: open arc welding on bright metal – Chapter 15
* dust fire and explosion: 11.4, 16.3, Table 16.1

Notes:

1. Oxides such as scale or corrosion removed by shot, wire or grit blast cleaning of metals.
2. Non-volatile chromium, nickel and copper in or on metals being welded contribute very little fume relative to: Volatile cadmium, zinc or lead coatings – Any metals in a consumable electrode – Organic coatings on metals being welded. See Section 17.10.
3. Joints between some steels or between steel and nickel alloy or cast iron.
4. See Section 17.10.2
5. SafeWork Australia keeps a database of exposure limits for atmospheric contaminants in Australia[1].
6. Manganese (Mn) compounds in welding fume are currently limited to 1 mg/ m^3 breathing air. Measures to reduce the exposure limits to manganese compounds to 0.1mg/m^3 TWA inhalable and 0.02mg/m^3 TWA respirable will apply from 1st December 2026. It is strongly recommended that respiratory protection be used to minimise the exposure to manganese bearing fumes.
7. Spray powders and wires, covered electrodes, solid and tubular wires.
8. Precautions depend on the matrix composition.
9. Precautions appropriate to the main contaminant given are adequate for bracketed elements also.
10. Meanings of chemical symbols are listed in Appendix D.
11. Agglomerated fluxes contain silicates which are hazardous during handling and recycling. Refer to the manufacturer's Safety Data Sheet (SDS). If doubt exists, refer to a qualified Occupational Hygienist (see www.aioh.org.au).

14. Electric Shock

14.1 Introduction

Although electric arc welding and other operations using electric power can be performed perfectly safely, there are circumstances when there is a substantial risk of electric shock. Precautions against this risk include reading and understanding the manufacturer's welding equipment manual, use of properly maintained and appropriate equipment, correct protective equipment and sound work practices. The severity of electric shock depends on many factors. The consequence may only be an unpleasant experience, but electric shock may also lead to muscular spasms causing a fall from a height or striking injury; and in a few circumstances, death by electrocution. Fatalities have occurred during electric arc welding, even when the equipment is sound, and the victim was of good health. These notes and those in Section 4.10.4 describe precautions necessary to avoid electric shock. Details of personal protective equipment are given in Chapter 19. For further information, refer to Australian Standard AS 1674.2[1] and Weld Australia's Technical Note 22: *Welding electrical safety*.

Before switching on the welding power source, the electrode holder, welding cables, and the welding power source itself should be inspected for signs of damaged insulation or conductive contaminants such as water and metallic particles that may bridge the insulation. If any faults are found, they should be repaired or replaced by a qualified person. Welding cables must not be rolled out to the workpiece with the welding power source switched on.

14.2 Factors Affecting Severity of Electric Shock

The Standard IEC 60479-1[2] describes the effect of current on the human beings and livestock. The severity of an electric shock depends primarily on the magnitude of the voltage applied, the level and type of current (alternating or direct) and the resistance of the body, and any insulation.

Table 14.1 gives average current levels for the various effects. Values may vary considerably, depending on circumstances and individual susceptibility. The table illustrates the greater risk with AC when current levels approach 10mA and the welder may be able to let go.

The risk of electrocution is dependent on a number of factors, including the current path, the touch voltage, the duration of the current flow, the frequency, the degree of moisture on the skin, the surface area of contact, the pressure exerted and the temperature. Whilst the electrical resistance of the human body varies typically from 650Ω to 6500Ω (see IEC 60479-1[2]), it can be reduced to less than 350Ω if the welder is sweaty, which means that electrical outputs from welding power sources can cause potentially hazardous or fatal electric shock. Other resistances in the electric arc-welding circuit, such as insulation and dry protective clothing are required to reduce the risk and severity of electric shock.

With welding power sources (as used for MMAW and GTAW) the OCV (40 to 113 volts) available when the welding power source is switched on is considerably higher than the arc voltage (10 to 35 volts) when the welding power source is welding. It is this open circuit

Table 14.1 The Effect of DC and AC Current Levels on the Human Body

Effect	DC	AC (50Hz)
Threshold of perception	• 2mA	0.5mA RMS
Threshold of "let go"	• No definable threshold of "let go" for DC. Making and breaking of current leads to painful and cramp-like contractions of the muscles.	10mA RMS
Threshold for ventricular fibrillation	• >100mA for shock durations longer than the cardiac cycle	40mA if exposed more than 3 seconds



voltage (OCV) that provides the most risk of an electric shock, and which can kill by electrocution in adverse circumstances. Electric shock is less likely to occur while the arc is operating as the resistance of welding circuit, including the arc, is relatively low, 0.025Ω to 0.25Ω and the voltage is also much lower than the OCV. Electrical currents as low as 40mA AC (40 milliamps) or >100mA DC can provide a fatal electric shock. The most common outcome from a severe electric shock is a condition known as ventricular fibrillation, which is a form of heart failure. Ventricular fibrillation results in the heart ineffectively pumping blood resulting in brain injury then death within a few minutes. Prompt resuscitation[3] may save the victim.

14.3 Electricity Supply to the Welding Power Source and Ancillary Equipment

It is generally well understood that the voltage on the input or primary side of the welding power source is dangerous. The welder must not tamper with the electricity supply for switching, plugging or unplugging the welding power source. Only a competent electrician with knowledge of welding power sources should perform repairs and maintenance to the electrical components of a welding power source. If a number of AC MMAW welding power sources are to be connected to the same workpiece, ensure a competent electrician is requested to connect all welding power sources to the same phase pair and with the same phasing (see Figure 4.3). This will ensure there is no voltage between adjacent electrode holders.

Care must be taken in positioning supply cables to welding plant and ancillary equipment where there is a risk of damage. Electrocution has occurred when a power supply cable rested on an overheated terminal of a power source. The power supply cable insulation melted allowing full mains voltage to contact the work terminal.

To minimise the risk of electrocution from contact with the primary circuit, it is recommended that all welding machines be connected to a power supply protected with operating residual current devices (RCDs), also referred to as earth leakage devices (ELDs) or core balance relays. For example, in a single-phase electrical circuit, these devices will automatically disconnect outlet power when a differential as a small as 30mA is detected between the active and neutral circuit.

AS/NZS 3000[4] requires RCD protection on all single and multiphase circuits up to 32A capacity including where switchboards are altered or replaced. RCDs are also available for higher amperage 3 phase power outlets.

14.4 Risk of Shock and Choice of Welding Process

14.4.1 General

It is generally less well understood that there is also a significant risk of electrocution from the output or secondary side of the welding power source. The risk is dependent on the welding process and the type of welding power source used (see Table 14.2 for typical OCVs). In most cases, a process using direct current (DC) is considered safer than one using alternating current (AC), because the threshold current (voltage ÷ impedance) for ventricular fibrillation is 2 to 3 times greater with DC than AC. The threshold for ventricular fibrillation for sinusoidal AC (15-100 Hz) is taken to be 40mA for exposures greater than 3 seconds (see AS 60479.1: 2010 Clause 5.5, and IEC 60479-1:2018 Clause 5.6[2]).

Another effect is that AC causes muscle spasms, perhaps causing the hand to grip onto the source of the electric shock rather than release it. The threshold of let-go for AC current is taken to be 10mA for adult males and 5mA for the entire population (see AS 60479.1: 2010, Clause 5.4), whereas there is no definable threshold of let-go for DC current (see AS 60479.1[5] and IEC 60479-1[6]).

Whilst the risk of a fatal electrocution is higher with AC welding processes, fatalities arising from electric shocks received from DC welding power sources are also being reported[7,8,9]. In many cases, the cause of death in welders receiving a fatal electric shock is believed to be due to ventricular fibrillation, however, there is some evidence that electric shock also causes other cardiac dysrhythmias and muscle paralysis (e.g. paralysis to breathing muscles and therefore a loss of oxygen to the brain causing death by hypoxia) whilst the current continues to flow[8].

It is important to consider the possibility of changes to the environment or the welders' condition as work progresses. If an environment is classified as Category A or Category B (see AS 1674.2[1]), the environmental conditions must be maintained to ensure there is not a drift towards a welding Category C environment and a higher potential risk to personnel. For this reason, many industrial workplaces are deemed to be Category C at all times to ensure appropriate equipment, personnel and practices are used (see also Section 4.4.3 and Table 4.2).

> **Note***: Weld Australia has published a guidance form to assist accident and incident investigators undertaking investigations on welding electric*

current shock injuries and electrocutions. The guide can be accessed via:

- Technical Guidance Note TGN-SW03 *Welding electrical safety—Electric shock injury and electrocution reporting*
- Technical Guidance Note TGN-SW07 *Health and safety in welding—Guides and forms*
- Technical Note 22 *Welding electrical safety*

14.4.2 Resistance Welding

Resistance welding processes provide minimal hazard to operators as voltages typically range from 4 to 12 V AC and DC – see Chapter 7.

14.4.3 Manual Metal Arc Welding (MMAW), Air Carbon-Arc Gouging

Most electrocutions have occurred with the MMAW process. The Open Circuit Voltage is usually 40 to 113 volts DC or 40 to 80 volts RMS AC with these welding power sources, unless fitted with a hazard-reducing device (HRD). The main risk occurs when changing electrodes, because the electrode is exposed and electrically live whilst in the electrode holder, if the circuit is not isolated. Isolation can mean either:

a) Switching off the welding power source; or,

b) Using an isolation switch, such as an output circuit safety switch as per AS 1674.2; or,

c) A hand-piece switch.

In high risk situations (see Clauses 14.5.2 and 14.6), especially environment Category B (welding without an observer) or Category C, AS 1674.2[1] recommends 0 volts at the electrode holder during electrode changes and whist the welder is repositioning.

14.4.4 Gas Tungsten Arc Welding (GTAW)

GTAW (or *TIG*) has similar OCVs to MMAW, both for AC and DC modes. The welding power source power should be turned off while changing tungsten electrodes. The arc should be struck on the workpiece before placing the tip of the filler-wire in the weld zone; otherwise it is possible to strike against the filler wire. The use of high frequency with GTAW adds another hazard. Although the voltages of the high frequency are very high (2000 to 10000 volts @ >50 kHz), their hazard is relatively low. This is because the response of the human body to these relatively high frequencies. There is reduced risk of ventricular fibrillation because high frequencies track along the skin rather than penetrating the body. The duration of HF pulses is very short. However, HF may damage sensitive electronic devices, such as clamp meters, multimeters, hearing aids and medical implant devices including heart pacemakers and cochlear implants.

14.4.5 Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)

The GMAW (*Mig*) and FCAW processes have a lower risk of electrocution because:

a) OCVs are lower;

b) Only DC is used; and,

c) The power source output is switched at the torch.

Table 14.2 Typical Open Circuit Voltage for Various Processes

Electric Welding Process	Relative Hazard	Open Circuit Voltages	Power Type	Refer Chapter
Resistance	Negligible	4-12	AC & DC.	7
MMAW	Medium	50-100*	AC & DC.	4
GTAW (TIG)	Medium	50-100*	AC & DC.	4
GMAW (MIG/MAG)	Low	15-60	DC	4
FCAW Low	Low	20-60	DC	4
Submerged arc	Low	25-100	AC & DC.	4
Electroslag	Low	30-100	AC & DC.	8
Underwater	Very High	50-80	AC & DC.	26
Air carbon arc	Medium	50-80	AC & DC.	4
Plasma arc cutting	High	100-700	DC	6
Electron beam	Very High	30,000-200,000	DC	8
Laser	High	1,000-40,000	DC	8 & 15
Arc metal spray	High	40-100	DC	11

* Maximum permitted OCV for AC = 80 volts (see Section 14.6)



On some equipment the OCVs can be as high as 70V DC, although OCVs are usually less than 50V DC at the workpiece. Welders and personnel working in the vicinity the GMAW and FCAW processes where wire spools may be exposed should be aware that the wire spool in the wire feed unit will be electrically "live" whilst welding is in progress. All contact with the wire spool must be avoided to minimise the risk of receiving an electric shock.

It is recommended that only fully enclosed wire feeders are used.

14.4.6 Submerged Arc Welding (SAW) and Electroslag Welding (ESW)

SAW and ESW processes both have a low risk of electrocution because the welder is remote from the nozzle. It is important, however, to turn off the power source while changing the electrode wire or assembling or disassembling the equipment.

14.4.7 Plasma Arc Welding (PAW) and Plasma Cutting

The voltage necessary to create a plasma is of the order of 100 to 700 volts. The risk of electrocution is high only if equipment is disassembled with the power on or if it is damaged. It is important to follow practices outlined in Chapter 6 and the manufacturer's instructions.

14.5 Avoiding the Risk of Electrocution in Manual Welding

The work practices that must be followed to prevent a welder being exposed to the electrical hazard of the secondary circuit involve a combination of four strategies. Specifically:

a) Avoiding contact with the electrode;

b) Avoiding contact with the workpiece;

c) Avoiding contact through damaged equipment or poor work practices; and,

d) Eliminating or limiting the OCV.

14.5.1 Preventing Contact with the Electrode

The most fundamental safety requirement is for the welder to avoid bare skin contact with the electrode or live parts of the electrode holder or gun. The electrode is an electrical conductor. During manual metal arc welding, dry welding gloves are required for handling the electrode holder, when inserting a new electrode or to steady its tip during welding. Bare hands, damp or defective gloves should never be used. The electrode holder for manual metal arc welding should preferably be of the IEC 60974-11 Class A type. Class B is only justified if large diameter electrodes beyond the capacity of a Class A electrode holder, are required. Partly used electrodes or stubs of electrodes should never be left in an electrode holder.

14.5.2 Preventing Contact with the Workpiece

Preventing contact with the electrode is regarded as insufficient to guarantee safety. There have been incidents of electrocution reported where there has been accidental contact between the electrode and the face, neck or armpit. Some other precaution is essential; ideally insulation from the workpiece.

All parts of the workpiece have to be regarded as electrically live, and live areas can surround the welder. Use dry leather or fibre mats or cushions and wooden duckboards to prevent direct contact with the work, or any damp surfaces that may be electrically connected to the work. Appropriate clothing (see Section 19.4 and AS/NZS ISO 11611[10]) that provides good coverage insulates the welder from the workpiece provided it is dry. The weaknesses of relying on clothing for insulation are that overalls, leather jackets and denim jeans are often fastened with brass studs, get worn and holed during use, may not provide complete coverage and get damp with perspiration (see Table 4.2).

All parts of the body should be covered. Dry fire-resistant and electrically resistive (see AS/NZS ISO 11611[10]) overalls or shirt and trousers in good condition, insulated boots (undamaged with the steel toe cap not exposed), welding gloves and welding screen are a minimum requirement. Cotton glove liners to absorb perspiration, leather jackets, leggings or kneepads worn as protection from heat from the job, also provide good electric shock protection. When working at a bench, stand on a wooden duckboard. When effective insulation cannot be guaranteed the precautions given in 14.6 should be applied.

> **Note***: Protective clothing for welding personnel conforming with the requirements of AS/NZS ISO 11611[10] may provide limited protection against accidental short-duration contact with the welding circuit in the normal conditions of welding. The level of protection will be reduced if the clothing is contaminated by sweat and other contaminants that adversely affects the resistivity of the fabric. See also Section 19.4 of this Technical Note.*

14.5.3 Avoiding Contact Through Damaged Equipment or Poor Work Practices

The diligence of daily and pre-start inspections (see Section 4.10.5), using safe work practices, equipment maintenance by competent persons and awareness of electrical hazards by welders or other personnel in the vicinity are key factors in prevention of electric shock.

14.5.4 Hazard-reducing Devices

Hazard-reducing devices are used to limit or eliminate the OCV from the welding output circuit or secondary circuit of the welding equipment.

The use of hazard reduction devices (HRDs) such as hand-piece trigger switches and voltage-reducing devices (VRDs) can greatly reduce the exposure of personnel to a hazardous OCV from a welding power source.

14.5.4.1 Voltage reducing devices

Voltage reducing devices (VRDs) are safety enhancements that reduce the potentially hazardous voltages produced by a welding power source. The function of a VRD is to reduce the OCV from up to 113V DC or 113VAC peak or 80V RMS (or 68V AC peak or 48VRMS with an "S" rating on the compliance plate), to a safer, lower level when welding ceases. A VRD or system should automatically reduce the no-load or OCV, to a no-load voltage of:

- 35V for DC and
- 35V peak, 25V RMS for AC

or less, when the resistance of the output circuit exceeds 200 Ohms. Response time for reaching the reduced voltage shall be 0.3 seconds.

VRDs have the following features:

a) When no welding is taking place and the output circuit resistance is high, the voltage is limited. Commercial VRDs reduce the OCV to values ranging from around 12 V, up to the maximum allowable.

> **Note**: *It is worth noting that the no-load voltages of some welding power sources fitted with VRDs are near the upper limits allowable by AS 1674.2*[1].

b) When the electrode is brought in contact with the work, lowering circuit resistance below 200Ω, the full secondary circuit voltage is applied and allows an arc to establish.

c) Full welding voltage is only present while welding is in progress and this significantly reduces the window of opportunity or risk of being exposed to a lethal OCV.

d) It is also important to understand the response time of a VRD and ensure that this is minimal (0.3 seconds).

e) Some VRDs have an intentional delay of some seconds after extinguishing the arc before they reduce the OCV. This is more than enough time for a welder, or other person in contact with the welding circuit, to be electrocuted.

f) When purchasing an external VRD for a welding power source or a power source with in built VRD, select one designed to fail in a safe manner. Failure must not result in unsafe conditions due to lack of protection.

g) VRDs are a popular option for achieving low OCV requirements, especially within a wet or hazardous environment when using a drooping characteristic power source (AC or DC). Whilst most commercial welding power sources now have an integrated VRD in built into the secondary circuit, the user should verify that the VRD is fully functional. Many welding machines come from the manufacturer with the VRD inactive or not connected to function, and therefore require the dealer to activate the VRD prior to delivery to the user.

> **Note**: *Whilst some reduction in the ease of arc striking was experienced with early model VRDs, these have been largely overcome*.

14.5.4.2 Indication of Satisfactory Operation of VRDs

Each VRD shall be provided with a reliable device that indicates that is operating satisfactorily. Where a lamp is used, it must light when the voltage has been reduced. Most of the newer VRD's have two lamps – green when the voltage has been reduced, and red at other times.

14.5.4.3 Hand-piece Switches

Another effective control is to use a switch on the electrode holder to isolate power output from the welding power source. Where an electrode holder (trigger) switch is used as a hazard-reducing device:

a) The voltage of its control circuit shall be not more than DC 35V peak or AC 25V RMS; and

b) Its switching mechanism shall:
   i. Return to the off position, immediately the welder releases pressure on the switch;
   ii. Be easy to hold in the closed position, enabling the welder to carry out normal welding operations, without muscle strain;
   iii. Have a two-stage operation to move to the on position, so that there is a low probability of accidental closure of the switch during any



hazardous operations (for example, changing electrodes); and,

iv. Automatically latch in the off position, on release of pressure by the welder.

Proper functioning of hazard-reducing devices shall not be affected by interference from remote controls, arc-striking devices or arc-stabilizing devices of the welding power source (that is, limits for no-load voltage shall not be exceeded).

Wireless electrode holder (trigger) switched devices are also available that provide wireless control of the power source output, automatically providing 0V output at the electrode holder upon the extinguishing of the arc.

14.6 Assessing the Risk of Electric Shock

Before welding commences, the work area should be assessed, the welding environment classified for risk of electric shock in accordance with AS 1674.2[2].
AS 1674.2 specifies three categories of environments for welding, all based on the risk of contact with the welding circuit and the potential severity of receiving an electric shock. These environment categories are:

(a) **Category A**: the welding environment is dry and the probability of contacting the workpiece is very low (Clause 14.6.1);

(b) **Category B**: the welding environment is dry, and the probability of contact with the workpiece is higher (Clause 14.6.2); and,

(c) **Category C**: the welding environment is either a confined space and/or is damp, and there is a risk of contact with the workpiece (Clause 14.6.3).

It is essential that appropriate control measures be implemented to eliminate (or minimised as far as reasonably practicable) the risk of the welder and any assistants being exposed to electric shock hazards. Importantly, welders should not work alone irrespective of the welding environment classification.

It is important to consider the possibility of changes to the environment or the welders' condition as work progresses. If a welding environment is classified as Category A or Category B, the environmental conditions must be maintained to ensure there is not a drift towards Category C and a higher electric shock risk to personnel. A drift towards a Category C can occur as the day warms up, where preheat is applied or maintained whilst welding, or, the welder's gloves and clothing becomes damp with sweat (see also Chapters 19 and 23).

For this reason, many industrial workplaces are deemed to be Category C at all times to ensure appropriate equipment, personnel and practices are used.

14.6.1 Category A Environment

14.6.1.1 Definition

A welding Category A Environment (Normal Environment in former editions) is a dry environment where there is a low risk of coming in contact with part of the welding circuit as described in AS 1674.2[1]. Category A is an environment where:

a) The risk of an electric shock or electrocution by arc welding is low.

b) Normal work practice is used; and

c) It is not possible for the welder or any other worker to be in contact with the workpiece, in the event of being in contact with a live part of the welding circuit.

If the welder or their gloves or protective clothing dampen with sweat, the environment must be treated as Category C.

14.6.1.2 Classification

In Category A environments, considerable effort is required to insulate the welder and others from the workpiece, such as bench-top welding where the workpiece is small and there is a low risk of the welder becoming part of the circuit; or where both the welder and any assistants are prevented from being in contact with conductive parts. For repetitive operations, such an environment is usually limited to carefully designed workstations, as well as welder training and welding procedure qualification test bays.

14.6.1.3 Control Measures

For welding in AS 1674.2 Category A environments[1] the following apply:

a) The electrode and workpiece must be regarded as electrically live, and, the welder should take care to avoid contact with them. For MMAW and GTAW welding, Weld Australia recommends the use of a VRD (see Section 14.5.4.1) to minimise the risk of electric shock should contact be made with the electrode and/or workpiece.

Notes

1. *A hand piece switch or an inline switch operated by the welder may be used to disconnect power to the electrode holder prior to the welder changing electrodes, or, the power source switched off during electrode changes. This removes the handling of the "live" circuit and therefore eliminates the risk of electric shock.*

2. *Most wire feed processes such as GMAW and FCAW meet this requirement as there is OV DC at welding torch until the welder activates the wire-feed trigger switch.*

b) Welding gloves must be sound, dry and used on both hands while welding or changing electrodes.

c) Welders should wear appropriate dry fireproof clothing that covers the legs and arms, and footwear should be rubber soled and not have bare steel toecaps.

d) Leather cushions, wooden duckboards or other means must be used to insulate the welder from damp concrete floors and any exposed parts of the workpiece.

e) Leads and equipment shall be inspected for damage, and damaged equipment and leads immediately removed from service for repair or discarded (a system of tagging of defective equipment is recommended).

f) The work area shall be kept tidy and free from tangled leads, discarded cut-offs and electrode stubs.

g) The electrode holder or gun should be placed on an insulated surface or within an insulated container, and must not be placed on the workpiece, where it may short circuit.

h) The power shall be turned off and MMAW electrodes and stub ends removed from the electrode holder, before the welder leaves the work area and whenever the leads have to be moved (see also Weld Australia's Technical Note 22).

14.6.2 Category B Environment

14.6.2.1 Definition

AS 1674.2 Category B Environment[2] (Hazardous Environment in former editions) is a dry environment where there is a significant risk of the welder contacting the workpiece or other parts of the welding circuit.

Such an environment may be found where:

a) Freedom from movement is restricted, so that an operator is forced to perform welding in a cramped position (e.g., kneeling, sitting, lying), with physical contact with conductive parts (e.g., the workpiece); or,

b) There is a high risk of accidental or unavoidable contact by the operator with conductive elements, which is not a confined space as defined in AS/NZS 2865[11].

Category B welding environments have the potential to become Category C welding environments without warning. If any of the following occur, the welding environment must be treated as Category C:

(i) the welder is working without a safety observer; or,

(ii) the welder's gloves or protective clothing dampen with sweat; or,

(iii) the welder's assistant's gloves or protective clothing dampen with sweat.

14.6.2.2 Classification

Category B environments (see AS 1674.2:2025 Clause 1.3.6.2[1]) are those with 'increased hazard of electric shock' and include general fabrication activities, large workpieces, steel building structures and on-board ships.

> **WARNING***: When the weather is hot or humid, when high preheat temperatures are employed or when the structure is exposed to the sun, many Category B environments become Category C environments.*

14.6.2.3 Control Measures

Whilst welding in AS 1674.2[1] Category B environments the following apply:

a) Where practicable, convert to a Category A environment. Insulating cushions, sheets, blankets, duckboards and other suitable protection should be used to insulate the welder, if practical.

b) The open-circuit voltage in a Category B environment is limited to 35V DC peak or 35V AC peak and 25V AC RMS, and the standard recommends that if necessary, the power source be fitted with a hazard-reduction device in order to comply with this requirement. Irrespective of this recommendation, Weld Australia recommends that all MMAW/GTAW power sources used in a Category B environment be fitted with a VRD (see Section 14.5.4.1 of this Technical Note).

> **Note***: Power sources complying with AS 60974.1 should have been marked with the letter S in a square on the compliance plate, to indicate its safety in such an environment (see Table 3.2.2). Many AC MMAW power sources, particularly older welding power sources, do not meet this requirement and should not be used in a Category B environment.*

c) Whenever the welder works without an observer, the open circuit voltage shall not exceed 35V DC peak (i.e. the same as in Item 2.3.3(e) for a Category C environment). A HRD may be required. The use of an AC power source (other than for GTAW) is not permitted.



d) The open circuit voltage should be measured, to ensure it is within the specified limits.

e) Where access to the space is restricted, a safety observer, as described in AS 1674.2, is required. These control measures should be included on the hot work permit described in AS 1674.1[12] (see also Weld Australia's Technical Note 22).

f) Where the environment is a confined space, the provisions of both Category C and AS/NZS 2865[11] apply.

In this case, the welder only has to touch the electrode accidentally to get a shock and fatal electrocutions in such circumstance have been reported[13,14]. This can occur by stroking the face with a live electrode, dropping it, or placing it under the armpit. Much work in a workshop can be conducted in a non-hazardous workspace, but if the workpiece is large, or is sitting on a steel plate on the floor, the workspace should be regarded as potentially electrically hazardous and VRDs used when appropriate to limit exposure to hazardous voltages (especially for the MMAW/GTAW welding processes). The workspace is not hazardous if insulating material can be used to prevent contact with the workpiece.

Standing in rubber-soled shoes is not hazardous, but if work is performed while sitting, kneeling or lying on the workpiece it may become hazardous[14]. The hazard can be minimised by lying on leather-covered cushions, wooden duckboards, or similar insulation and through the use of HRDs. It is not sound practice to rely on normal work clothing for insulation, because it is easily holed or moistened with sweat[13,14], and may have metal button or zip closures.

> **Note***: It has been shown in a recent investigation of an electrocution that very low moisture levels, of the order of 5%, were sufficient to reduce the insulation properties of industrial clothing to a point where dangerous currents could pass at welding voltages[15].*

If the workspace is a small space closely confined by conducting elements, then insulation from contact is almost impossible. Such a workplace could be inside a pipe or small vessel. The hazardous environment may or may not be a confined space as defined by AS/NZS 2865[11]. A confined space without an electrically conducting boundary is not electrically hazardous. A room with electrically conductive walls, such as ship's engine room is not a confined space (it is a normal place of work), but it may be electrically hazardous. If the workspace is a confined space then the precautions specified for Category C and those in AS/NZS 2865[11] are mandatory to prevent electric shock, asphyxiation, entanglement with machinery, entrapment or engulfment (refer Table 14.3).

If MMAW (or non-switched GTAW) and allied processes have to be performed in these hazardous environments, a hazard-reducing device (HRD) is recommended[37]. These devices are designed to eliminate OCV or reduce the OCV to safer levels if the circuit resistance exceeds 200Ω. Weld Australia also recommends that a contactor switch that is operated by the welder or observer should be arranged so that there is 0 volts at the electrode holder except when striking the arc and welding. An observer is necessary to operate the contactor switch in restricted spaces.

If the workspace is electrically hazardous, the following additional precautions apply:

(i) If possible, the area must be made non-hazardous by using insulation, in which case it can be treated as a normal environment.

(ii) Before welding, an emergency response plan should be written to cover the eventuality the welder suffers a serious shock and has to be extricated and resuscitated, or indeed for any other risk.

(iii) The welder must not work alone. Someone in the area must be given the task of observing all welders, even if normal duties are acting as a trade's assistant, passing electrodes or tools to the welders as required. The observer must be trained in emergency procedures, particularly how to disconnect the power and obtain help. They should carry a radio or mobile telephone to be able to call for assistance.

(iv) There must be some means of breaking the circuit close to the observer within the electrode (work lead) cable. This should preferably be an in line safety switch for speed of response, or alternatively a twist lock.

> **WARNING***: Removal of the work return clamp to break the circuit is extremely hazardous as it can expose the welder to dangerous open circuit voltages and a high risk of receiving a severe electric shock. It also requires the observer to make contact with the electrical circuit on a component that is usually uninsulated placing the safety observer at risk of receiving a severe electric shock.*

(v) A person trained in resuscitation must be available at the work site.

> **NOTE**: *Following the fatal electrocution of a welder, the Coroner recommended that VRDs be fitted to all welding power sources used in a Category B environment[13]. AS 1674.2[1] incorporated this recommendation in the 2025 edition.*

Welding in hazardous environments where the welder may be exposed to water (e.g. in the splash zone close to the water's edge, rain, or standing in water),



or welding in a hot or humid area when it is impossible to avoid accumulation of perspiration or condensation, must be considered as a Category C environment. Humidity and the resulting dampness arising can be particularly problematic for welders in ambient temperatures warmer than 25°C, and, when the relative humidity is 70% or higher or dew point is ≥19°C.

As many Category B environments become Category C environments without warning, particularly when the weather is hot or humid, when high preheat temperatures are employed or when the weldment is exposed to the sun, it is considered industry best practice to adopt Category C safety requirements at all times when performing welding and related activities.

14.6.3 Category C Environment (formerly *Environment with a High Risk of Electrocution*)

14.6.3.1 Definition

AS 1674.2[1] Category C Environment (*Environment with a high risk of electrocution in former editions*) is an environment where the risk of an electric shock or electrocution by arc welding is greatly increased due to low body impedance of the welder and a significant risk of the welder (or their assistant) contacting the workpiece or other parts of the welding circuit.

Low body impedance is likely in the presence of water, moisture or heat, and particularly where the ambient temperature is above 25°C, or gloves or protective clothing dampens with sweat. In wet, moist, humid or hot locations, increased perspiration levels are likely. Perspiration considerably reduces the skin resistance of the human body, and, the insulating properties of personal protective equipment accessories and clothing. The appropriate controls as determined by the JSEA or risk assessment, must be implemented as for a Category C welding environment.

A dedicated welding safety observer and lower OCV are always required in a Category C environment.

WARNING: *A welding safety observer should not perform any other role if it compromises their primary role as a welding safety observer i.e. to monitor the welder's activity and respond appropriately in an emergency (see AS 1674.2[1]).*

14.6.3.2 Classification

Category C environments include, but are not limited to, coffer dams, trenches, underground mines, in rain, partially submerged areas, splash zones (see also Appendix B of AS 1674.2[1]) and confined spaces[9].

Whilst AS 1674.2 does not define "high humidity", consistent with AS 60974.1[5] and IEC 60974-6[6], relative humidity levels of 50% or higher should be regarded as placing the welder at increased risk of receiving an electric shock due to the potential build-up of moisture and sweat in their protective clothing and gloves. Welders (including their assistants) are likely to experience dampness discomfort and AS 1674.2[2] warns that low body impendence is likely in the presence or moisture or sweat, and are regarded as being at high risk of electric shock particularly where the ambient temperature exceeds 25°C in combination with a relative humidity exceeding 70%, i.e. the dew point is ≥19°C.

Relative humidity and dew point can be monitored via the use of wet and dry thermometers, hygrometers and via smart phone Weather Apps.

NOTES:

1. *It may be possible to derate Category B and Category C environments, where effective control measures are taken to eliminate or reduce the risk (e.g. air conditioning, special insulating clothing).*
2. *High levels of humidity can be typically encountered:*
   a. in coastal regions of Australia or near large bodies of water;
   b. throughout northern areas of Australia during the wet season;
   c. in most areas of Australia in the period before the fall of rain, whilst it is raining and in the hours after rain has fallen.

14.6.3.3 Control Measures

For welding in AS 1674.2[1] Category C environments the following apply:

a) Where it is determined that the welder or welding equipment can become wet from rain, splashing, partial submersion or other external sources, then adequate control measures shall be implemented before welding commences.

b) Every effort shall be made to make the environment as cool as possible to minimise perspiration.

c) A welding safety observer shall be appointed to monitor the welder. The welding safety observer or a third person working close by shall be trained in rescue and emergency procedures. The observer may monitor more than one welder, provided that the welders being monitored can be observed at the same time.

d) Maintenance of welding equipment shall not be undertaken in this environment.

The voltage between the electrode holder and the workpiece while an arc is not present must be 0 volts during electrode changes until the welder is ready to strike the arc. Immediately prior to striking the arc, the



OCV shall not exceed 35V DC peak. For other than the GTAW process, the use of AC power sources is not permitted.

NOTES:

1. *The use of covers to protect from water exposure (e.g., rain or a dripping roof), air-conditioning and frequent changes of clothing (particularly cotton glove liners) should minimise the risk.*
2. *Most equipment for GMAW, FCAW and GTAW complies with this requirement, because the current is switched with a trigger switch.*
3. *For MMAW or GTAW without a trigger switch, or similar processes, such as carbon-arc gouging, the power source may require an additional hazard-reducing device e.g. an in line emergency stop switch in the electrode work lead, that enables the work lead to be de energised by the welding safety observer prior to the welder/welding operator changing the electrode. This removes the handling of the "live" circuit and therefore eliminates the risk of electric shock.*
4. *Further detailed advice may be obtained from Weld Australia's Technical Note 22.*

In these situations, the water or perspiration makes insulation of the welder from the workpiece extremely difficult. There are often large contact areas between the welder's skin and the workpiece and the skin resistance is low. In addition, perspiration-dampened gloves make the risk of contact with the electrode high. The risk of a shock is high and the consequences of one are likely to be serious.

The precautions above are even more important, but the following additional ones also apply:

a) Where possible, every effort should be made to make the environment safer. The use of covers to protect from rain, air conditioning in a hot confined space, or frequent changes of damp clothing (particularly gloves) is encouraged. The frequent changing of cotton liners avoids gloves becoming saturated with perspiration. It may be possible to avoid this situation altogether.

   Note*: Due to the risk of electrocution, a welder should never weld when they are wet or damp. Welding when it is raining should only be undertaken when overhead protection is provided AND the welder can stay dry.*

b) An assistant must closely observe the welder at all times. The assistant must be trained in emergency response, particularly how to isolate the current and call for assistance.

c) Equipment maintenance must not be undertaken in this environment.

The maximum permitted voltage when an arc is not present is 35V DC. Plasma processes should not be used in this environment. To comply with the low OCV, some hazard protection device is required for the MMAW, air-arc gouging and GTAW processes. This can be a switch, such as a trigger switch or remote control transmitter, on the hand piece operated by the welder. GMAW, FCAW and most GTAW are conducted with such a switch, and it is possible to use a switch on MMAW or arc gouging torches. Where a switching device is used, the device should meet the following requirements:

i) The voltage of the control circuit or remote-control device should not exceed 35V DC or 25V RMS AC; and

ii) The switching system should:

   I. Switch the output circuit of the welding power source to the OFF position, immediately the welder releases pressure on the switch or for auto latching types, when the arc is broken;
   II. Be easy to hold in position, enabling the welder to carry out normal welding operations. Some devices auto latch when there is a welding current present and do not require constant pressure on the switch;
   III. For MMAW and carbon-arc gouging have a two-stage operation to move to the ON position, so that there is a low probability of accidental activation of the secondary circuit during any hazardous operations (for example, changing electrodes).
   IV. Automatically latch in the OFF position, on release of pressure by the welder.

An alternative solution is to use a contactor switch operated by the welder or safety observer to disconnect power to the electrode holder during electrode changes.

GMAW and FCAW welding power sources comply with the restriction on maximum OCV because they are switched, and they operate with low OCV DC. There is no benefit in fitting VRDs to these welding power sources.

AC welding power sources should not be used in a hazardous environment or an environment with a high risk of electrocution. The use of DC welding power sources in place of AC significantly reduces this risk.

Note: *For environments with an increased risk of electric shock, Canadian Standard CSA W117.2-19[16] requires the use of a HRD to either:*

1. *Isolate the welder from the power source during MMAW electrode changes i.e. 0V at the electrode holder; or,*
2. *Use a VRD with 12VDC maximum output at the electrode holder.*

14.7 Hazard Reducing Devices (HRDs) and In-line Switches

If MMAW and allied processes have to be performed in electrically hazardous environments, a HRD is recommended. The function of a HRD is, when not welding, to eliminate the OCV or reduce the OCV to a safe level. If a VRD is used the maximum OCV is 25V RMS for AC or 35V ripple free for DC output welding power sources. In the case of a VRD, when the electrode is brought in contact with the job, lowering the circuit resistance below 200Ω, the full secondary voltage is applied allowing the arc to establish.
It is important that operators are trained in the function of a VRD and are aware of the indications that the VRD is working correctly. If the VRD fails to operate correctly then the welding power source should be designed to reduce the open circuit voltage to less than 25V AC or 35V DC i.e. fail-to-safe.

> **Note***: A number of welding power source suppliers offer VRDs that are claimed to be "fail-to-safe". Weld Australia recommends that operators of welding power sources fitted with VRDs seek written confirmation from their suppliers attesting that they are fail-to-safe. This usually requires an independently verified Failure Modes, Effects, and Criticality Analysis (FMECA).*

In the case of a handpiece switch type HRD, the full open circuit voltage of the power source is applied, for a maximum period of two seconds, to enable striking of the electrode and initiation of an arc. On breaking the arc, the output voltage is reduced to zero within 300 milliseconds.

It must be emphasised that HRDs do not protect the welder and others in the vicinity of welding in all situations, but they significantly reduce the risk of electric shock and electrocution by:

- Reducing the periods that full OCV is present, and
- Limiting the time that full OCV is applied both before and after a welding arc is established.

In high risk environments, a contactor switch that is operated by the welder or welding safety observer may also be required to be operated in conjunction with any VRD or other HRD. Such a switch should be arranged so that the welding current is cut off except when striking the arc for welding. An observer is necessary to operate the contactor switch in confined spaces. The use of contactor switches is subject to human error, discipline and response times (a person can be electrocuted in less than 1 second).

To minimise the risk of electrocution of welders, many Australian companies now require their worksite to be considered as a Category C work site at all times. It is a requirement on their work site that:

a) All welding be undertaken using DC welding power sources; and,

b) The power source be fitted with an operating VRD; and,

c) An in-line contactor switch operated by the welder or observer is used to ensure 0V at the electrode holder whilst the welder is not welding e.g. when changing electrodes or repositioning themselves.

Table 14.3 Critical Open Circuit Voltages (see AS 1674.2[1])

Environment	Maximum OCV – DC		Maximum OCV – AC	
	Working with an Observer	Working without an Observer	Working with an Observer	Working without an Observer
Non Electrically Hazardous AS 1674.2 Category A	113V		113V peak or 80V RMS	
Electrically Hazardous (dry) AS 1674.2 Category B	35V	35V	35V peak and 25V RMS	Not permitted
Electrically Hazardous (damp/ wet) AS 1674.2 Category C	35V	Not permitted	GTAW: 35V peak, 15V RMS MMAW: Not permitted Air-carbon arc: Not permitted	Not permitted

NOTE: Power sources compliant with AS 60974.1[1] or IEC 60974.1[17] marked with the letter S in a square on the compliance plate may have an OCV of up to 113C DC and 68VAC peak and 48V RMS until the VRD is activated. AC power sources without the "S" marking may have an OCV of 113V AC peak and 80V RMS until the VRD is activated.



This combination approach is consistent with the recommendations of Canadian Standard CSA W117.2-19[11] in high electrocution risk environments.

> **Note***: In severe maintenance welding environments, e.g. in humid high salt environments, where there is an increased risk of electric shock due to the lower surface resistance of the welder's body, it is recommended that the no load OCV voltage should be 12 volts or less and the VRD trigger resistance be less than 100Ω.*

14.8 Multiple Welding Power Sources

Dangerous voltages may occur between electrode holders if two or more welding power sources are connected to the same workpiece. This can happen with DC welding power sources if one welding power source is connected DC- and the other DC+. In this case a voltage of twice the OCV (up to 226V DC) may occur between the two electrode holders.

A more dangerous situation can also occur if two AC welding power sources are connected to different phases of the mains, or with their connections opposed. In this case the voltage between the two electrodes is either 1.73 or 2 times that of the individual welding power sources (up to 160V AC).

a) Ensure that the terminal on each welding power source marked "Electrode" is connected to the electrode and not the work piece, and vice versa.

b) Check the voltage between adjacent electrode holders,

c) Do not site two electrode cables close to one another unless there is no voltage between the holders.

d) Ensure multiple AC welding power sources are installed by a competent electrician and connected in phase.

Refer to AS 1674.2:2025[1] Clause 4.4 *Connecting Multiple Power Sources to a Common Workpiece*.

14.9 Rescue of Victims

Rescue plans should be developed and rehearsed. All persons who work near or assist in, welding operations should be familiar with rescue procedures including the principles of DRSABCD (Danger, Response, Send for help, Airway, Breathing, CPR, Defibrillation). Basic actions are:

a) *Act Quickly*: A few seconds delay in rescue may have serious consequences but take care to avoid becoming another victim.

b) *Isolate*: Always isolate power. It may not be possible to determine if the victim is in contact with the conductor and direct contact with the victim may result in a shock to the rescuer. Switch off the electrical supply and pull out the plug if at all possible. If this is not possible, the rescuer must be adequately insulated. Do not attempt to kick the casualty clear.

c) *Rescuer Insulation*: If the victim cannot be isolated, adequate insulation for the rescuer includes dry rubber gloves, dry cloth or dry timber without metal attachments. Releasing the victim may require the use of great force if the conductor is still live. Special care in releasing the victim is required if working above ground level to prevent a subsequent fall.

d) *Confined Spaces*: Extra insulation for rescuers operating in confined space situations is a necessary precaution as the surrounding may be electrically alive.

e) *Basic Life Support*: If breathing has stopped or cardiac arrest has occurred, commence resuscitation as quickly as possible. If the casualty is unconscious, treat as if unconsciousness is from any other cause. Send for an ambulance and/or medical assistance urgently. All persons sustaining an electric shock, irrespective of the severity, should be medically examined before returning to work as the effects of electric shock can be delayed, including internal burns along the current path, organ failure, and death.

f) *Further Precautions*: Ensure that the circumstances of the accident are investigated, and that no person touches any conductor until it is declared safe by a qualified authority.

14.10 Welding Electrical Safety Industry Best Practice

A summary of welding electrical safety best practice can be found within the pop-out guide at the end of this Chapter (see also Section 4.10.5 of this Technical Note). It was developed by a number of companies following a fatal electric shock received by a welder[14] and has since been widely accepted.

In addition to the recommendations within this pop-out guide, other companies have implemented more extensive requirements, particularly in high risk environments such as underground mines for example where high humidity levels, general dampness and water flows can be encountered. Aside from requiring the welding power source to be operated only from RCD protected electrical circuits, an example of such MMAW welding power source specifications include:

a) Armoured power cable from the power source to the 240VAC (or 415VAC) input power plug.

b) Power plug to be a screw type fitting to limit the ability for accidently removal and contact with live conductor parts.

c) Power source output to be DC only with active VRD limiting output to 12DC or less.

d) Deadman switch to be fitted to electrode holder to ensure that there is 0V output available at the holder whilst electrodes are being changed.

Welding power sources are commercially available pre fitted with such options and similarly, existing welding machines with a VRD compliant with the 12VDC output limit can be retro fitted with the heavy duty armoured power cable, screw-type power plug, and dead-man switch fitted to the electrode holder.

> **Note***: After-market wireless dead-man switch devices are also commercially available and can be retrofitted to most MMAW power sources.*

Until such times that fabricators can replace their older power sources with safer and more power-efficient alternatives, there are actions open to the fabricator at minimal cost that will reduce the risk of their welders suffering an electric shock. Specifically:

1. All welding power sources should be fed from an RCD protected power supply. RCDs are mandatory on all new or modified switchboards for circuits up to 32A including 3 phase systems. Higher amperage RCDs are readily available.
2. External VRDs are available commercially and these should be fitted to older power sources where possible.
3. Where fitment of an VRD is not feasible, ensure 0 volts at the electrode holder whilst changing electrodes. This can be achieved by:
   a. Fitting an inline switch to the work lead to be operated by the welder or safety observer; or
   b. Using an electrode holder with a functional dead-man trigger switch.

Critically, these older power sources must never be used in a Category C environment unless compliant with AS 1674.2[1] Category C requirements. Fabricators should be vigilant in that Category B environments can become Category C without warning and therefore need to ensure that their welders' clothes, gloves and PPE remains dry and electrically non-conductive at all times. See also the pop-out guides at the end of this Chapter.

14.11 Additional Guidance

Refer to Weld Australia's Technical Note 22 *Welding Electrical Safety* for further guidance.

14.12 References

1. Standards Australia, AS 1674.2, *Safety in welding and allied processes Part 2: Electrical*
2. International Electrotechnical Commission, IEC 60479-1 *Effects of current on human beings and livestock Part 1: General aspects*
3. *Occupational First Aid*, Authorised Manual of the St John Ambulance Association in Australia (effect of electric current on the human body)
4. Standards Australia, AS/NZS 3000, *Electrical installations (known as the Australian/New Zealand Wiring Rules)*
5. Standards Australia, AS 60974.1, *Arc welding equipment Part 1: Welding power sources - (IEC 60974-1:2017, MOD)*
6. International Electrotechnical Commission, IEC 60974-6, *Arc welding equipment Part 6: Limited duty portable arc welding and allied process power sources*
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10. Standards Australia, AS/NZS ISO 11611, *Protective clothing for use in welding and allied processes*
11. Standards Australia, AS/NZS 2865, *Confined spaces*
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14. Industrial Court of NSW, Inspector Mulder v South Coast Equipment Pty Ltd, 2007
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Welding and Minimising the Risk of Electrocution: Industry Best Practice

Introduction
Unless a welder can be isolated from the power source, they can be at risk of receiving an electric shock. Power for an electric shock can come from either the mains-powered primary circuit including input cables, or, from contact with the secondary output circuit. Devices are available to reduce the risks of receiving a fatal electric shock up to and including isolation of the welder from the circuit.

Minimising the Risk of Electrocution from the Primary Power Circuit
All power sources should have their covers removed by a qualified electrician at least on an annual basis to remove dust and other conductive contaminants within, verify all connections and cables are in good condition, any VRD within is functioning correctly, and the power source is safe for ongoing use. Mobile welding power sources should be inspected more frequently, at least on a quarterly (3-monthly) basis.

Connection to mains power via a residual current detector or RCD (also referred to as a core-balance relay or earth-leakage device (ELD)) may reduce the consequence of electric shock in the event of a power supply fault, and are highly recommended for all welding power sources. Note that AS/NZS 3000 requires that RCDs be fitted to all single and 3 phase circuits of up to 32A capacity (higher amperage RCDs are available).

Prior to use, all welding power sources should be subjected to a pre-start safety inspection including verifying that all plugs, cables and switches are in good condition and in working order. Damaged or defective equipment must not be used.

Minimising the Risk of Electrocution from the Secondary Circuit
As the secondary voltage available at the power source outlet produces a voltage capable of inflicting a fatal electric shock, wherever possible, the welder should be isolated or insulated from direct contact with the secondary or output circuit of the welding power source. This can be achieved by:

a) The welder standing on wooden duckboards or rubber insulating mats, and or wearing rubber soled safety boots in good condition;
b) If required to kneel or lie on the workpiece, use a fibreglass or similar insulating mat to work off or lean on to avoid direct contact with the workpiece;
c) Wear clothing and gloves suitable for welding i.e. hole-free and dry. Clothing and PPE that dampens from perspiration, sweat, or water/moisture exposure must be replaced with dry clothing and dry PPE. Welders working at ambient temperatures higher than 25°C in humid conditions, especially ≥70% relative humidity or dew point ≥19°C, are particularly at risk. These humid conditions should be managed as a Category C environment (see AS 1674.2).

If MMAW, GTAW, air-carbon arc and allied constant current processes have to be utilised, use hazard reducing devices (HRDs) to reduce the OCV to a safe level, and eliminate the open circuit voltage (OCV) during electrode changes and repositioning of the welder to eliminate risk of electric shock.

(i) For cool and dry (low humidity) Category A or Category B environments, the maximum OCV should be limited to 25V RMS for AC or 35V ripple free for DC output welding power sources. A VRD may be required.
(ii) For warm/hot or humid Category B or higher risk Category C environments, Weld Australia recommends that the OCV not exceed 12V DC, and use of an additional HRD such as an inline switch operated by the welder or a welding safety person to disconnect power to the electrode holder prior to the welder changing electrodes. This removes the handling of the “live” circuit and therefore eliminates the risk of electric shock. AC power sources should not be used in Category C environments.

Note*: Most wire feed processes such as GMAW and FCAW meet Category C requirements as there is OV DC at the welding torch until the welder activates the wire-feed trigger switch.*

Where a number of welding power sources are used in close proximity, especially on the same workpiece, all AC MMAW power sources must be connected to the same phase pair and with the same phasing, and, for DC power sources, all welders must use the same polarity. Phasing and polarity faults can lead to OCVs between electrode holders being double the permitted levels and placing the welder(s) at a high risk of receiving a severe (or fatal) electric shock.

Welding and Minimising the Risk of Electrocution: Use of Older Power Sources

Introduction
Unless a welder can be isolated from the power source, they can be at risk of receiving an electric shock. Power for an electric shock can come from either the mains-powered primary circuit including input cables, or, from contact with the secondary output circuit. Devices are available to reduce the risks of receiving a fatal electric shock up to and including isolation of the welder from the circuit.

Minimising the Risk of Electrocution from the Primary Power Circuit
All power sources should have their covers removed by a qualified electrician at least on an annual basis to remove dust and other conductive contaminants within, verify all connections and cables are in good condition, any VRD within is functioning correctly, and the power source is safe for ongoing use. Mobile welding power sources should be inspected more frequently, at least on a quarterly (3-monthly) basis.

Connection to mains power via a residual current detector or RCD (also referred to as a core-balance relay or earth-leakage device (ELD)) may reduce the consequence of electric shock in the event of a power supply fault, and are highly recommended for all welding power sources. Note that AS/NZS 3000 requires that RCDs be fitted to all single and 3 phase circuits of up to 32A capacity (higher amperage RCDs are available).

Prior to use, all welding power sources should be subjected to a pre-start safety inspection including verifying that all plugs, cables and switches are in good condition and in working order. Damaged or defective equipment must not be used.

Minimising the Risk of Electrocution from the Secondary Circuit
As the secondary voltage available at the power source outlet produces a voltage capable of inflicting a fatal electric shock, wherever possible, the welder should be isolated or insulated from direct contact with the secondary or output circuit of the welding power source. This can be achieved by:

a) The welder standing on wooden duckboards or rubber insulating mats, and or wearing rubber soled safety boots in good condition;

b) If required to kneel or lie on the workpiece, use a fibreglass or similar insulating mat to work off or lean on to avoid direct contact with the workpiece;

c) Wear clothing and gloves suitable for welding i.e. hole-free and dry. Clothing and PPE that dampens from perspiration, sweat, or water/moisture exposure must be replaced with dry clothing and dry PPE. Welders working at ambient temperatures higher than 25°C in humid conditions, especially ≥70% relative humidity or dew point ≥19°C, are particularly at risk. These humid conditions should be managed as a Category C environment (see AS 1674.2).

If MMAW, GTAW, air-carbon arc and allied constant current processes have to be utilised, the use of hazard reducing devices (HRDs) is recommended to either eliminate the open circuit voltage (OCV) or reduce the OCV to a safe level.

Until such times that fabricators can replace their older power sources with safer and more power efficient alternatives, there are actions open to the fabricator at minimal cost that will reduce the risk of their welders suffering an electric shock. Specifically:

1. External VRDs are available commercially and these should be fitted to older power sources where possible.
2. Ensure 0 volts at the electrode holder whilst changing electrodes or the welder is repositioning. This can be achieved by:
   (i) Fitting an inline switch to the work lead to be operated by the welder or safety observer; or,
   (ii) Using an electrode holder with a functional dead-man trigger switch.

Notes:
1. *Older power sources must never be used in a Category C environment unless compliant with AS 1674.2 Category C requirements. AC power sources should not be used in Category C environments.*
2. *Category B environments can become Category C without warning and fabricators must ensure that their welders' clothes, gloves and PPE remain dry and electrically non-conductive at all times.*
3. *Most wire feed processes such as GMAW and FCAW meet Category C requirements as there is OV DC at the welding torch until the welder activates the wire-feed trigger switch.*

Where a number of welding power sources are used in close proximity, especially on the same workpiece, all AC MMAW power sources must be connected to the same phase pair and with the same phasing, and, for DC power sources, all welders must use the same polarity. Phasing and polarity faults can lead to OCVs between electrode holders being double the permitted levels and placing the welder(s) at a high risk of receiving a severe (or fatal) electric shock.



15. Arc, Flame and Laser Radiation

15.1 Radiation (Non-Ionising) and its Effects

Three types of non-ionising radiation (NIR) are emitted by electric arcs, plasma arc processes and laser processes, these being ultraviolet, visible and infrared[16,17,18]. The last two types are also emitted from flames in gas welding. Over exposure to each of these types of radiation can cause damage or discomfort to the eyes or skin.

It is important also to note that:

a) Visible and infrared radiation is emitted from hot work in flame cutting.

b) All three radiations can be reflected (see Section 15.2).

c) Radiofrequency radiation is another form of radiation associated with GTAW. This type of radiation does not require the wearing of special clothing.

d) Increasing distance from a welding arc reduces the intensity as the inverse of the distance squared (see AS/NZS 1336[1]).

e) Industrial LASER beams are usually highly collimated – hence divergence with distance is minimal and safe distances may be in the order of kilometres!

15.1.1 Ultraviolet Radiation (UV)

Brief exposure to this radiation can produce an inflammation to the cornea of the eye and produces a condition commonly known as "arc eye". The severity of injury depends upon factors such as wavelength, exposure time, radiation intensity, distance from the source and sensitivity of the individual (AS/NZS 1336[1]). Thus, in a given occupational situation, some may develop arc eye, others not. The symptoms do not appear until several hours after exposure. Pain, watering of eyes and photophobia (marked intolerance to light) occur. Although severe short-term discomfort occurs, generally there is no permanent damage.

Ultraviolet Radiation and the Risk of Cancer

Introduction
In March 2017, the International Agency for Research on Cancer (IARC) evaluated ultraviolet light from arc welding and classified it as *Carcinogenic to Humans* (Group 1). Their assessment was subsequently published in IARC's Monograph 118 in July 2018.

The IARC assessment of data relating to welder's exposure to ultraviolet radiation has confirmed an increased risk of skin cancers and ocular (eye) cancers. The classification of ultraviolet light from arc welding as *Carcinogenic to Humans* (Group 1) is consistent with previous evaluations of ultraviolet radiation as a human carcinogen published in Monograph 100D in 2012.

Recommendations
In addition to and in support of any control measures recommended by the Australian workplace safety regulators, Weld Australia recommends members ensure welders avoid all direct exposure to ultraviolet radiation from arc welding processes. Recommended control options include:

1. Wearing of approved protective clothing specifically designed for welding (see AS/NZS ISO 11611), and, covering all exposed areas of the skin with clothing that incorporates a high UPF rating (see AS/NZS 4399).
2. Use of suitable darkened eye filters (or auto darkening face shields) e.g. conforming with AS/NZS 1338.1 or AS/NZS 16321.
3. Regular application of sunscreen with a high SPF factor (see AS/NZS 2604) in conformance with the manufacturer's instructions is recommended to reduce the adverse effects of UV on exposed skin.

Whilst exposure of bare skin to UV radiation produces an effect similar to severe sunburn, it has now been established that long term exposure to UV radiation from welding can cause skin cancer[2,3] and ocular cancer[3].

Welders and those working nearby should be aware that the use of certain medications can increase the user's sensitivity to UV exposure. Examples of common medications include (but are not limited to) antibiotics, antidepressants, acne medication, some cancer medications, diabetic medication, diuretic medication etc. Personnel exposed to arc welding taking any medication should review the end-user literature published by the manufacturer and/or discuss the potential photosensitisation effects of the medication with their doctor.

In conformance with good industry practice, welders should avoid all direct exposure to ultraviolet radiation from arc welding processes (see also Appendix C and the text box).

15.1.2 Visible Radiation

Exposure to high intensity visible radiation may result in "dazzle" with temporary loss of vision. The intensity of some visible light generated from laser processes may be sufficiently high to cause more than a temporary effect. The visible light, if sufficiently intense, can cause damage to the retina that may not be temporary. Photo-toxicity may contribute to age related macular (skin) degeneration. The photosensitisation effects of some therapeutic drugs can exacerbate this.

15.1.3 Infra-red Radiation (IR)

The main effect of this radiation on tissues is thermal. Fortunately, because the skin has a pain threshold below that of the burn threshold, harmful effects do not usually occur.

The intensity of radiation depends on the process (e.g. open arc or submerged arc, or gas flame) and the energy released at the arc or flame e.g. intensity increases with welding current or electrode size or the size of the flame. Exposure close to the arc or flame requires suitable protection. The special precautions necessary with lasers are given in Section 8.2 and Weld Australia's Technical Guidance Note TGN-SW02 *Laser safety*.

It is important also to realise that:

a) Visible and infrared radiation is emitted from hot work in flame cutting.

b) All three radiations can be reflected (see Section 15.2).

c) Radiofrequency radiation is another form of radiation associated with GTAW. This type of radiation does not require the wearing of special clothing.

d) Some industrial lasers operate in the IR wavelength range. These lasers are not visible but have very high energy densities capable of causing severe injury.

15.2 Personal Protection

Special precautions are required in confined areas to prevent exposure to reflected radiation.

Protection is required for both the eyes and skin. Table 19.2 lists suitable filter shades for goggles and face shields. Chapter 19 indicates general protective requirements.

Protection is also required against indirect radiation. Bright rolled aluminium reflects 90% of incident ultraviolet radiation, while stainless steel reflects about 30%. Plastic curtains also have reflective surfaces and increase the indirect ultraviolet radiation for welders and other personnel.

15.3 Protection of Other Personnel

a) *Adequate protection* should be provided for all personnel within approximately 10 metres of open arc, plasma arc and laser processes. The standard AS/NZS 1336[1] provides guidance on the recommended protection required for exposure to lasers, and, for personnel working within 250 metres of open arc and plasma arc processes. The level of protection required for personnel working in proximity of an open arc or plasma process will depend on:
   i) The welding process;
   ii) The welding amperage;
   iii) The distance from the arc; and,
   iv) The cumulative exposure over an 8 hour working day.

   Note*: AS/NZS 1336 indicates that for a welding process that requires a No10 filter, any person that does not approach within 25m of the arc for less than 2 hours in an 8 hour working is not at risk from the arc.*

b) *Screens* of either a portable or permanent type may be used to screen persons who are required to work within the distances above. These should be non-flammable and permit circulation at floor level and ceiling level. Plastic curtains through which the welding arc may be viewed, by casual



passing personnel, with minimal exposure to UV are also available.

> **Note**: *These screens do not provide sufficient protection for viewing the welding arc, and accordingly, the correctly shaded viewing lens should be used for this purpose – refer AS/NZS 1336*[1].

c) *Portable screens* may be of plastic, fabric or canvas, and should be of light, robust construction and readily movable to encourage maximum usage.

d) *Walls and partitions* should have a 'matt' finish and light colours are permissible provided they are based on suitable pigments. Zinc oxide reflects only 3% of incident ultraviolet radiation and titanium dioxide 7%. Both are therefore suitable pigments.

e) *Colours* of walls and partitions should contribute towards a good general level of illumination.

f) *Site operations* require particular attention to the provision of screens especially where welding may be intermittent or in view of the general public. All unauthorised persons including workers and children should be kept away.

g) *Intermittent arc flashes* can cause distraction and eyestrain.

h) Special precautions are required in confined areas to prevent exposure to reflected radiation.

15.4 Screens and Curtains

Screens and curtains used for shielding the workplace from arc welding should comply with AS/NZS ISO 25980[4] and be selected in accordance with AS/NZS 1336[1] (see 19.5).

Laser-blocking curtains and screens certified to EN 12254[5] and AS/NZS IEC 60825.4[6] are also available. These curtains and screens are designed to protect personnel from reflected and scattered laser radiation, especially during laser cleaning operations where cleaning inside a laser-protective booth may not be reasonably practicable. If used, precautions must be taken to configure the laser-blocking curtains and screens so as to prevent incidental laser radiation exposure beyond the boundaries of the laser-controlled area.

Gaps in protection can typically occur should the protective materials not seal against the floor, above the laser-controlled area or should there be gaps or holes in the protection materials.

> **WARNING**: *Laser-blocking curtains and screens WILL NOT protect personnel from direct exposure to the laser beam (see Section 15.5).*

15.5 Laser Radiation

Specific guidance on safety precautions for laser radiation can be found in AS/NZS IEC 60825.1[7], AS/NZS IEC 60825.14[8], ISO 11553-1[9], ISO 11553-2[10] and AS/NZS ISO 19818.1[11], AS/NZS 1336[1] and AS/NZS 1337.4[12]. Refer also to Weld Australia's Technical Guidance Note TGN-SW02 – *Laser Safety*.

The use of appropriate personal protective equipment including welding gloves, welders clothing, and face shield/goggles designed for laser welding will provide the user with protection from incidental exposure to reflected and scattered laser radiation and radiant heat but will not protect from direct exposure to the laser beam due to its power density.

Users of laser processes for welding, cutting and cleaning should be aware that the focussed beam has an energy density in the order of MW/cm^2 which is sufficient to vaporise most materials directly impacted by the beam. This includes personal protective equipment such as gloves, protective clothing, face shields, and goggles etc. There have been multiple known incidents where operators using hand-held laser welders have misdirected the beam and pierced their glove and finger within.

15.6 Welding, Electromagnetic Radiation and Medical Implants

All welding power sources will generate a level of electromagnetic radiation. In most instances, such radiation is well within safe working limits and special precautions are not required. For wearers of medically implanted devices such as heart pacemakers and cochlear implants, it is important for the wearer to seek specialist advice from the device manufacturer to ascertain the suitability of the device for use in or near strong magnetic fields.

In many instances, the use of welding power sources is unlikely to interfere with the operation of a pacemaker or cochlear implant, however, the exposure to electro-magnetic radiation should be minimised. This can be achieved by:

- Minimising the welding current (preferably to less than 200 amps) and do not weld with currents exceeding 400amps;
- Keep the welding power source away from the work area, and avoid working close to spot welders;

- Keep the work lead and return lead close together, preferably taped together so that any emitted radiation can be minimised;
- Avoid repeated arc starting attempts and wait for at least 10 seconds between attempts when having difficulty arc striking or starting. Pulsating the arc can induce large electro-magnetic emissions which can interfere with the operation of the pacemaker.
- Do not use plasma cutting equipment or GTAW welding equipment with high frequency capabilities.

The following precautions should be followed:

a) The welder should follow the doctor's advice at all times.

b) Ensure that the nominated electrical safety person (see AS 1674.2[13]) is kept fully informed of precautions required when working with welders with pacemakers fitted.

c) Avoid working in confined spaces and in hot, damp or humid environments where the risk of electrocution is high.

d) Should the welder feel unwell, lightheaded, dizzy, or faint, they should cease welding immediately and move away from any welding arcs nearby. The work should be arranged so that should the electrode holder be dropped, electrically live components cannot come into contact with the welder.

e) Welders with pacemakers should not work at heights or on ladders, or in restricted or confined spaces.

f) The use of a power source with an operational voltage reduction device with an OCV not exceeding 12V DC is recommended.

For further information, refer to AS 1674.2[13].

15.7 References

1. Standards Australia, AS/NZS 1336, *Eye and face protection — Guidelines*
2. Blunt J and Balchin N, *Health and safety in welding and cutting*, Pub. Woodhead Publishing, series in Welding and other Joining technologies No. 49, 5th edition 2002
3. International Agency for Cancer Research, *Welding, molybdenum trioxide, and indium tin oxide*, IARC working group on the evaluation of carcinogenic risks to humans, IARC Monograph 118, 2017: Lyon France.
4. Standards Australia, AS/NZS ISO 25980, *Health and safety in welding and allied processes - Transparent welding curtains, strips and screens for arc welding processes*
5. European standard EN 12254, *Laser safety screens for workplaces*
6. Standards Australia, AS/NZS IEC 60825.4, *Safety of laser products Part 4: Laser guards*
7. Standards Australia, AS/NZS IEC 60825.1, *Safety of laser products Part 1: Equipment classification and requirements*
8. Standards Australia, AS/NZS IEC 60825.14, S*afety of laser products Part 14: A user's guide*
9. International Standards Organisation, ISO 11553-1, *Safety of machinery — Laser processing machines Part 1: Laser safety requirements*
10. International Standards Organisation, ISO 11553-2, *Safety of machinery — Laser processing machines Part 2: Safety requirements for hand-held laser processing devices*
11. AS/NZS ISO 19818.1, *Eye and face protection — Protection against laser radiation Part 1: Requirements and test methods*
12. Standards Australia, AS/NZS 1337.4, *Personal eye-protection Part 4: Filters and eye-protectors against laser radiation (laser eye-protectors)*
13. 1Standards Australia, AS 1674.2, *Safety in welding and allied processes Part 2: Electrical*

16. Fire and Explosion Protection

16.1 Introduction

Flame cutting and welding operations are a major cause of industrial fires. Each year losses amounting to several million dollars and loss of life or severe injury result from fires. The required precautions depend largely upon the processes being used and location of the work. This Chapter provides basic guidance in the prevention of fire and explosion when using arc or flame processes.

Protection against fire and explosion should comply with statutory regulations covering fire prevention and with AS 1674.1[1] (see also Chapters 20, 21, 22, 24 and 28).

16.2 Causes of Fire

Fire is a chemical reaction that produces heat, light and energy. For a fire to occur, you need four (4) elements:

a) Fuel (solids, liquids or gases)

b) Heat or an ignition source

c) Oxygen

d) Chemical reaction

This is called the fire tetrahedron as shown in Figure 16.1. Fire is prevented or extinguished by removing one element.

In cutting and welding, the elimination of heat is not possible, therefore whilst most strategies are based on minimising the spread of heat, the main focus is on elimination of fuel and / or oxygen. In many situations elimination of fuels is not practical, and exclusion of all oxygen is also not practical, so close monitoring and careful management are required to prevent incidents. The temperature of the arc or flame used in welding or cutting is sufficient to cause combustion of many materials where direct contact is made. There are, however, many less obvious sources of heat and flammable material including from lasers where the beam is inadequately contained within the laser-controlled area (refer to Section 8.2).

16.2.1 Sparks and Hot Metallic Particles

Flame or arc cutting and gouging processes as well as welding and brazing processes generate sparks and particles at high temperature. Such particles can travel quite long distances whilst retaining sufficient heat to cause combustion as illustrated by Figure 16.2. Even

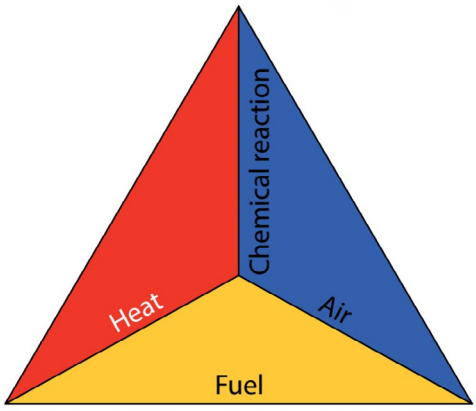


Figure 16.1 The fire tetrahedron

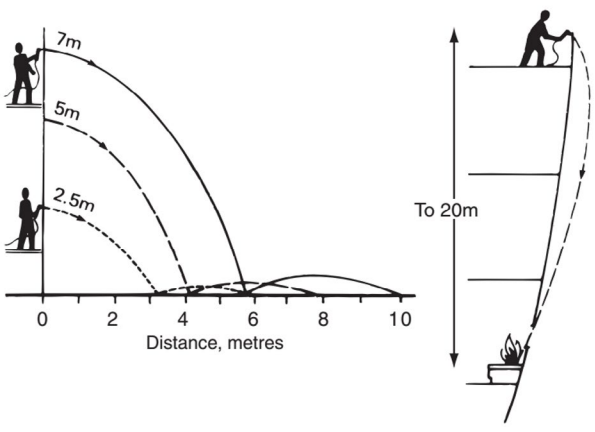


Figure 16.2 Travel distances for hot or molten metal particles in cutting

if fires do not commence immediately, smouldering of combustible matter leading to fire at a later time may result.

Work area cleanliness and constant vigilance are the best way of ensuring hot particles or sparks cannot lodge in fissures, crevices or any combustible material. Recognition of the added dangers of working at heights with respect to the location of combustible materials (see Figure 16.2, refer also to Section 25.6) is important.

16.2.2 Electrode Stubs

Even if they are not at red heat, hot stubs may cause ignition of wood or paper products.

Electrode stubs should be carefully discarded, preferably in a suitable metal storage bin for this purpose.

16.2.3 Oxygen and Fuel Gases

As has been pointed out earlier, oxygen and fuel gases can add appreciably to the risks of fire and/or explosion unless sensible operating procedures and precautions are adopted.

Avoid gas leakages, improper use of oxygen or fuel gases, unsafe equipment and other practices that increase fire risks (see Chapter 5).

16.2.4 Hose Locations

Pressure hosing for gases may be pierced or cut by sharp objects or burned by sparks, hot slag, hot objects or flame unless care is exercised. Chances of accidental damage will lead to greater risks especially if such damage remains unnoticed.

Carefully choose hose locations so that the chances of accidental damage are minimised. Always allow ready access for checking of hoses and any connections.

16.2.5 Gas Cylinders

Heating of any cylinder by an arc or flame may cause an explosion. In the case of oxygen and fuel gas cylinders, a serious fire may also occur.

Flashback into or heating of an acetylene cylinder can cause a cylinder fire that may result in rupture of the adjacent oxygen cylinder (see Section 5.6).

Never permit heating of a gas cylinder by direct or nearby welding, cutting or any other heat generating sources.

16.2.6 Containers and Piping

Special care is required when welding or cutting on or near containers or piping. The welder may not know the contents and the application of heat may be sufficient to cause ignition or explosion. The use of suitable heat shielding should be considered in such cases.

Work permits may be required – the recommendations of Chapters 21, 22 and/or 24 should be strictly observed.

Aerosol cans are often used in hot work areas and are generally poorly controlled. Examples of products used in aerosol cans include anti-spatter, paints, dye penetrant and magnetic particle consumables. Stray arcs, hot metal or spatter can cause incidents with aerosol cans.

16.2.7 Partitions and Walls

Fires have been caused by ignition of partitions and walls, by burning through them or by igniting material on the other side. The latter has for example occurred when welding on bulkheads in ships.

Before welding, check partitions, walls and materials that may be present on the other side for flammability.

16.2.8 Electrical Connections

Poor quality or poorly maintained connections or work clamps may cause sparking or overheating and subsequently cause ignition. It can also increase the risk of a welder receiving a severe electric shock from the welding power source. Attachment of work cables to a structural system, piping etc. may cause such sparking at locations remote from the welding operation.

Ensure all electrical connections are of adequate quality and capacity and select work cable connection points carefully.

16.2.9 Ignition Temperature

Many materials such as wood, wood-based products, paper, synthetic materials, oil and grease soaked materials and some gases such as acetylene have ignition temperatures below about 400°C. Metallic particles, stubs etc. at lower than red heat temperatures can cause fire if they lodge in such materials.

Investigate flammability of all materials including flammable vapours within range of sparks or spatter (Figure 16.2) as well as in the immediate vicinity of cutting, heating or welding.



Flammable vapours from solvents and adhesives typically have low ignition temperatures and are often heavier than air. Unless dispersed with good ventilation practices, fumes can accumulate or spread over large distances.

16.2.10 Flammable Dusts Causing Fire and Explosion

Metallic and non-metallic dusts may be capable of causing fire or explosions. With the exception of surfacing and additive manufacturing processes, these hazards are unusual in most welding locations. Refer to Section 16.3 for additional information.

16.3 Dust and Fires in Explosions

16.3.1 Hazardous Dusts

All organic and many inorganic materials will burn and propagate flame if they are ground finely enough. Table 16.1 gives details of the explosion characteristics of various dusts that may be present in areas where welding could be carried out.

Section 11.4 provides detailed information in respect of causes of dust fires or explosions in metal spraying applications. Details of appropriate preventative and firefighting procedures are given below.

16.3.2 Prevention of Dust Explosions or Fires

The two basic means of prevention are:

a) Prevent formation of explosive mixtures of dust and air or the collection of dusts.

b) Prevent ignition of collected dusts or dust-air mixtures.

The following represent the basic features of preventative actions.

i) Clean up dust accumulation, preferably by the use of vacuum cleaners so that dust dispersal cannot occur. Dust dispersion in the air can produce explosive mixtures.

ii) Store accumulated dusts and explosive or flammable type in safe area free of ignition sources.

iii) Dust collecting equipment is required in buildings with high explosion hazards, e.g. grain elevators, flour handling, wood product processing (saw dust), plastic plants and aluminium dust generating processes.

iv) Ventilation systems should be designed by qualified ventilation engineers (See Section 16.3.3).

v) When cleaning booths, rooms etc., it is necessary to eliminate all ignition sources and keep the ventilation system running.

Table 16.1 Explosion Characteristics of Various Dusts

Type of Dust	Ignition Temperature of Dust Clouds in Air (21% O_2) — C°	Oxygen Percentage Above which Ignition of Dust Clouds by Electric Sparks Occurs (%)
Metals		
Aluminium (atomised)	640	7
Iron	320	10
Magnesium (atomised)	600	3
Zinc	600	10
Plastics		
Polystyrene	490	14
Polyvinyl acetate resin	520	—
Vinyl butyral resin	390	14
Agricultural Products		
Sugar	350	—
Wheat dust	470	—
Wheat flour	380	—
Miscellaneous		
Cellulose	480	13
Coal	610	16
Wood flour	430	17

vi) Ignition sources such as open flames, friction sparks, welding flames, arcs or spatter, static electricity, should not be present or introduced when any hazard exists.

vii) Un-nailed footwear should be used in hazardous dust areas.

viii) Non-sparking tools should be used for all work including cleaning and repair.

ix) Prior to commencing work, run the ventilation system for a short time to remove any potentially dangerous airborne dust or gas that may have arisen through leakage or valves left open.

16.3.3 Ventilation Ducting

Ducting systems almost always accumulate dust at corners, crevices and the like. A wide variety of dusts in air can explode if the correct conditions for ignition exist.

a) All ducting for ventilation requires provision of explosion relief panels and fire doors at bends or other location where accumulation can occur.

b) All equipment such as motors, fans and ducting should be earthed to prevent either electrical short circuits or a build-up of static electricity. Totally enclosed fan-cooled motors are recommended.

c) Separate ducting systems are required for ventilation of metal spraying and blasting areas to prevent the mixing of iron oxide and metal powders.

16.3.4 Fighting Dust Fires

In the case of dust fires:

a) Clear combustibles from the surrounding area as quickly and carefully as possible.

b) Do not disturb burning dust as the dust cloud formed may well result in explosion (see Section 11.4).

The use of a sand dry powder fire extinguisher, or other inert materials to smother dust fires; these are the only suitable means for extinguishing metal dust fires.

In the case of metal dust fires (only):

i) Do not use water or foam as explosion can result due to rapid generation of hydrogen.

In the case of non-metal dust fires (only):

ii) Foam extinguishers or a fog nozzle or finely divided water streams are more effective than hose type water extinguishers as they are less likely to stir up dust.

16.4 Location of Hot Work

16.4.1 Designated Hot Work Area

A designated hot work area should be managed to maintain continuous compliance with the requirements of AS 1674.1[1]. This is typically a part of a workplace where hot-work is routinely undertaken, such as welding bays and fabrication shops and where it is understood that flammable and combustible materials are managed according to standard procedures to manage the risk of fire and explosion.

It is important that designated hot-work areas are routinely inspected and that every effort is made to prevent the introduction of uncontrolled flammable or combustible materials.

16.4.2 Hazardous Areas

A hazardous area is defined in AS 1674.1[1] as an area in which flammable liquids, vapours or gases, combustible liquids, dusts or fibres, or other flammable or explosive substances may be present. Additional guidance can be found in AS 1674.1[1].

The location where welding or cutting operations are being carried out is one of the main factors in determining the risk of fire and explosion. Special care is required when working in unfamiliar areas or areas in which hot work is not generally carried out. Procedures designed to ensure safety in most locations include the following:

a) When welding or cutting or heating (i.e. hot work) is to be carried out in an area not designed for these purposes, all hazards in the location where the work is to be performed must be identified and a risk assessment conducted to ensure that suitable controls are in place to safely manage the hazards identified, with particular emphasis on managing the risks consistent with the hierarchy of controls (see Section 3.2.2). A nominated person must inspect the area and issue a hot-work permit before work commences. This person is defined as a Responsible Officer (RO) in AS 1674.1[1].

   Note*: AS 1674.1 provides an example of a hazardous area checklist form and a typical hot-work permit. There is a more detailed example hot work permit form provided in Appendix E.*

b) Investigate all objects in the area where hot or molten metal or sparks could possibly cause fire or explosion (see Figure 16.2).

c) Remove all objects to be welded or cut to a safe location if this is possible.



d) Fire Hazards that cannot be avoided by relocation of the work must be removed where possible or other suitable safety precautions taken. For example:
   i) Ropes (including access ropes) must be protected from the arc, any flames, sparks, spatter, slag etc that could damage the rope;
   ii) Pipe lagging should be protected to prevent the spread of fire along the lagging;
   iii) Any other materials present in the hot work zone should be identified and flammable materials either protected or removed from the hot work zone.
   iv) Hot work that includes the use of lasers such as hand-held laser welders, laser cutting systems and laser cleaners must ensure that the laser radiation is contained within the laser-controlled area. Laser radiation used for cutting, cleaning and welding is a fire hazard and may be a source of ignition at ranges beyond the intended surface to be processed, especially if used in or near explosive or oxygen enriched atmospheres.

e) Guards that are non-combustible should be used to confine flames, sparks and molten metal to the safe area.

f) For work outdoors, grassed areas should be thoroughly soaked prior to commencement of any welding or cutting operation, a competent firewatcher should be on duty (Section 16.5).

g) High wind conditions can increase the size of the fire danger/ hazard area when working outdoors.

h) HOT WORK must not be undertaken outdoors on any days that have been declared as *TOTAL FIRE BAN* days.

i) Where welding blankets are required to mitigate the risk of fire, only use blankets rated for welding activities and manufactured from materials with a high melting temperature e.g. fibreglass with a silicon or vermiculite coating, or silica vermiculite coated blankets.

> **Note***: Leather welding blankets are only suitable as a fire control method for light duty welding activities.*

16.5 Fire Protection

16.5.1 Fire Extinguishers

Fire extinguishers of the correct type or other suitable fire extinguishing facilities are essential where welding and cutting are being carried out and there is a risk of fire. Reasonable access to such equipment should always be provided and the equipment maintained in good order.

16.5.2 Firewatchers

Notwithstanding the issuing of hot-work permits (Sections 16.4 and 16.7) firewatchers should be available when welding or cutting is being carried out in locations where other than a minor fire could develop. Reasonable precautions should be extended to sometime after operations have ceased where the possibility of smouldering materials leading to later ignition exists.

Additionally, firewatchers are required where any of the following conditions exist:

a) *Presence of combustibles*: If combustible materials (e.g. those used in construction of a building) are closer than 15 metres to the location of the arc or flame.

b) *Openings*: Any wall or floor openings that expose combustible materials within 15 metres of the location of the work. This includes concealed spaces such as in double walls or floors.

c) *Metal walls*: If combustible materials are adjacent to the opposite side of metal walls, partitions etc. and could possibly be ignited by conduction or radiation.

d) *Ship work or segmented containers*: Where direct penetration of sparks, conduction or radiation could cause combustion in an adjacent compartment.

16.5.3 Fire Watch Duties

To be effective, firewatchers should:

a) Be alert to any fire outbreak or hazard;

b) Inspect adjoining compartments, if heat transfer is possible;

c) Take immediate action to combat any outbreak of fire that may occur;

d) Not allow hot work to occur outside the area specified on the hot-work permit;

e) Immediately stop the work and withdraw the hot-work permit, if a hazardous condition is observed;

f) Monitor changes in wind direction e.g. by means of a windsock;

g) Be aware of the need to use eye protection to protect eyes against flashes where hot work involves arc welding, cutting or arc gouging;

h) Be trained in the use of fire extinguishing equipment and ensure adequate firefighting equipment is on hand;

i) Be familiar with location and method of sounding alarms;

j) Remain continually on the job for the duration of the permit unless properly relieved by an authorised person; and,

k) Maintain the watch for at least 30 minutes after work ceases – this greatly increases the chance of detecting smouldering fires.

Firewatchers should not perform other duties. AS 1674.1[1] though does permit the firewatcher to perform additional safety related tasks as defined within AS1674.2[2] and AS/NZS 2865[3] unless these tasks compromise their primary responsibility as a fire watcher. It is important to note that if there are multiple locations where ignition can occur, multiple firewatchers may be required.

16.6 Responsibility for Fire Protection

16.6.1 Responsible Officer

AS 1674.1 defines a responsible officer (RO) as a person having the relevant experience and knowledge of the fire, explosion and toxicity hazards associated with hot work in hazardous areas and who is adequately trained and experienced in the testing procedures and precautions necessary for the elimination (or minimisation if not practicable) of any risk associated with the hazards present as proscribed in WHS regulations. The RO has the responsibility for ensuring safe conditions apply and issuing hot-work permits in all areas where either the risk or consequences of a fire is appreciable. Attention is drawn to the special considerations applicable to welding on containers or piping (Chapters 21 and 22).

16.6.2 Welders and Other Workers

The welder should ensure that all suitable measures have been taken to avoid fire. Caution should always be exercised even where hot-work permits have been obtained.

16.6.3 Firewatchers

See Sections 16.5.2 and 16.5.3.

16.7 Hot-Work Permits

A common method for managing the risk of fire and explosion is to implement a hot-work permit (HWP). Refer AS 1674.1[1].

An example of a hot-work permit is given in Appendix E.

Permits provide a systematic approach to identification of hazards, management of hazards to minimise risk, identification of personnel, accountabilities and actions to be taken to ensure that risks are minimised.

16.7.1 Hazard Identification, Risk Assessment and Risk Management

Hazard identification, risk assessment and implementation of appropriate control measures are essential to developing effective hot-work permits. AS 1674.1[1] contains an example of a hazardous area checklist that can be used assist in the identification of hazards associated with hot work.

16.8 References

1. Standards Australia, AS 1674.1, *Safety in welding and allied processes Part 1: Fire precautions*
2. Standards Australia, AS 1674.2, *Safety in welding and allied processes Part 1: Electrical*
3. Standards Australia, AS/NZS 2865, *Confined spaces*

17. Fume and Ventilation

17.1 Introduction

This Chapter should be read in conjunction with Weld Australia's *Fume Minimisation Guidelines*[1], Appendix C, and Safe Work Australia's code of practice *Welding processes*[2].

In all arc or gas welding and cutting operations hazardous fume is produced. WHS legislation require that these hazards are identified, and controls implemented to ensure that the welder and people work-ing nearby, are protected from exposure to fume from welding and welding-related processes (including thermal cutting, gouging etc).

Studies[1] have shown that under still air conditions exposure limits for particulates and ozone levels can be exceeded in MMAW, GMAW, FCAW, hardfacing, plasma cutting and oxy-fuel cutting. In GTAW, only the exposure limits for ozone were exceeded. Hence it is important to adopt welding practices using appropriate controls to reduce exposure. The components and amount of fume present could affect the comfort and health of all exposed personnel necessitating special precautions.

> **NOTE**: *The referenced studies[1] were based on weld fume generated from welds on carbon-manganese steels. Users should aware that the welding of stainless steels is likely to expose the welder to hexavalent chromium (Cr_{VI}). Refer also to Section 17.5.1.1*

Welding fume is classified as a carcinogen[3] as it is known to have a small but significant risk of causing lung cancer. Based on the hierarchy of controls (Figure 17.1), the following (listed in order of most effective to least effective) are recommended to minimise exposure to welding fume for all personnel:

a) Eliminate the hazard where possible by removing the welder from the source of fume by mechanising or automating the welding process.
b) Substitute a lower fume process or weld procedure. For example:
   (i) Optimise the weld procedure to maximise arc stability, minimise spatter and minimise weld fume production. Arc stability is enhanced through the use of an inverter-based welding power source, and there is limited anecdotal evidence that arc stability for GMAW and FCAW processes is improved through the use of copper-free consumable wires.
   (ii) For the GMAW process, waveform controls are highly effective at reducing weld fume. e.g. Figure 17.3 (up to 80% reduction possible)[3,4].
   (iii) For the GMAW and FCAW (including metal cored FCAW) processes, reduce the CO_2 content of the shielding gas to minimise the amount of fume generated. e.g. Figure 17.3.
c) Use engineering controls to effectively capture welding fume at the source as it is generated and provide a good general ventilation system. A suitable overall general 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 the welding related processes must also be prevented to ensure that co-workers are not exposed to the fume.

   NOTE: *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 (see AS/NZS 21904) prior to being exhausted, preferably outside of the workshop in a non-occupied area.*

d) Consistent with Weld Australia's Fume minimisation guidelines, arrange the work piece so that the welder's head is not in the plume.

   NOTE: *The plume may not be visible to the welder, and depending on the process, nor the observer.*

e) The use of personal protective equipment such as



Weld Fume 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 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.). The following actions, based on the Hierarchy of Control measures, should be considered in the risk assessment:

1. **Elimination**: Where practicable, 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 the use of an inverter-based welding power source, and there is limited anecdotal evidence that arc stability for GMAW and FCAW processes is improved through the use of copper-free consumables.
   (b) For the GMAW process, waveform controls are highly effective at reducing weld fume (up to 80% reduction possible).
   (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 general 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 the 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 (PAPR), especially if the welder's head is in the plume.

A combination of fume control methods that includes higher order controls (e.g. substitution, fume capture systems, good ventilation) supplemented by PPE (e.g. powered air purifying respirators (PAPR) or air-fed helmets etc) may be required to minimise the welder's exposure to weld fume. 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. In addition, if there is a lack of engineering controls in use, it is likely that a regulator will require air monitoring (fume exposure assessment) to be performed by an occupational hygienist. Portable real-time air monitors are also available to assist fabricators to monitor the potential for fume exposure of those working near welding operations. Specialist advice may also be sought from an occupational hygienist e.g. www.aioh.org.au, particularly in the preparation and implementation of the risk assessment, and verifying the application of the controls.

a respirator (e.g. powered air purifying respirator or PAPR) is likely required to be worn by the welder to ensure conformance with the 1mg/m^3 work-place exposure limit, especially if the welder's head is in the plume.

Depending on the welding process and materials being welded, a combination of fume control methods will be required (see Tables 17.1 and 17.2) to control the welder's exposure to welding fume. Additional controls are required if welding stainless steels, hardfacing, or through coatings.

Where doubt exists on control effectiveness, the WHS regulations require that exposure air monitoring is undertaken. In addition, if there is a lack of engineering controls in use, it is likely that a regulator will require air monitoring (welding fume assessment) to be performed by an occupational hygienist.

Portable real-time air monitors are also available to assist fabricators to monitor the potential for fume exposure of those working near welding operations in workshops, however this type of equipment does not replace the requirement for formal exposure monitoring undertaken by an occupational hygienist using a validated sampling methodology.

Further information on fumes and gases in the welding environment has been published by the American Welding Society[6] and the TWI[7].

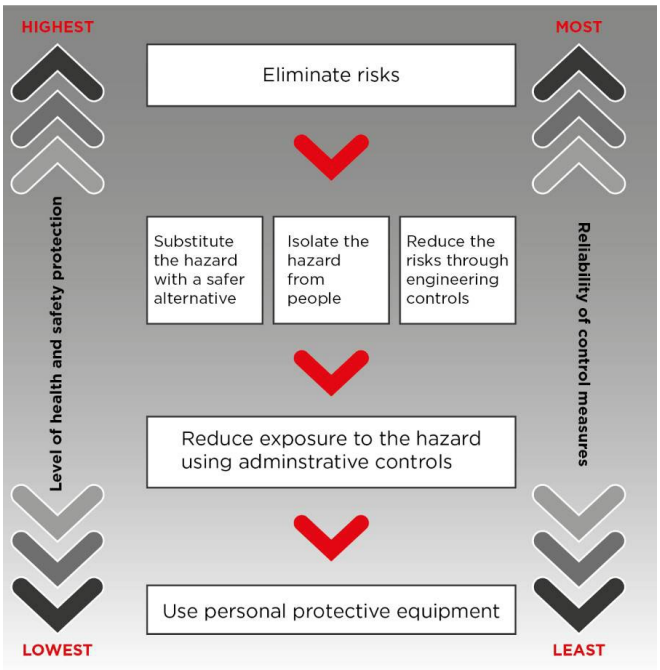


Figure 17.1 **Hierarchy of controls**
Source: Safe Work Australia[8]

17.2 Fume

This general term is used to describe the mixture of:

a) *Airborne particulates*, i.e. solid particles, usually less than 1 μm covering a wide range in size (Figure 17.2). Larger particles (e.g. those generated by tasks such as grinding) settle out relatively quickly, whereas small particles (such as fume) can remain airborne for long periods leading to increased opportunity of inhalation.

b) *Gases* are also generated during welding (e.g. ozone) and can mix with the surrounding air and any shielding gases. Shielding gases may be potentially toxic or asphyxiant where the amount present builds up and excessively lowers the oxygen leve, particularly in a confined space or restricted space with poor ventilation.

17.3 Formation of Fume

Fume results from vaporisation and subsequent condensation of solids/metals melted during the welding process and from the formation of gases by various materials in the weld area.

The composition of the fume therefore depends upon:

a) *Consumables*: electrodes or filler metals, heating or shielding gases and fluxes.

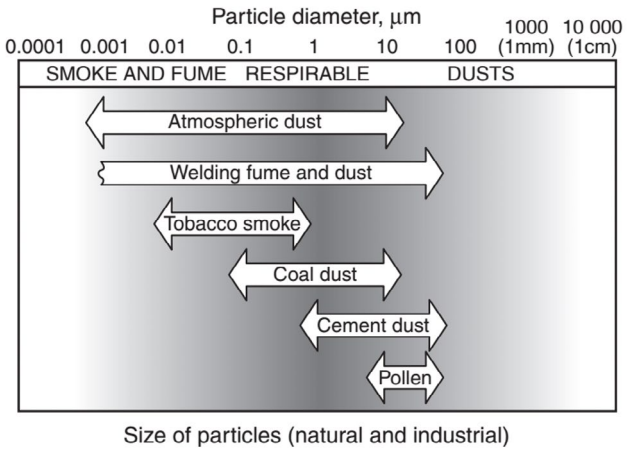


Figure 17.2 **Size of fume particle**[7]

b) *Material*: chemical composition of metal being cut or welded and of any protective coating (e.g. galvanised coating), or paints which contain heavy metals (e.g. lead-based paints) (see Table 13.1 and Section 17.2) or contaminants.

c) *Operating conditions*, e.g. temperature, current.

The amount of fume generated depends on:

i) *Process and thermal conditions*, e.g. amperage, voltage, gas and arc temperatures and heat input that might also vary with the welding position and the degree of skill of the welder.

ii) Consumables.

iii) Materials being welded.

iv) Duration of welding or cutting.

17.4 The Constituents of Welding Fume

Welding fume may have short or long-term irritant, toxic or other effects. The components and levels of fume in the air a welder breathes must be controlled so as to not cause either undue discomfort or a hazard to health.

When considering exposure to welding fume, the total fume concentration as well as the concentration of individual components has to be taken into account. The hazards associated with fume are outlined in Tables 13.1 and 17.2.

17.5 Welding Fume Concentrations

Practical experience supported by fume measurement has shown that fume concentrations will generally be at satisfactory levels when working conditions, including work practices and ventilation, are in accordance with Sections 17.6, 17.7, 17.8 and 17.9, and Tables 17.1 and 17.2. The *Fume Minimisation Guidelines*[1] show however, that under still air conditions exposure limits can be exceeded for a number of welding processes. Accordingly, it is essential that the welder's head be kept out of the plume or personal protective equipment such as an air-fed welding helmet (PAPR) may be required irrespective of the fume management and ventilation conditions applied.

Through the use of occupational hygienists or by purchase of equipment for use by competent persons, companies may, from time to time, monitor breathing zone fume levels in their own workplaces. The exposure monitoring for fumes will determine compliance against the workplace exposure limit and provide information on the effectiveness of the controls. Exposure monitoring may also be conducted for other hazards such as gases or noise.

Comparatively inexpensive equipment, designed for spot testing of a variety of gases, is commercially available. Such measurements have significant limitations with regard to establishing exposure levels. However, they are useful in assessing acutely toxic situations such as ozone, or carbon monoxide and oxides of nitrogen levels in confined spaces. Refer

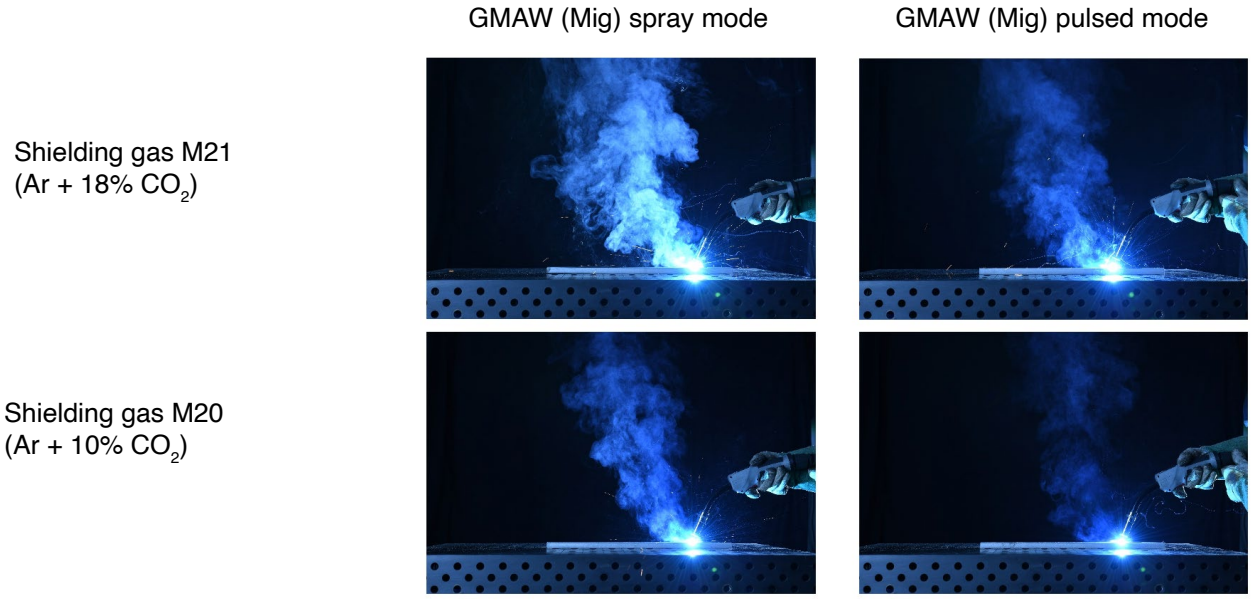


Figure 17.3 Substitution example (*Source: Linde/BOC*)

NOTE: Effect of conventional spray mode welding on the left and pulsed mode welding on the right. Reducing the CO2 content from 18% to 10% can further reduce the level of fume generated (lower photographs) where technically feasible subject to the consumable's classification.



Chapter 20 for details regarding welding in confined spaces.

The concentration of inhalable welding fume including airborne particulates and gases can be sampled for subsequent analysis by using methods described in ISO 10882-1 and ISO 10882-2[9] respectively. Note that AS 3640[10] has been withdrawn.

Measurement of fume is recommended where abnormal or special conditions occur, for example where the recommendations of Tables 17.1 and 17.2 are not practicable. The assistance of a specialist occupational hygienist may be required.

17.5.1 Workplace Exposure Limits

For any given chemical substance or agent there are exposure limits under WHS regulations. The workplace exposure limits (WELs) are defined using a number of terms.

17.5.1.1 Workplace Exposure Limits

From 1st December 2026, Australia will adopt Workplace Exposure Limits (WELs) to replace the Work-place Exposure Standards (WESs). The WELs provides the statutory maximum concentration of a chemi-cal substance or physical agent that a person can be exposed to. WELs are based on an understanding of the known short-term (acute) and long-term (chronic) toxicity of a given chemical substance to humans or animals and the reliability and accuracy of the latest sampling and analytical methods. The WELs are available from Safe Work Australia's website. Changes in information and new research can result in changes to the WES and can modify the risk assessment of substances. New laboratory or instrumental analysis methods can also improve analytical detection limit to determine compliance with lower WEL values. The exposure limits are published in booklet form by Safe Work Australia[11].

The list of exposure limits is updated from time to time, and changes to that list automatically take effect in most jurisdictions. As part of the development of the WELs many were reduced below that specified within the previous Workplace Exposure Standard.

Of particular note, with the introduction of WELs, 33 chemicals have been identified as non-threshold genotoxic carcinogens (NTGCs) due to limited data and the nature of their effects i.e. they are known to cause genetic mutations that may lead to cancer for which no known safe exposure limit can be guaranteed. Where possible they must be eliminated from the workplace, or if not possible, the risks must be minimised to as low as reasonably practicable. An example of an NTGC includes Chromium VI compounds (Cr_{VI}) found within weld fume when welding stainless steels and high chromium alloyed material.

State and territory WHS regulators can provide further information on when changes to exposure standards/ limits take effect in their jurisdiction.

17.5.1.2 Time Weighted Average (TWA)

An eight hour TWA is the maximum average airborne concentration of a substance when calculated over an eight hour working day, for a five day working week. These 8-hour TWA exposure limits may require reduction where work shifts are longer than 8 hours, there is less recovery time between shifts, or if workers work more than 5 days in a week[12]. Guidance on the adjustment of exposure periods for extended shifts is available in the Safe Work Australia publication *Technical Guide: Air monitoring and the workplace exposure limits for airborne contaminants*[13].

17.5.1.3 Short Term Exposure Limit (STEL)

A short-term exposure limit is the time weighted average maximum airborne concentration of a substance calculated over a 15 minute period. Worker exposure must not be higher than the STEL at any time, even if the overall exposure during the workday is less than the TWA exposure limit. Exposures at the STEL must not be longer than 15 minutes and cannot happen more than 4 times per day. There must be at least 60 minutes between each exposure at the STEL.

17.5.1.4 Peak Limitation

A peak limitation is one that may not be exceeded for any period of time, and is applied to irritants and other materials that have immediate effects. The peak limitation is a maximum or peak airborne concentration of a substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

17.5.2 Optimising welding conditions

Rates of fume generation during welding are influenced by a number of factors. These include:

a) Welding process.

b) Arc voltage.

c) Arc current.

d) Shielding method.

e) Shielding gas composition.

f) Electrode type and composition, arc stability.

Welding processes can be optimised to minimise fume generation. The following are known to be particularly effective:

(i) For the GMAW and FCAW processes:
- use a copper-free wire consumable for the GMAW and FCAW (including metal cored FCAW) processes; and
- reduce the CO_2 content of the shielding gas to minimise the amount of fume generated.

(ii) For the GMAW process, waveform controls are highly effective at reducing weld fume.

Arc stability can also be enhanced through the use of inverter-based power sources.

17.6 Exposure Monitoring

17.6.1 General

Welding fume is measured in milligrams per cubic metre (mg/m^3) because it is a weight per cubic metre of air. The gaseous components in the emissions are measured in parts per million (ppm) as gases are molecules and atoms per million parts of air.

Exposure limits apply to all personnel in the workplace, i.e. welders, other workers, customers, visitors, members of the public etc[12]. Importantly, it should be noted that exposure limits are not necessarily protective of all people in the workplace. You should reduce exposure for each worker as much as reasonably practicable, which may be different for workers in different roles depending on which controls can be applied[13].

Exposure monitoring is only required where there is uncertainty as to the extent of welding fume exposure[12,13].



Figure 17.4 Sampler worn by a welder

17.6.2 Personal Sampling of Fume

Occupational hygienists conduct exposure monitoring by sampling the air in the welder's breathing zone. Sampling typically occurs via a sampler with the sampling head being mounted inside the helmet in or near the welder's breathing zone (Figure 17.4). Air is drawn through the sampling head, with a portable pump unit worn on the belt of the welder.

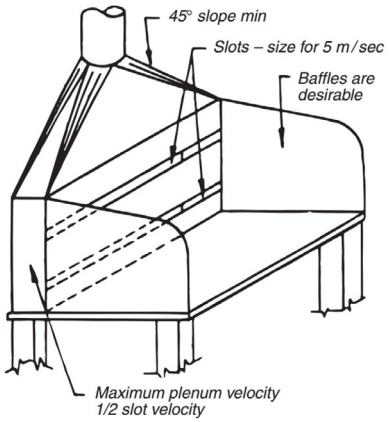
It should be noted that sampling within a PAPR is not usually possible and should be avoided. The reason for this is that as space within the PAPR helmet is limited, the sample head may not sample correctly due to airflow effects, potential sampling inaccuracies and equipment limitations i.e. they interfere with the known (i.e. calibrated) sample capture flow rate used to calculated exposure.

In this case, the sampler must be placed on the welder's lapel.

The sample filter within the sampling head undergoes analysis in the laboratory for general welding fume, and speciation for the various elements within the fume.

Separate to this, a supplementary chemiluminescence sampler (with the head unit head mounted inside the helmet in the breathing zone), can be used for gas detection on a continuous basis.

As an alternative to the chemiluminescence method, gas detector or indicator tubes (e.g. Draeger tubes) can be used as a spot measurement for presence of various gases. The sealed glass tubes are about



Q = 33m^3/lineal m of hood
Hood length = required working space
Bench width = 0.6 m maximum
Duct velocity = 5-15 m/sec
Entry loss = 1.78 slot VP + 0.25 duct VP

Figure 17.5 Welding booth with ventilation

100mm long, and filled with chemical reagents which undergo a colour change when exposed to a specific gas. In this latter case, each tube gives just one, instantaneous, reading which relates to the concentration of gas at that particular time. These tubes cannot be used to determine the average exposure (e.g. TWA) over a period of time nor can they be used to compare to the WEL.

Further information on the monitoring of welding fume can be found at the Breather Freely website https://www.breathefreelyaustralia.org.au/welding/.

For personnel working in coal mines, the Queensland Coal Mines Inspectorate have published a guidance note which provides additional guidance on weld fume including monitoring in their Queensland Guidance Note QGN36[14].

17.7 Control of Fume

To ensure that the concentration of fume and exposure to fume at the welder are within the recommended workplace exposure limits, welding fume can be controlled by:

a) *Work methods*: Mechanising or automating the welding process removes the welder from direct exposure to the welding fume.

b) *Substitution*: Substituting a less dangerous material, process or procedure where this is practicable (see 17.2).

c) *Engineering controls*: Using any of the various types of ventilation to capture fume at the source and disperse as discussed in Section 17.8.

d) *Administrative controls:* Reduce the hazard by adopting good housekeeping and work practices to avoid the unnecessary generation of fume and exposure to it. This includes using manufacturer's operating parameters, avoidance of excessive welding and repair, selection of optimum welding process and procedures. Limiting the time any one welder is exposed to an excessive fume concentration. While the method is not suitable if health effects are possible from short-term exposure, it may be applicable in some circumstances where effects from long-term exposure are of concern. This method of control

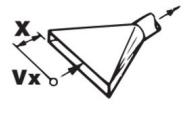
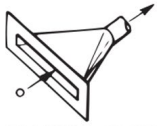
HOOD TYPE	ASPECT RATIO	AIR FLOW RATE
 SLOT	greater than 5 : 1	$Q\ (m^3/s) = 5LXVx$ where L = slot length (m)
 FLANGED SLOT	greater than 5 : 1	$Q\ (m^3/s) = 4LXVx$
	less than 5 : 1 or circular	$Q\ (m^3/s) = (10X^2 + A)Vx$ where A = opening area (m^2)
	less than 5 : 1 or circular	$Q\ (m^3/s) = 0.75(10x^2 + A)Vx$

Figure 17.6 Details of moveable exhaust hoods
(o indicates location of welding arcs)

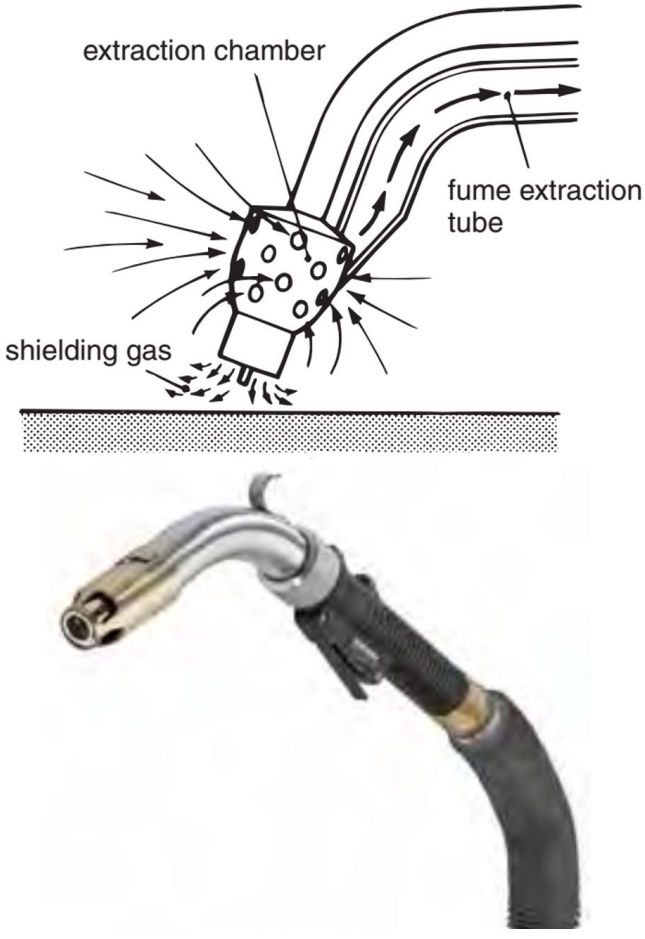


Figure 17.7 Principle of "on gun" fume extraction
(Image courtesy The Lincoln Electric Company)

should only be adopted if other methods are impractical and the welder's head is kept out of the plume.

e) *Respiratory Protection*: Where adequate general and local ventilation cannot be readily adopted, personal respiratory protection will be required (refer to Section 19.6).

Whilst engineering controls such as a combination of local exhaust and general ventilation is the most usual method of fume control, it should be remembered that a combination of methods will be necessary in many situations (see also Appendix C), especially where the welder's head (i.e. breathing zone) is likely to be positioned within the plume.

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

17.8 Ventilation

17.8.1 Necessity for Ventilation

In order to avoid build-up of fume to unacceptable concentrations, both in the general work area and in the local vicinity of the welder, ventilation will be needed to remove, dilute or disperse the fume. Refer to the *Fume Minimisation Guidelines*[1].

17.8.2 Selection of Ventilation Method

In determining the suitability of various ventilation systems, the following factors should be considered:

a) The expected amount and type of fume produced (Section 17.3).

b) The proximity of welding and other operations and their location relative to ventilation.

c) The level of ventilation, natural or mechanical, both for the whole workshop and local to the welding operation. This will depend also on screens, partitions etc. that may restrict free crossflow at the work area.

d) The proximity and height of the welder's breathing zone to the fume source.

17.8.3 Local Exhaust Ventilation

The preferred method of controlling welding fume is to use local exhaust ventilation (i.e. "fume extraction"). This collects fume at its source and directs it away from the general work area. The suction inlet should be as close as possible to the source of fume without affecting the shielding gas, and above the source if possible. In this way the fume is drawn away from the welder.

The main methods are:

a) Fixed local exhaust units to which the components are brought for welding. These fall into two broad categories:
   i) Welding bench of rear slot design to remove fume away from the welder (Figure 17.5).
   ii) Specific purpose ventilation that is advantageous for some production processes. Fixed, appropriately sized local exhaust is provided at critical locations. It may be incorporated into jigs and fixtures. This method can reduce energy requirements and provide improved fume control.

   With any local exhaust, any degree of enclosure will assist in controlling airflow and reduce the effects of cross draughts. This could take the form of a totally enclosed booth and be incorporated in (i) and (ii).

b) Movable exhaust hoods attached to ducting by flexible tubing (preferably at least 150 mm diameter) that allows the welder to re-position the suction inlet as welding proceeds (see Figures 17.6 and 17.8). This method is often used where welding cannot be suitably positioned.

c) *"On gun" fume* extractors of the low volume, high velocity type (Figure 17.7). There are several designs that aim to remove fume close to source. The efficiency of fume extraction is partly dependent on the angle of the welding gun. A balance needs to be struck between the extraction rate of fume and the loss of any externally applied shielding gases. This may mean higher shielding gas consumption. Good ergonomic design is essential for welder acceptance. A thoroughly planned maintenance program has been shown to be essential for these systems to be successful.

d) Downdraught ventilation tables and "push-pull" ventilation systems though, have not proved widely successful in controlling welding fume.

Local exhaust systems must be designed to provide a minimum capture velocity at the fume source of 0.5m/sec away from the welder. This figure should



be verified and recorded at the commissioning of the system and at regular intervals thereafter to ensure continued fume control.

Local exhaust systems should be designed to suit the particular application. For guidance, the following factors are noted, but to obtain maximum efficiency experienced ventilation engineers should be consulted:

I. Where several welding locations require local exhaust facilities, individual flexible ducts are useful, particularly where welding locations are near one another. To reduce energy requirements, flexible ducting with a smooth interior should be utilised and lengths be kept to a minimum.

II. The exhaust system should not unduly disturb the gas shield that protects the pool. In general, air speeds of about 1m/sec over the weld will not cause deleterious weld effects.

III. Exhausted air and fumes should be discharged outdoors in a way that will not cause environmental problems and in a position such that fumes will not be recycled into any building. i.e. must not impact any person in proximity to the discharge point. It is recommended that captured weld fume be filtered prior to being exhausted to atmosphere to remove particulates to at least the equivalent of a filter class efficiency of 95% for all 0.3µm particulates (e.g. EN1822-1 E11)[15].

IV. Air cleaning equipment where toxic or hazardous contaminants including weld fume are collected will require special working procedures to protect maintenance personnel.

V. Recirculation of air is permissible to maintain temperature control provided effective air cleaning equipment is utilised in the system, including for portable extraction systems. The captured fume should:
   A. be filtered using a multi-stage filter system to extract both coarse and fine particulates;
   B. the final filter stage should comply with AS/NZS 21904 W3[16], or preferably HEPA; and,
   C. a carbon filter stage may also be required to remove ozone and other odorous materials

17.8.4 Dilution Ventilation

17.8.4.1 General

Dilution ventilation refers to dilution of contaminated air with uncontaminated air in a general area or building for the purpose of health hazard or nuisance control. Ventilation, and in particular dilution ventilation, is a component in the hierarchy of controls to assist with the management of weld fume exposure, however it is noted that this form of ventilation does not remove the airborne material from a worker's breathing zone, it merely dilutes it. It is important to note that dilution ventilation alone may not be sufficient to protect the welder, particularly if their head is positioned in the plume.

17.8.4.2 Mechanical Dilution Ventiliation

Mechanical dilution ventilation refers to dilution of contaminated air with uncontaminated air being either blown into the workplace or extracted from the workplace by mechanical means such as roof fans or wall exhaust fans.

Successful dilution ventilation depends not only on the correct exhaust volume but also on control of the airflow through the workplace. Careful positioning of air inlets and outlets is required to ensure that only clean air is moved through the workers' breathing zones and that other workers in surrounding areas are not exposed inadvertently.

Some limiting factors of dilution ventilation to be considered are:

a) The quantity of contaminant must not be too great, or the air volume required for dilution will be impractical.

b) The toxicity of the contaminants must be low.

c) The evolution of contaminants must be reasonably uniform.

d) The source of evolution must be such that a system can be designed to protect workers taking into account the constraints regarding the positioning of air inlets and outlets described above.

Applications of mechanical dilution ventilation are listed in Tables 17.1 and 17.2.

17.8.4.3 Engineered Natural Ventilation

Similar in concept to mechanical natural ventilation, engineered natural ventilation uses a combination of convective heat flow and louvres (see also AS 4740) to generate a natural air flow through the workshop so as to draw air from outside the building, across the welder's breathing zone and then rise towards the roof space where it is removed via roof vents, or in some cases, extractive roof fans. Unlike natural ventilation, it is not reliant on wind for air flow.

Engineered natural ventilation within a building is particularly effective at providing good general ventilation when air flow movement can be modelled and building layout adjusted to maximise the required

air movement and appropriate flow pattern where it is needed.

Engineered natural ventilation is gaining in usage, especially where there is pressure to reduce greenhouse gas emissions or existing ventilation systems have proved ineffective or expensive.

17.8.5 Natural Ventilation

Natural ventilation is often considered a form of dilution ventilation supplied by natural air movement. This type of air movement is highly variable whether indoors or out. On some days there will be hardly any air movement at all and consequently little dilution and dispersion of the contaminants. If persons must work at a fixed position in relation to the process, depending on the natural wind direction they may be significantly exposed by working downwind of the fume source.

Natural ventilation is effective at fume control only when:

a) The strength of the wind is constant and sufficient to disperse the emitted fume away from both the welder and other people in the vicinity; and,

b) The wind is a cross-breeze; and,

c) The welder's head is not in the plume; and,

d) The materials being welded are not hazardous or likely to generate hazardous contaminants when welded (refer to the material's SDS sheet).

Gusting or swirling wind, or strong breezes are also ineffective as they create turbulence and remove the weld shielding leaving a porous or poor-quality weld at the very least.

Where the above conditions cannot be met then additional fume controls will be required. Depending on the welding process, this could be as simple as a fan, or more complex including multiple control measures e.g. a fan to disperse the fume and a PAPR where the welder's head is within the plume.

Welders working on outdoor breakdown work where the airflow within the workspace is limited due to local walls, piping, machinery etc, may require local exhaust ventilation supplemented by personal respiratory protection e.g. a PAPR. Refer also to Table 17.1.

17.9 Ventilation for Particular Processes

17.9.1 Gas Welding, Flame Cutting and Gouging Processes

Process – each uses a flame from oxygen-fuel gas mixture that contributes to the fume in proportion to the amount of gas used.

Particulate fume – is mainly metal oxides from the workpiece or filler, in welding, cutting and gouging. Refer also to Section 17.10.

Gases – are mainly carbon dioxide with some oxides of nitrogen and some carbon monoxide.

Precautions and recommendations – see Table 17.1 and Table 13.1.

17.9.2 Manual Metal Arc Welding (MMAW)

Process – the amount of fume and its components depend mainly upon the type of electrode (core-wire and coating), size of the electrode and welding current.

Particulate fume – oxides of iron in welding of steel, alloying elements in the core-wire and compounds of constituents in the coating.

Gases – mainly carbon dioxide and carbon monoxide from electrode coatings together with high ozone and very small amounts of oxides of nitrogen[1].

17.9.3 Flux Cored Arc Welding (FCAW)

Fume and gases – similar to that for manual metal arc welding but generally in greater amounts. May include any additional gas mixtures or fluxing agents used to protect the weld pool.

Due to the relatively high levels of fume generated, there is a greater likelihood of both welders and co workers exposure exceeding the relevant exposure limits unless fume capture and good ventilation is implemented. The use of self-shielded FCAW (especially for hardfacing) is not recommended for welding when indoors. The interaction of the arc with the flux is known to produce carbon monoxide (CO) and carbon dioxide (CO_2).

Precautions and recommendations – see Table 17.1 and Table 13.1, and *Fume Minimisation Guidelines*[1]. Fume levels can be reduced through the use of inverter-based power sources to enhance process stability and in the case of gas-shielded FCAW welding, via the use of a reduced CO_2 shielding gas content (see Section 17.5.2).



17.9.4 Gas Metal Arc Welding (GMAW or ISO *MIG/MAG*)

Process – with spray transfer the amount of particulate fume produced is similar to but higher than that from manual arc welding; less is produced with short-arc (or dip) transfer. Gaseous fume depends mainly on the shielding gas although ozone levels should be considered in aluminium welding. With this process distinction should be made between ferrous and non-ferrous applications in assessing the precautions required.

Due to the levels of fume generated, there is a greater likelihood of both welders and co-workers exposure exceeding the relevant exposure limits unless fume capture and good ventilation is implemented.

Particulate fume – mainly oxides of iron and alloying elements from filler material and the workpiece. Small amounts of copper from copper coated wires but with significant amounts in the welding of copper. Aluminium oxides in aluminium welding.

Gases – mainly from the shielding gases, e.g. carbon monoxide, carbon dioxide, argon, helium. In the welding of aluminium, higher than normal concentrations of ozone may result.

Precautions and recommendations – see Table 17.1 and Table 13.1. and *Fume Minimisation Guidelines*[1]. Fume levels can be minimised through the use of:

- inverter-based power sources to enhance process stability;
- a reduced CO_2 shielding gas content;
- copper-free welding wires;
- waveform control technologies (see Section 17.5.2).

17.9.5 Plasma Arc Welding (PAW) and Cutting

Process – plasma welding can be conveniently subdivided into low current (approx. 0.1A to 15A) and high current (75A to 300A) applications. Low current welding generally does not result in significant fume levels and in the worst situations local exhaust ventilation would be sufficient to remove fume. High current cutting and welding both generate fume levels that are comparable with high amperage gas metal arc welding.

Particulate fume – oxides of constituents in the workpiece and filler metal if used.

Gases – chiefly determined by the plasma gas used but high levels of ozone and oxides of nitrogen may be formed.

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. Water shields and/or underwater cutting eliminates fume.

Precautions and recommendations – see Table 17.1 and Table 13.1. and *Fume Minimisation Guidelines*[1].

17.9.6 Gas Tungsten Arc Welding (GTAW/TIG)

Process – normally a low powered operation with small generation of fume.

> **Note**: *The GTAW process is often used to weld stainless steel. Users should be aware of the potential for Cr_{VI} emissions (a genotoxic carcinogen) within the fume (see Table 17.2).*

Particulate fume – generally levels are quite low compared to manual metal arc welding. Where filler metals are used particulate fume is increased.

Thoriated Tungsten dust – thoriated tungsten electrodes contain approximately 2% thorium. Thorium is slightly radioactive and has a very long half-life. Whilst there are no specific hazards regarding storage, handling or welding use of these electrodes, precautions must be taken when grinding the tungsten tip in preparation for use. Specialised dust extraction equipment should be used when grinding and respiratory protection should be worn by the operator as the dust is hazardous, particularly if inhaled. Specialised self-contained tungsten grinders suitable for use with thoriated tungsten electrodes are readily available. Consult the SDS for further information and follow the manufacturer's advice regarding control and disposal of the grinding dust.

The hazards associated with radioactivity from thoriated tungsten dust can be readily eliminated through the use of alternative tungsten types including ceriated and lanthanated tungsten electrodes when GTAW welding. This is now common practice in many Australian companies where the use of ceriated or lanthanated tungsten electrodes is specified for GTAW welding.

Gases – include ozone, argon shielding gases and mixtures and some oxides of nitrogen.

Precautions and recommendations – see Table 17.1 and Table 13.1. and *Fume Minimisation Guidelines*[1].

Table 17.1 Guide to Ventilation Required for Welding and Cutting Uncoated Carbon and Low Alloy Steels (see Note 1)

	Work Situation (see Notes)				
Process	**Scale of Production (Note 3)**	**Outdoor**	**Open Work**	**Restricted Work Space**	**Confined Space** (see also Chapter 20)
Gas Welding Gas Tungsten Arc Welding Brazing and Soldering (See also Chapter 9) Gas Preheating	All	N	M (Note 6)	M (Note 6)	LE
Flame Cutting and Gouging	All	N+RPE	M or LR or WT (Note 6)	M or LR or WT (Note 6)	LE+RPE
Manual Metal Arc Welding Gas Metal Arc Welding Plasma Arc Welding	All	M+RPE	M+LE+RPE (Note 6)	M+LE+RPE (Note 6)	LE+RPE
Flux Cored Arc Welding	All	M+RPE	M+LE+RPE	M+LE+RPE	LE+RPE
Plasma Arc Cutting (Assessment by test is often needed in limited or confined space)	All	M+RPE or LE+RPE (Note 6)	M+LE or WT	M+LE+RPE or WT	LE+RPE
Submerged Arc Welding	All	N	N	M	LE
Electroslag Welding Electrogas Welding	All	N	M+LE	M+LE	LE
Aluminothermic Welding	Normal	N	M+LE	LE	LE
Air-arc Gouging	All	N+RPE	M+LE+RPE	M+LE+RPE	LE+RPE

Notes:

1. This Table applies to uncoated carbon and low alloy steel with or without rust or scale. Additional controls may be required (e.g. air fed helmets, PAPR or respirator masks) if the welder's breathing zone is within close proximity to the plume. Table 17.2 identifies materials for which more stringent ventilation is required.
2. N – Natural ventilation (see 17.8.5).
   M – Mechanical (general exhaust or plenum) or dilution ventilation (see 17.8.4).
   LE – Mechanical ventilation by local exhaust systems (see 17.8.3).
   RPE – Respiratory protection equipment (see 19.6). Powered air purifying respirators (PAPR) recommended for other than confined space.
   WT – Water table.
   Good general mechanical ventilation is required even where other forms of fume control are used except where fume measurements show other ventilation is acceptable.
3. High production refers to duty cycles exceeding approximately 40% and/or high amperage processes, e.g. in excess of 350A.
4. Open work is defined as an area where:
   a. The average space per welder exceeds 300 cubic metres (minimum height 3 metres)
   b. Free cross ventilation occurs, and fume disposal is not obstructed by the work, partitions, balconies or screens.
   c. The welder generally keeps their head out of the plume.
   d. The shop has operating roof or high wall vents (at least 9m above ground level) with large open doors (i.e. is not airtight construction). Roof and/or wall extraction fans may be required to ensure adequate air flow at all times.
   e. Air flow is sufficient to ensure that visible fume cannot accumulate within the building's air space (see also 17.8.4).
5. Natural ventilation may be inadequate to ensure sufficient air flow during outdoor breakdown work due to the presence of local barriers (e.g. walls, machinery, pipes etc). LE may be required in combination with personal respiratory protection.
6. Restricted workspace is an area that does not fulfill the requirements of an open workspace but is not a confined workspace.
7. Confined workspace is defined in 20.1.
8. Operational conditions will determine the degree of ventilation required.
9. Mechanical or local exhaust ventilation (as appropriate) may not be required if process working time is not more than 5% (24 minutes) of an 8 hour work day, provided that the process is used at reasonably intermittent periods (i.e. say a maximum of 5 minutes in any 1 hour). Where mechanical or local exhaust ventilation is not used, good general ventilation in combination with personal respiratory protection is recommended. Assessment may be required to confirm that exposure limits are not exceeded.



17.9.7 Submerged Arc Welding (SAW)

This is inherently a low fume process not requiring particular attention in respect of fume control. Any dust arising from flux handling operations is generally non-hazardous where recommended ventilation conditions apply (see Table 17.1 and/or Table 13.1).

Care must be taken when recycling SAW fluxes as repeated cycles increases the volume of fine particulates and resultant dust. Flux manufacturers typically recommend that recycled flux be mixed with a minimum portion of new (unused) flux, and places a limit on the number of times that the flux can be recycled before its performance degrades.

Users also should be aware that agglomerated fluxes usually contain silica particles within their formulation, the dust from which is particularly hazardous when inhaled. The manufacturer's SDS should be consulted for guidance on safe handling.

17.9.8 Aluminothermic Welding

Large volumes of particulate fume, generally oxides of iron, are given off in this process. Where the process is used inside workshops, local extraction should be used to maximise the capture of the fume, supplemented by mechanical ventilation to rapidly disperse any remnant (see Table 17.1 and/or Table 13.1).

17.9.9 Air-arc Gouging

This process is also referred to as air carbon-arc gouging. As directed jets of air are used in this process, it is usually possible to direct the most of fume away from the welder by use of good technique. As very high levels of fume are generated by the process, with heavy duty gouging a good level of general ventilation is required to ensure that the general workshop atmosphere is safe. Alternatively, specially designed work booths may be used. Fume exhaust systems may be difficult to design but are required in confined spaces where it may be necessary or advisable for operators to use protective devices (see Table 17.1 and/or Table 13.1).

Local exhaust ventilation is often ineffective in the management of fume from the air arc process. This is primarily because ventilation systems are unable to capture the fume generated near its source due to the very high levels of kinetic energy of the fume particles arising when the compressed air used in the process blows molten particles away from the arc. Whilst, a significant measure of fume management can be achieved where the molten swarf and particulates are directed towards the fume extraction inlet during the gouging process, it is usually necessary for the welder to also wear respiratory protection whilst arc-air gouging.

17.9.10 Thermal lancing

This process is also referred to thermic lancing and oxy-lancing. As a high pressure jet of oxygen is used in this process, it is usually possible to direct most of fume away from the operator by use of good technique. As very high levels of fume are generated by the process, heavy duty lancing is usually conducted outdoors in the open. In some workplaces, it may be necessary to conduct the lancing indoors, preferably in a large open work area open on the sides to assist with fume dispersal. If conducted indoors, a good level of general ventilation is essential to ensure that the general workshop atmosphere remains safe.

A task-based risk assessment should be conducted prior to the commencement of thermal lancing activities to ensure that all hazards are identified and that appropriate controls are in place to minimise the risks to health and safety including exposure to the fume by the operator and any personnel in the vicinity where fume can accumulate or disperse.

17.10 Materials and Consumables

17.10.1 Source of Fume

The major source of particulate fume in welding is from vaporisation within the arc and subsequent solidification of the consumable. The contribution of the workpiece should not, however, be ignored particularly with toxic metals or applied coatings.

The gaseous components of welding fume arise from a number of sources dependent upon the process being used i.e.:

a) Decomposition of fluxes in manual metal arc or flux-cored arc welding of steel produces mainly carbon dioxide and carbon monoxide gases.

b) Where external shielding gas sources are used, e.g. inert gases (argon, helium) or carbon dioxide, the fume contains these gases and those formed from them or air, e.g. carbon monoxide and oxides of nitrogen.

c) Combustible reaction products such as carbon monoxide from incomplete oxidation and carbon dioxide from complete combustion in oxygen-fuel gas flame processes.

d) Thermal reactions between oxygen and nitrogen, either from the gases used or ambient atmosphere, form oxides of nitrogen.

e) Ultraviolet radiation is capable of forming ozone from oxygen in the atmosphere. This process is more significant in high-energy gas metal or tungsten arc welding or plasma processes and when working with aluminium or stainless steel.

17.10.2 Special Materials

In addition to the ventilation guidelines for welding and cutting given in Table 17.1, specific ventilation requirements for the special materials listed in Table 17.2 are required. Refer also to Table 13.1.

17.10.3 Coated Metals

There are occasions when metals that have been coated with plastics, polyurethane, epoxy materials, paint or metallic coatings are to be welded, soldered, brazed or cut. The most common examples are steels coated with priming paint for rust prevention, galvanised steels and chrome plating. In certain instances cadmium and lead plated, coated or sheathed metals may be encountered.

17.10.4 Hazards

Coated metals present two major hazards to welders: fumes given off by thermal decomposition during welding, and dusts created during surface preparation work. The dusts can also create a fire/explosion hazard.

a) *Metallic coatings*: Metal coatings may be galvanised (zinc), metal sprayed (aluminium, zinc and others) and electroplated (chromium with copper and nickel underlays, cadmium, zinc or tin). Regardless of the process used to deposit the coatings, fume and dust emissions can be identified from knowledge of the metals involved (refer to Table 13.1).

   Of particular concern are beryllium, cadmium, chromium, lead and nickel.

b) *Paints*: These give off a complex mix of fumes and dusts. Metals such as lead, zinc, chromium and cadmium may come from pigments in the paint. Organic compounds come from the pigments, resins and other materials in the paint (see (c) below). Although "weld through" primers have been developed, these only reduce the amount of fume, not necessarily remove the problem.

c) *Plastics*: Like paints, these can generate a complex mixture of emissions (fumes). The emissions can be irritant, corrosive, asphyxiating or toxic, for example ammonia, hydrochloric acid, carbon dioxide, cyanides. Dusts from plastics create the risk of dust explosions and fire.

17.10.5 Control Measures

A number of measures can be taken to avoid or minimise the health and safety hazards associated with fume and dust.

a) *Identification of the coating*: The coating should be identified before carrying out processes that may create dust or fume. If this is not possible then local ventilation is required.

b) *Removal of the coating*: The coating may be removed before welding using procedures that do not create dust or other hazards. The following clearances should be used as guidelines only:

   i) For welding, a band of 20 to 25 mm should be removed each side of the weld line.
   ii) For flame cutting, a band of 50 to 100 mm should be removed on both sides of the cut.

   Note*: The removal of lead bearing paints is regarded as a lead process and may be subject to controls under the applicable Federal, State or Territory legislation.*

c) *Ventilation*: Natural and general mechanical ventilation are only suitable for low levels of fume or dust. Toxic or hazardous fume or dust should be controlled by local exhaust ventilation.

17.11 Metal Preparation Processes

17.11.1 Introduction

Welding on some non-ferrous alloys, particularly aluminium, nickel alloys and some stainless ferrous alloys, involves the use of degreasing agents prior to welding. Such agents reduce the risk of weldment defects due to the influence of hydrocarbons in grease and oil but may cause fume. They may also cause skin irritation.

Commonly used degreasing agents are:

a) Chlorinated hydrocarbons
   - trichloroethylene – (should only be used in a vapour degreasing tank, cold cleaning is not recommended.)
   - perchloroethylene
   - trichloroethane

b) Acetone

c) *Freon's* (CFCs) have been outlawed

17.11.2 Hazard

Under certain circumstances, chlorinated hydrocarbon degreasing agents decompose to form the highly toxic gas phosgene. Dangerous concentration of phosgene can be produced from small amounts of vapour.

Formation of phosgene from the above and other chlorinated hydrocarbons is promoted by:

a) Ultraviolet radiation

b) Hot metal surfaces

c) Welding arc (ultraviolet radiation)

d) Flame

e) Cigarette smoking

The gas shielded arc-welding processes (GMAW and GTAW) and plasma processes provide greater light radiation intensity than the flux-shielded welding processes.

17.11.3 Precautions

Some metal preparation processes can contribute to fume hazards during welding. In particular the fire risk with flammable solvents and the decomposition of chlorinated hydrocarbons to form toxic gases needs to be highlighted.

a) Where degreasing agents are used, great care is required if gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) or plasma processes are used.

b) Plates that have been degreased must be thoroughly dried before welding or plasma cutting.

c) No solvent vapours are to be present during welding or plasma cutting.

d) The location of degreasing operations and welding operations should be well separated, preferably in different rooms.

e) Chlorinated hydrocarbon degreasing solvents must not be used or stored near welding operations.

f) Manufacturer's Safety Data Sheet recommendations must be adhered to in handling all degreasing solvents.

g) AS 1627.1[17] provides information on preparation and pre-treatment of metal surfaces.

h) When degreasing must be carried out in the welding area, use acetone. Note though that acetone is highly flammable (more so than petrol). If used near welding or other sources of ignition it should be dispensed from a flameproof container such as a plunger can.

Precautions are dealt with in Section 10.3.1.

17.12 Contaminated Surfaces

In maintenance or repair operations, the surfaces to be welded or cut are frequently contaminated with various materials, sludge etc. To provide quality welds, it is usually essential that such materials be removed. Likewise, unless the materials are known to be non-hazardous, they should be removed as in Sections 10.2 and 17.10.5 (see also Chapter 21).

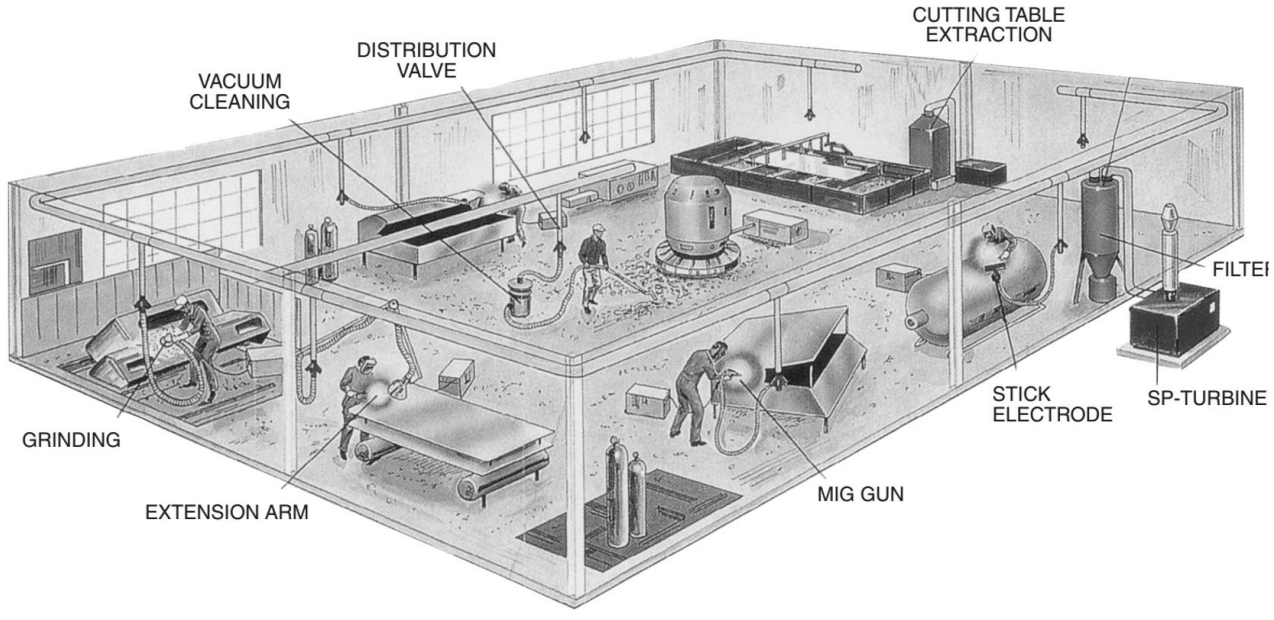


Figure 17.8 Control of welding, cutting and guiding fume using fume extractor

17.13 References

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16. Standards Australia, AS/NZS 21904 (series), *Health and safety in welding and allied processes — Equipment for capture and separation of welding fume* (4 parts, ISO 21904 modified)
17. Standards Australia, AS 1627.1, *Metal finishing – Preparation and pretreatment of surfaces Part 1: Removal of oil, grease and related contamination*

Table 17.2 Ventilation for Special Materials During Welding, Brazing, Cutting and Gouging (see Notes)

Contaminant (Note 2)	Fume Produced	Medical Effects	Recommended Ventilation (Notes 3 and 4)		
			Open and Outdoor Work Space	Restricted Work Space	Confined Work Space (see also Chapter 20)
Aluminium (Note 8)	Aluminium oxides	Irritant (respiratory tract)	M+LE+RPE (Note 9)	M+LE+RPE	LE+RPE
Barium	Barium oxides and fumes	Respiratory tract and skin irritant, benign pneumoconiosis with heavy exposure	M+LE+RPE	M+LE+RPE	LE+RPE
Beryllium	Beryllium oxides and fume	Very toxic (respiratory tract, lungs, general poisoning, skin). Quick acting. Carcinogen	All locations LE and RPE or special glove box		
Cadmium	Cadmium oxide	Very toxic (lung damage, general aches). Quick acting. May be fatal	All locations LE and RPE or special glove box		
Chromium (Notes 8 and 13)	Chromium (VI) oxide	Toxic (respiratory tract, lungs) irritant and corrosive to skin, genotoxic carcinogen (refs. 1 and 43).	LE+RPE	M+LE+RPE	LE+RPE
Cobalt		(Notes 5 and 7)	M+LE+RPE	M+LE+RPE	LE+RPE
Copper (Note 8)	Copper oxides	"Metal fume fever" (Note 8)	M+LE+RPE	M+LE+RPE	LE+RPE
Fluorine	Fluorides (of calcium, sodium, potassium	Irritant (mucous membranes)	M	M+LE	LE
Lead	Lead fumes	Toxic. Cumulative poison (regular lead in blood tests recommended), ototoxic	LE+RPE	M+LE+RPE	LE+RPE
Manganese (Notes 8 and 12)	Manganese oxides	Toxic (tiredness, nervous system, pneumonia), ototoxic	M+LE+RPE	M+LE+RPE	LE+RPE
Nickel (Note 7 & 8)	Nickel Fumes	"Metal fume fever" (Note 7) carcinogenic	M+LE+RPE	M+LE+RPE	LE+RPE
Ozone	Ozone	Respiratory tract irritant	LE+RPE	LE+RPE	LE+RPE
Zinc	Zinc oxide	"Metal fume fever"	M+LE+RPE	M+LE+RPE	LE+RPE

NOTES:

1. The level of ventilation given is the minimum recommended for average conditions. Depending on the location of the welder's breathing zone, RPE may also be required (see Section 17.1). For confined spaces, refer also to Chapter 20.
2. For origins of contaminants, see Table 13.1.
3. Open workspace is defined as an area where:
   a. The average space per welder exceeds 300 cubic metres (minimum height 3 metres).
   b. Free cross-ventilation occurs and fume disposal is not obstructed by the work, partition, balconies or screens.
   c. The welder generally keeps his head out of the main plume.
   d. The shop has operating roof or high wall vents (at least 9m above ground level) with large open doors (i.e. is not airtight construction). Roof and/or wall extraction fans may be required to ensure adequate air flow at all times.
   e. Air flow is sufficient to ensure that visible fume cannot accumulate within the building's air space (see also 17.8.4).
4. Restricted workspace is an area that does not fulfill the requirements of an open workspace but is not a confined workspace.
5. Confined workspace is defined in 20.1.
6. M – Mechanical or dilution ventilation (see 17.7.4).
   LE – Mechanical ventilation by local exhaust systems (see 17.7.3).
   RPE – Respiratory protection equipment (see 19.6). Powered air purifying respirators (PAPR) are recommended for other than confined space. Good general mechanical ventilation is also required even where other forms of fume control are used.
7. Health hazards from welding fume containing cobalt are not documented, but there are well-known dangers associated with the processing of cobalt by other techniques. It is recommended that the precautions prescribed for nickel are applied when cobalt is present in welding consumables.
8. "Metal fume fever" is temporary tiredness and irritation of the respiratory tract, like influenza, with fever. Recovery usually occurs within 24 hours.
9. When nickel and chromium fume occur together, ventilate for chromium.
10. The ventilation recommended in this Table does not apply when these elements are present in carbon and low alloy steels. The level of each element is very low in such materials.
11. Fumes can exceed exposure standards under still air conditions – refer to Weld Australia's *Fume Minimisation Guidelines*[1].
12. Ototoxic – can cause hearing loss, see Section 18.8.7.
13. Cr_{VI} is a genotoxic carcinogen meaning that it can cause genetic damage and may lead to cancer. Exposure should be minimised to a level that is as low as reasonably practicable.

18. Noise Control

18.1 Need for Noise Control

To prevent hearing loss and damage, WHS regulations requires the PCBUs to manage the risks to health and safety relating to hearing loss associated with noise, and they have a duty to ensure that the noise a worker is exposed to at the workplace does not exceed the exposure standard for noise.

Noise has been recognised as one of the most serious occupational health issues in industry for many years. Noise can temporarily and permanently impair hearing. Even at levels below the threshold for hearing damage, it can create a psychosocial hazard, especially where it is difficult to communicate, concentrate and complete tasks. It can also annoy, cause fatigue and reduce concentration and efficiency in workers.

Hearing loss caused by noise usually has an insidious onset and is permanent. It can cause social isolation at home, work, and in group situations. Noise induced hearing loss (NIHL) is selective, because it affects higher pitched sounds first. This filtering effect leaves some sounds unaffected and others, such as consonants in speech, impossible to understand.

Hearing damage can be temporary or permanent and depends on the intensity of the noise and the duration of noise exposure. Surgery or medication cannot restore lost hearing. Hearing aids provide only limited help as they amplify noise and compensate for the filtering to reduce the distortion of the message received. Hearing loss does not protect you from further hearing loss and deafness may occur if exposure continues. Hearing damage is cumulative, meaning multiple exposures to hazardous noise can cause/contribute to hearing damage.

There are many welding and hot work tasks (e.g. grinding) that expose workers to hazardous and damaging levels of noise, including exposures to sudden bursts of loud noise. Furthermore, some welding tasks, themselves posing no threat to hearing, may take place in areas with hazardous levels of background noise.

Psychological hazards resulting from noise can also interact and combine to create new, changed or higher risks. For example, noise in the workplace may increase the risk of high job demands if it interferes with concentration.

18.2 Effect of Noise on the Ear

Sound travels through air in the form of pressure waves. The ear detects the pressure changes and sends messages to the brain:

a) Sound travels through the outer ear and causes vibrations in the ear drum.

b) The ear drum vibrates three tiny bones (the auditory ossicles) in the middle ear and transmits the sound to the inner ear.

c) The inner ear (the cochlea) is full of fluid and lined with tiny auditory hair cells. These hair cells detect the pressure changes and the transmit the associated electrical impulses to the brain which we recognise as “sound”.
   (i) It is these auditory hair cells that are damaged by excessive noise.
   (ii) If the noise is not excessively loud and the person has good hearing, with enough quiet the cells may recover (temporary hearing loss).
   (iii) Repeated excessive noise exposure will lead to permanent damage.

Damage usually occurs gradually however extremely loud noises can cause immediate lasting damage.

- Early stage hearing loss affects higher pitched sounds first leaving some sounds unaffected.
- Longer term it can make speech difficult or impossible to understand.

Ringing or buzzing noises in the ears, or dullness or fuzziness of hearing after a shift, can indicate excessive noise exposure. Exposure to noise can also lead to tinnitus.

18.3 Noise

Sound is characterised by its frequency and intensity. Frequency is a measure of the number of sound pressure waves passing a stationary point per second; i.e. cycles per second or hertz. The average young person can detect sound from 20 to 20,000 hertz. Noise induced hearing loss occurs to a different extent at different frequencies and is usually most pronounced around the 4,000 hertz frequency.

Intensity or loudness expresses our general response

to the sound; it is not an accurate way to assess the damage the noise can do. For this purpose, the total energy content over time of the sound wave is measured. This is expressed in decibels (dB) for an 8-hour day or L_{Aeq8h}. Since the potential for hearing damage varies with frequency, the noise level is weighted to reflect this i.e. dB (A). The decibel is a unit of logarithmic scale that means that a 3dB increase in noise level corresponds to a doubling of the sound energy. This means that every 3dB increase in noise level can cause the same damage in half the time. Essentially, a worker who is exposed to 85 dB(A) for eight hours receives the same noise energy as someone exposed to 88 dB(A) for four hours, with the balance of the day in a very quiet environment.

Figure 18.1 shows the typical noise levels of a number of sound sources.

18.4 Noise Sources

The principal sources of noise in metal fabrication are shown in Figure 18.1.

It is important to realise that tasks or equipment that result in short, sharp noises (also known as Peak Noise) can be equally if not more hazardous to hearing than continuous noise sources.

18.5 Detection of Hazardous Noise

Hazardous noise levels may be present in the workplace if:

a) There is difficulty with speech communication e.g. voices have to be raised between people at arm's length.

b) People complain of ringing or buzzing noises in their ears after a shift (i.e. temporary threshold shift or tinnitus).

c) There are complaints from people of dullness or fuzziness of hearing at the end of a shift.

18.6 Noise Measurement

When a problem is thought to exist and cannot be controlled, the extent of the problem should be determined through a noise survey. A noise survey should detail the levels present, the sources of the noise, and the people affected by the noise. A noise survey must be carried out by competent persons, or those under the supervision of a competent person using equipment approved/compliant to AS IEC 61672[1], sound level meters and measurement techniques as detailed in AS/NZS 1269.1[2].

The measurement of noise levels and the measurement of noise exposure must be distinguished.

Noise levels are measured using a sound level meter. The results are expressed in dB and use A-weighting for Time-Averaged Exposure (dB(A)) and the C-weighted Peak (LC, peak) limits for impulsive/impact noise. Both continuous (dB(A)) and Peak (impulse as dB(V)) noise levels must be measured. Sophisticated meters will allow frequency analysis of noise sources; however, standard sound level meters may miss or clip very short, high-level peaks, so peak noise is generally assessed using instruments with true peak (LC,peak) capability.

Noise exposure is calculated using the measured noise levels and the exposure time to determine the to-tal energy of exposure using results from the sound level meter, timer and calculations. Personal sound exposure meters (PSEM) are worn by the worker (next to the ear) and the results can be used to determine the overall noise exposure to a worker. PSEMs give a daily noise exposure result, and they can also provide a minute-by-minute log of noise exposure during the measurement period. This allows the identification of high noise or peaks during the monitoring period.

Full details for undertaking noise measurements and assessments are available in AS/NZS 1269.3[3].

18.7 Noise Exposure Standard

Always refer to the current statutory requirement when assessing noise exposure. As well as the *daily noise dose*, a peak noise level is set. This level is intended to control impact or sudden noises.

Under WHS regulations a person conducting a

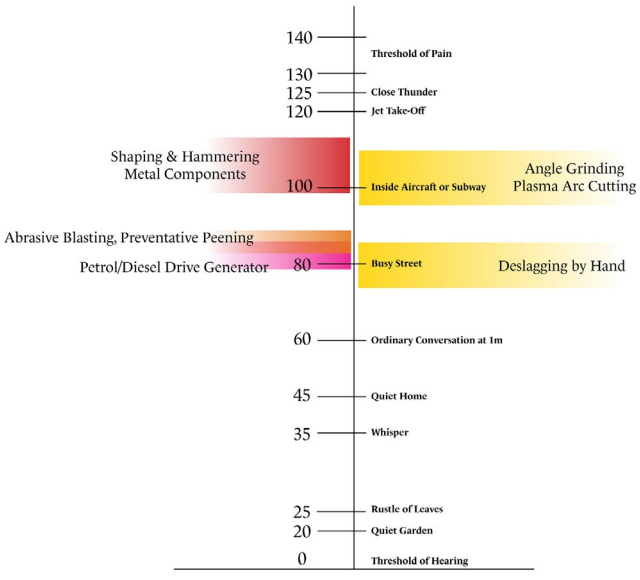


Figure 18.1 Noise levels of common noises
(Note the relative intensity of noise in metal fabrication)

business or undertaking (PCBU) must ensure that no person in the workplace is exposed to noise exceeding the exposure standard of:

(a) $LA_{eq,8h}$ of 85 dB(A); or

(b) LC,peak of 140 dB(C).

This means a person cannot be exposed to noise exceeding $LA_{eq,8h}$ 85 dB(A) averaged over 8 hours or a peak noise greater than 140 dB(C).

18.8 Control of Noise

18.8.1 General

People differ in their susceptibility to noise-induced hearing loss. As a guide, daily exposure below 75 dB(A) averaged over the 8 hour working day or peaks below 130 dB(C) are unlikely to cause harm, with risk increasing as levels rise. The WHS Regulations prescribe an exposure standard of $LA_{eq,8h}$ 85 dB(A) and $LA_{eq,8h}$ 140 dB(C); these values protect most, but not all workers, so noise should be reduced so far as is reasonably practicable.

In workplaces, noise from many welding and thermal cutting operations commonly exceeds 90 dB(A), so controls are typically required to protect both operators and nearby workers. While the welding arc itself is not always the dominant source, associated tasks, such as grinding, hammering, peening, plasma cutting, air-arc gouging, and thermal/oxy lancing, often generate very high, potentially damaging noise levels.

Under the WHS framework, risks from hazardous noise must be eliminated or minimised so far as is reasonably practicable using the hierarchy of control.

In practice, start by eliminating the noisy task or substituting quieter plant/processes. If that is not reasonably practicable, apply engineering controls at the source (e.g. fully enclose the noise source, silencers on pneumatic exhausts, damping and isolation, low-noise tools), then treat the transmission path (increase distance and separation; install barriers/baffles; use room acoustic treatments).

Doubling the distance from a noise source can reduce the noise level by approximately 3dB(A) i.e. halve its intensity, depending on the workplace environment. At the receiver (reception of noise), manage the remaining residual risk with administrative controls (scheduling, exclusion zones, maintenance regimes) and, as the last line of defence, hearing protection. Ensure all controls are maintained and verified so they remain effective over time.

As welding and thermal cutting processes are often manually operated, noise control methods are typically limited to the use of personal protective equipment as passive methods (i.e. those not requiring worker action) are not practical.

Examples of where additional controls are preferred or recommended include:

a) CNC Plasma cutting: Noise from cutting and profiling can be limited at the source over a water table with the plate and cutting head submerged minimises both noise and fume. Suitability of sub-merged cutting is material dependent and not all materials can be plasma cut in this manner.

b) Air arc gouging and thermal/oxy lancing: These processes generate noise levels that exceeds the noise exposure standard for the highest level of hearing protection available (Class 5 to AS/NZS 1270[4]) and specialist advice may be required prior to use. Administrative controls are usually recommend-ed in combination with double hearing protection (i.e. ear muffs and ear plugs worn at the same time). Administrative controls include operating the process away from other people either in a special sound absorbing booth or in the open air to minimise noise reflections and transmission.

c) Air compressors and motor generator sets can be readily insulated or muffled to minimise noise. They can also be operated away from people to further limit noise exposure.

18.8.2 Control by Elimination and Substitution

The best means of noise control is the elimination of the noise source. The next best is the substitution of the noisy operation or equipment with a less noisy alternative. Both elimination and substitution of high noise equipment or processes should be considered before all other control levels and whenever:

a) Setting up a new workplace or redesigning an old one;

b) Reviewing work operations or tasks; and,

c) Purchasing new equipment.

A large range of equipment is readily available on the market that not only does the job but also is designed to minimise noise and vibration levels.

18.8.3 Isolation Control of Noise Transmission

If the noise source is separate from the exposed workgroup e.g. isolating noisy work from other working areas, then the noise path can be reviewed. Increasing the distance between the noise and the exposed group decreases the noise exposure level. If practical,

noisy machines can be put in a separate building. Sound baffles can be installed in the noise path and appropriate building materials can be used to reduce reverberations and reflected noise.

18.8.4 Engineering Control of at the Noise at the Source

If elimination or substitution is not possible, control of the noise at its source is the best approach. This typically takes the form of enclosing the noise source or modifying it e.g. fitting silencers to noisy air exhausts. Adequate maintenance of moving parts in machinery (oiling and greasing), replacing worn out parts, and replacing defective silencers or mufflers are effective in minimising noise. Where the noisy operation is a manual task, then mechanisation or automation may be the only alternative.

18.8.5 Administrative Noise Control

Administrative noise control includes:

a) Limiting the exposure of individuals by limiting the exposure time of personnel working in the noisy area.

b) Signposting quiet areas or pathways through a noisy plant.

c) Rescheduling work to minimise the work exposure of people not directly involved with noisy tasks.

18.8.6 Control through Personal Protective Equipment (PPE)

When the above methods cannot reduce noise to acceptable levels then it is necessary for personnel to use PPE, i.e. a hearing protection device.

In selecting appropriate hearing protection devices (HPDs), consideration must be given to other risks that may arise when incorrect HPD for the work task/ workplace is used, such as blocking more noise than needed and affecting the ability to hear emergency alarms.

Hearing protection takes the form of earplugs (passive disposable, and other, for example, push-to-fit, banded and reusable), earmuffs (passive headband, neckband, and helmet attach versions), and communication solutions (active level dependent, in-ear, headband, neckband, and helmet attach versions) (Figure 18.2).

All hearing protection used in Australian workplaces must be tested and approved to AS/NZS 1270[4] with test results (SLC80, Class (1–5)), and octave-band attenuation data shown on the product packaging. The selection and maintenance of hearing protective devices should conform with AS/NZS 1269.3[3].

> **NOTE**: *NRR test method is used is the USA and SNR test method is used in Europe. These methods of testing are not acceptable in Australia as the method of testing is different from the AS/NZS 1270[4] test method.*

There are a wide variety of hearing protectors on the market and each does not suit all situations. Points to consider when choosing hearing protection include:

a) How much a hearing protector reduces the sound level at the ear, expressed in decibels (dB) (i.e. its "attenuation").

> **NOTE**: *Attenuation isn't the same at all frequencies (lows vs highs), and real-world protection depends on fit, size, seal, application and compatibility with other PPE. In practice, you pick a protector that will bring the workers' in-ear exposure below the exposure standard, with many programs aiming for about 70-80 dB(A) in-ear to avoid both under protection, and over-protection (can mask speech/ alarms). For impulsive/peak noise risk, double protection (plug + muff) may be warranted. Refer*

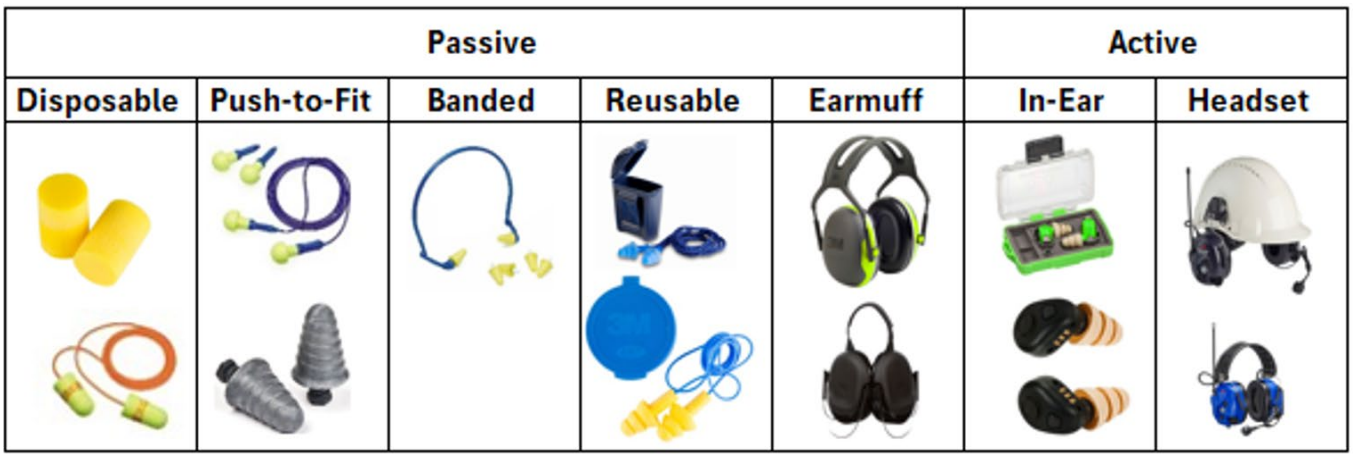


Figure 18.2 **Hearing personal protective equipment**
(Images courtesy 3M)

to AS/NZS 1269.3[3] for further information on the implementation of a 'Hearing Protector Program'.

b) Correct individual selection of noise protection devices.

c) Acceptability by the user i.e. comfort.

d) Compatibility with other protective equipment, e.g. welding face shields.

e) The necessity of having reliable and effective cleaning and maintenance facilities and procedures for the hearing protection.

f) The necessity of user training and motivation.

g) The suitability for the particular work environment.

h) Ease of use and comfort factors.

The level of hearing protection essential for specific tasks should be clearly marked (i.e. signposted with mandatory safety signage – refer AS 1319[5]) throughout the workshop where hearing protection is required.

Earplugs for example, generally offer limited protection in a metal fabrication environment unless suitably fit-tested. Likewise, unless moulded to the wearer to ensure good fitment, they are typically limited to use within environments with a noise level not exceeding 100dB(A) i.e. Class 3 to AS/NZS 1270[4]. It should be noted ear plugs require rolling by the fingers for proper insertion, hence in dirty workplaces, ear muffs may be preferred if they are compatible with other PPE such as welding helmets and safety glasses worn by welders. There are a variety hearing-device fit-test systems in the market that enable the worker to successfully utilise the hearing protector of choice. These systems require a general noise assessment of the working environment to ensure that the choice of hearing protection product is appropriate for the noise hazards present.

Earplugs custom-moulded to the wearer and fit tested are rated at Class 4 or 5 to AS/NZS 1270[4] and may offer a higher level of protection.

Class 5 earmuffs offer the highest level of hearing protection to the wearer.

Some employers use a colour coded hearing protection system, with the level of hearing protection required shown as a specifically coloured hearing protection symbol, and only supply appropriate colour coded hearing protection conforming to this scheme. An example is shown in Figure 18.3.

WARNING: *Noise cancelling headphones and/or earbuds (including Airpods®) or Bluetooth devices are not suitable substitutes for hearing protection unless specifically designed and Class-rated to AS/NZS 1270[4] for industrial use. A limited range of noise cancelling and Bluetooth/Wifi enabled headsets Class-rated to AS/NZS 1270[4] for industrial use are commercially available, however they require checking to ensure that noise levels are controlled/limited below 85 dB(A). WHS regulations may require audiometric surveys of workers in high noise areas where hearing protection is required. It is recommended to check state or territory regulatory information regarding audiometric testing requirements.*

18.8.7 Ototoxicity

Ototoxicity is damage to the hearing system caused by certain substances ("ototoxins"), including some solvents, metals, asphyxiants and medications. These agents can be inhaled or absorbed through the skin, reach the inner ear and/or auditory pathways, and lead to hearing loss or tinnitus. These agents can cause noise-induced hearing loss either with or without noise exposure. Combined exposure to noise and ototoxins increases the risk compared with exposure to either alone i.e. the combination of risk factors can be synergistic.

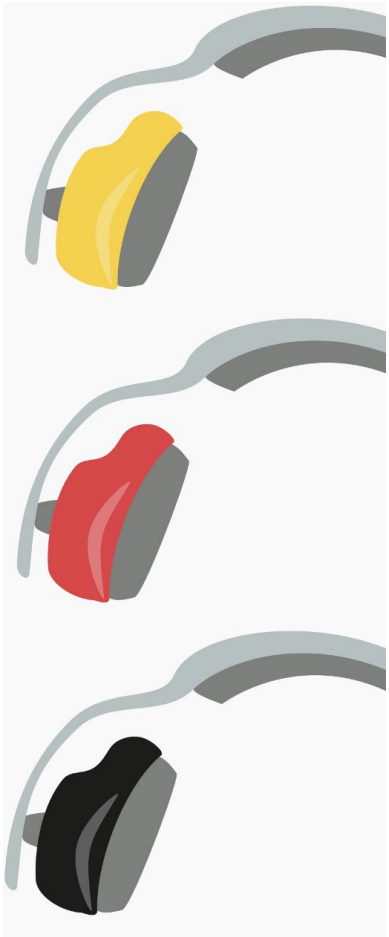


Figure 18.3 Examples of colour coded earmuffs



Ototoxins are not unique to welding—they occur across many industries (e.g., painting, printing, construction, manufacturing, degreasing, fuelling, firefighting), and Safe Work Australia's Model Code of Practice *Managing noise and preventing hearing loss at work*[6] applies the same recommendations to all workplaces.

Where ototoxic exposures are possible, the Code advises aiming to reduce daily noise to around 80 dB(A), providing workers with information on ototoxic risks, and arranging audiometric testing when triggers are met (e.g. any listed ototoxin in COP >50% of its WES regardless of noise level; or any ototoxin present with $L_{Aeq,8h}$ > 80 dB(A) or $L_{C,peak}$ > 135 dB(C).

In welding and allied fabrication, typical ototoxic co-exposures include solvents and fuels (trichlorethylene, toluene, xylene, styrene, white spirits), metal fumes (e.g. manganese or lead), and asphyxiants (notably carbon monoxide).

Control ototoxic chemicals at the source via substitution, isolation and local ventilation, and use appropriate PPE (see Chapter 19 of this document) to prevent skin and respiratory uptake—then verify risk reduction with information provision and audiometric testing.

18.8.8 Audiometry

Audiometry is the measurement of an individual's hearing in order to determine the hearing threshold and any hearing loss. Audiometry only measures the effects of noise exposure, and whilst it gives little useful information about noise sources, amounts of exposure or appropriate noise control measures, it is used to determine if a hearing loss is due to noise or other factors.

Importantly, it can detect a hearing loss before it gets noticeable, so that appropriate noise control actions can be undertaken to prevent further hearing losses. Audiometry is not an acceptable means of noise control.

Audiometry is not an acceptable means of noise control.

WHS regulations in all jurisdictions requires Audiometric testing to be provided to workers although the specifics of requirements may differ between the various jurisdictions. Importantly, workers who are frequently required to use hearing protection devices for protection from the risk of hearing loss associated with noise that exceeds the exposure standard for noise, should be regularly tested.

Monitoring hearing with regular audiometric testing is also recommended in situations where:

(a) workers are exposed to any of the ototoxic substances listed in Appendix B of WorkSafe Australia's Model Code of Practice *Managing Noise and preventing hearing loss at work*[5] where the airborne exposure is greater than 50 per cent of the workplace exposure limit for the substance (without regard to respiratory protection worn), regardless of the noise level

(b) ototoxic substances at any level and noise with $L_{Aeq,8h}$ greater than 80 dB(A) or $L_{C,peak}$ greater than 135 dB(C), and

(c) hand–arm vibration at any level and noise with $L_{Aeq,8h}$ greater than 80 dB(A) or $L_{C,peak}$ greater than 135 dB(C).

18.8.9 Summary

Exposure to high noise levels can cause permanent serious damage to hearing. The hierarchy of noise control measures suggests a number of practical approaches to noise control. In reality any particular workplace will probably use a combination of the above strategies once economics and technology are considered.

Noise control and audiometry require professional advice. The introduction of hearing protection should occur under professional supervision and be supported by a thorough noise assessment and a hearing protection device (HPD) program.

In the welding area there many avenues for noise reduction, either through the use of quieter welding techniques, less chipping, use of nylon or plastic hammers, vibration damping or better placement of heavier welding screens to shield other workers.

18.9 Vibration

18.9.1 General

Exposure to vibration is often associated with excessive noise due to the type of equipment in use that exposes the user to both. Furthermore, there is evidence that workers who are exposed to both hand-arm vibrations and noise at the same time are more likely to suffer hearing loss than workers exposed to the same level of noise alone.

Exposure to excessive hand-arm vibrations may notice pain in their hands and arms and reduced muscle strength. Longer term health effects can include:

- Disrupted circulation leading to vibration "white finger";
- Damage to nerves resulting in tingling and numbness in the hand;
- Damage to tendons, muscles, bones and joints, and

- Disorders such as carpal tunnel syndrome and vibration white finger.

Exposures to excess vibration is typically associated with:

a) Poor tool maintenance;
b) Little or no handle vibration;
c) Heavy tools;
d) Large surface areas of the hand in contact with the tool;
e) Prolonged exposure during the shift, particularly over a number of years;
f) Short or few rest periods;
g) Poor posture and working overhead.

In addition to possibly causing extreme noise and fatigue, vibration may be a problem where prolonged use of hand tools such as grinders occurs.

Vibration exposure may be minimised by good tool design and regular tool maintenance[7].

Gloves should not be relied on for protection from vibration – they may make the vibration exposure worse if glove thickness requires an increase in grip force applied to the tool.

Additional information on the management of vibration may be found on the Safe Work Australia publication *Hand-arm vibration information sheet*.

18.9.2 Effect of Vibration on Pregnancy Outcomes

As noted previously, exposure to excessive vibration is often associated with excessive noise due to the type of equipment in use that exposes the user to both.

Women, and the foetus if they become pregnant, may face poorly documented hazards as they move into work traditionally carried out by men. Welding tasks entail heavy physical and ergonomic demands, together with exposure to metals and particles in welding fume. There have been few studies of such working conditions on the foetus.

A study by Dr Nicola Cherry[8] identified that risk of foetal loss increased with whole body and hand arm vibration. In the electrical trades, foetal loss increased with work schedules of greater than eight days without a rest day. The study reported: *"In this group of women actively engaged in welding during the time surrounding conception, the outcome of pregnancy was strongly related to work exposures, particularly vibration (reported in grinding tasks), manipulation of heavy objects, and perceived intensity of noise and heat."*
Ergonomic interventions to reduce and minimise workplace hazards will improve conditions for all welders, and especially pregnant welders.

18.10 Long-term Health Effects of Excess Noise Exposure

Aside from the risk of hearing loss and vibration issues, there are a range of studies published that link excess noise exposure to a range of adverse health effects in the longer term including an increased risk of accidents, dementia and cardiovascular disease. Whilst ageing is a well-known risk factor in the onset of dementia, there are a range of known lifestyle factors that contribute to the risk, many of which are modifiable. Hearing impairment is common in people with dementia with cognitive impairment higher than in the general population. The actual mechanism underlying this decline is not clear, but it has been stated that hearing loss may result in cognitive decline through reduced cognitive stimulation[9].

Hearing aids may help relieve and slow the development of the symptoms of dementia, but it is unclear if they can reverse the effects of hearing-loss induced dementia by stimulating the affected areas of the brain affected by the hearing loss.

Regarding the risk of cardiovascular disease, a range of studies (both epidemiological and experimental) have demonstrated that exposure to excessive occupational noise not only leads to hearing loss, it con-tributes to hypertension, which in turn is linked to cardiovascular diseases. Occupational noise is a known environmental stressor that stimulates the sympathetic and endocrine systems, thus triggering the release of stress hormones associated with hypertension (high blood pressure).

18.11 References

1. Standards Australia, AS IEC 61672
2. Standards Australia, AS/NZS 1269-1, *Occupational noise management, Part 1: Measurement and assessment of noise immission and exposure*
3. Standards Australia, AS/NZS 1269-3, *Occupational noise management, Part 3: Hearing protector program*
4. Standards Australia, AS/NZS 1270, *Acoustics – Hearing protectors*
5. Standards Australia, AS 1319, *Safety signs for the occupational environment*
6. Safe Work Australia, Model Code of Practice, *Managing noise and preventing hearing loss at work*
7. Australian Institute of Occupational Hygienists (AIOH), *Principles of Occupational Health & Hygiene*
8. Cherry N, Galarneau J, *Fertility in a prospective Canadian cohort of women in the welding and electrical trades*, Occupational and Environmental Medicine, BMJ Journals, 2025
9. Audiology Australia, Position Statement: *Hearing Health and Dementia*, March 2023

19. Protective Equipment for Welding and Allied Processes

19.1 Introduction

During welding operations, the welder may be exposed directly to radiation, heat, fumes, particles etc. This requires the use of special equipment for personal protection in addition to the use of safe welding equipment and a tidy workplace.

This Chapter deals with the types, use, selection and care of personal protective equipment and clothing for the protection of welders and other personnel in the immediate vicinity of welding, cutting and allied operations.

Protective equipment and clothing is of no value unless it is used correctly at all appropriate times and maintained in good condition. It should also conform to the relevant the AS or AS/NZS or AS/NZS ISO (e.g. the new RPE standards).

Importantly, personal protective equipment should be part of a specific PPE program which supports assessment, selection info, training, use, cleaning/ maintenance, fit testing etc requirements.

19.2 Recommended Equipment for Various Processes

Protective equipment and clothing that should be used for various processes is listed in Table 19.1.

19.2.1 Hierarchy of Control

PPE is the last option in the hierarchy of control of hazards (see Section 3.2.2.2). For a number of hazards encountered in cutting and welding, PPE is the only defence against the hazard. It is therefore of great importance to use the correct equipment.

19.3 Protection of Eyes and Head

19.3.1 Purpose

Accidents involving the eyes are most common in welding. The eyes and head including ears are particularly sensitive parts of the body and almost always require some protection during welding against:

a) Radiation (see Chapter 15).

b) Burns that may result from small globules of hot metal or slag.

c) Particles from welding, chipping, gouging etc. entering the eye or ear.

d) Falling objects, especially when working at heights or below construction activities (see Chapter 25).

e) Noise (see Chapter 18).



Figure 19.1 **Typical self-darkening welding helmet**
(Images courtesy BOC)



Table 19.1 Minimum Personal Protective Equipment for Various Welding and Allied Processes (Notes 1, 2)

Process (Note 3)	Hazard	Personal Protection (Note 3)
Flame cutting	Radiation Burns (heat)	Goggles with appropriate filters (Table 19.2) Adequate clothing (19.4.2) gloves (19.4.3) and footwear (19.4.4) Suitable head protection for overhead welding (19.4.1 & 19.4.2)
Gas Welding	Radiation Burns	Goggles with appropriate filters (Table 19.2), gloves (19.4.3) Adequate clothing (19.4.2)
Plasma Cutting (Power source)	Radiation Burns (heat) Noise Fume (see Note 2)	Full face protection shield with filters (19.3.2 & Table 19.2) Adequate clothing (19.4.2) Ear protection (Chapter 18)
Arc Gouging / Cutting	Radiation Burns Electric Shock Noise Fume (see Note 2)	Goggles with appropriate filters (Table 19.2). Adequate clothing (19.4.2), gloves (19.4.3) and footwear (19.4.4) Dry gloves, clothes and footwear Ear protection (Chapter 18)
Arc Welding (Manual) (Note 4)	Radiation Burns Electric Shock Fume (see Note 2)	Full face protection shields with filters (19.3.2 & Table 19.2) Adequate clothing (19.4.2), gloves (19.4.3) and footwear (19.4.4) Dry gloves, clothes and footwear
Arc Welding (Mechanised or automated) (Note 5)	Radiation Burns Electric Shock Fume (see Note 2)	Goggles with suitable protective filters (Table 19.2) Adequate clothing (19.4.2) Dry clothing etc.
Grinding	Hard Particles Noise	Eye protection (goggles with lens, 19.3.3) Adequate clothing (19.4.2) Ear protection (Chapter 18)
Chipping	Hard Particles (possibly hot) Noise	Eye protection (goggles with lens 19.3.3) Adequate clothing (19.4.2) Ear protection (Chapter 18)

NOTES:
1. Often, the particular circumstances in which the process is used may dictate the use of additional protective clothing to that listed.
2. For protection against fume, see Table 17.1, 17.2 and Section 19.6 and Chapter 17.
3. It is recommended that adequate protective footwear by used in all industrial applications (19.4.4).
4. Manual welding includes processes where the welding torch or gun is held by the welder. Additional protection from burns, hot or molten particles will be required in overhead and some positional (e.g. vertical up) welding.
5. Operator not adjacent to arc e.g. submerged arc, electroslag, electrogas, fully automatic GMAW (MIG/MAG) or GTAW.

19.3.2 Helmets and Hand Shields

A typical helmet is shown in Figure 19.1. The construction of such devices, together with the protective filters incorporated within them, should conform to AS/NZS 1337.1[1] and AS/NZS 1338.1[2].

> **NOTE**: *AS/NZS 1338.1[2] is being revised to be superseded by the AS/NZS 16321 standard series (ISO 16321 mod.)[3].*

Where possible, welders should always use full helmet equipment to provide the maximum possible protection. Such helmets or hand shields should be constructed of non-flammable, non-conducting materials with non-reflecting surfaces e.g. fibre glass reinforced plastic or similar materials. Helmets should have sufficient clearance from the face to permit ventilation and should be light yet durable.

The welding helmet must be marked as complying with AS/NZS 1337.1[1]. AS/NZS 1337.1[1] requires the helmet to have an impact rating of at least a medium impact protector. High impact protection is considered by Weld Australia to be necessary for grinding operations.

> **WARNING**: *Welding helmets without some form of supplied air flow (i.e. positive internal air pressure to exclude weld fume – see Section 19.6) are ineffective at preventing weld fume exposure exceeding the workplace exposure limit in the welder's breathing zone without the application of additional control measures (see Chapter 17).*

19.3.2.1 Clear Lenses

Many welding helmets are fitted with clear lenses. Clear lenses are of two distinct types i.e. spatter resistant, and impact (shatter) resistant. The spatter resistant lenses are placed in the moveable part of the eye protector.

The impact (shatter) resistant lenses are placed in the fixed part of the eye protector i.e. behind the spatter protection and filter lenses and directly in front of the welders' eyes. It is a requirement of AS/NZS 1337.1[1] that impact resistant lenses are at least medium impact protectors and that they are marked accordingly.

19.3.3 Protective Goggles

Protective goggles should conform to AS/NZS 1337.1[1], which covers a wide variety of suitable types. The primary features are an ability to provide protection against flying particles and fragments, dusts, splashing materials and molten metals, harmful gases or vapours and against the appropriate optical radiation. Some types allow for fitting of filters that protect the eyes against harmful ultraviolet or infrared radiation.

These wavelengths constitute the major radiation hazard generated by the welding process (see AS/NZS 1336[4]). Goggles should be non-flammable preferably with anti-glare sides.

It is good practice for welders to wear safety spectacles with side shields underneath helmets to provide increased protection at all times.

For most open arc welding operations, goggles, even with appropriate filters, will not afford sufficient facial protection for welders. However, they often give:

a) Added protection against stray arc flashes particularly if welders are working closely together.

b) Adequate protection for observers or welders' assistants provided they are sufficiently far away from the arc to avoid skin burns due to radiation or molten or hot particles.

Similarly, it is strongly recommended that all persons working in the vicinity of any welding operations wear either protective goggles or safety glasses with side shields as these will provide limited protection against accidental arc flash and exposure by absorption and reflection. This type of eyewear is not glare resistant nor is it guaranteed to be 100% UV/IR resistant unless specifically tested for this. Such eyewear cannot guarantee that people working in the vicinity of welding operations will not suffer from adverse effects of excessive UV exposure, as there is no substitute for the appropriate shielding of welding operations of nearby activities.

19.3.4 Contact Lenses

Persons who wear contact lenses should ensure precautions are taken to avoid dust, metallic particles and the like being lodged in their eyes. Foreign bodies can be very difficult to remove in these circumstances and can, if they collect behind the lens, cause severe discomfort and an increased risk of more severe damage to the eye.

Suitable protective filters must be worn during welding operations (see Section 19.3.5), and similarly, welders and any persons working in the vicinity of welding operations should wear suitable protective goggles or safety glasses.

There is no additional radiation risk arising from any welding process or operation such as exposure to arc flash when using contact lenses[5].

19.3.5 Protective Filters

19.3.5.1 Protective filters suitable for arc and flame processes

Protective filters (see AS/NZS 1336[4] and AS/NZS 1338 parts 1 to 3)[2,3,6,7] are provided to reduce the intensity of radiation entering the eye and thus effectively filter out part of the visible, infrared and ultraviolet radiation. Such filters are incorporated within welding helmets and can be fitted to certain goggles. To prevent damage to the filters from molten or hard particles an additional hard clear glass or CR39 plastic external cover is provided (see Figure 19.2). This cover should always be kept in place and replaced before the damage becomes sufficient to impair vision.

Lift-front welding helmets should incorporate a high impact resistant chipping lens made of polycarbonate material.

When selecting an appropriate filter, the following factors should be kept in mind:

a) The intensity of radiation, and thus degree of protection required, depends mainly on the process and welding current (AS/NZS 1336[4]). Table 19.2 gives recommendations for suitable filters and should provide the basis for selection.

b) The objective is to achieve protection for the eyes whilst maintaining adequate visibility of the workpiece. Poor visibility causes eyestrain and spoiled work.

c) If, after selecting a filter suited to the welding process and conditions (Table 19.2), vision is poor, attempts should be made to improve illumination of the work-piece rather than using an inadequate filter.

d) Observers who are required to closely view the arc, particularly from a distance of less than 3 metres, should also wear full-face protection and select filters as recommended in Table 19.2.

e) For welders' assistants and other personnel who are often within about 6 metres of the arc, it is safe practice to wear goggles with a filter shade No.3 even though it is generally not necessary for them to view the arc. Protection of others situated further from the arc is accomplished by the use of suitable protective screens or partitions (Sections 15.2 and 19.5).

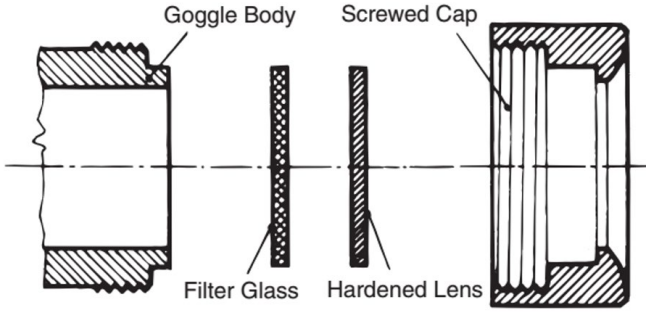


Figure 19.2 Protective filters

NOTE*: At the time of publication of this Technical Note, AS/NZS 1338.1[2] was being replaced by the AS/NZS 16321 standard series (modified ISO 16321 adoptions)[3]. As the densities of welder's eye shade filters used in Australia have been based on ISO standards, with the publication of the new standards, no change is required on the part of the end user in terms of shade numbers recommended for specific welding processes and amperages.*

19.3.5.2 Protective filters suitable for laser welding, cleaning and cutting processes

Welding filters do not provide suitable protection from laser radiation, especially when subjected to high-intensity visible and ultraviolet radiation from the plasma at the welding or cutting point, and at the near infrared wavelengths typically used in hand-held laser applications. Separate filters must be specified to meet the protection requirements for the laser beam which includes minimum optical density (OD) and resistance as specified within AS/NZS ISO 19818.1[8] and AS/NZS IEC 60825.14[9]. Refer also to Section 8.2 of this Technical Note.

19.3.6 Welding Helmets with Self-darkening Filters

19.3.6.1 Use of self-darkening filters in arc applications

Welding helmets are available with light reactive filters that change automatically and almost instantaneously from the light to the dark state when the arc is struck and return automatically to the light state as soon as the arc is extinguished.

The most significant requirements and benefits of self-darkening filters are:

a) That the levels of UV and IR filtration in the light state are to be the same as in the dark state.

b) Specified response times for the changeover from light to dark state.

c) Frees both hands for welding.

d) Eyes are permanently protected from harmful radiation (in both the light and dark state).



Table 19.2 Guidance on Selection and Use of Filters for Protection Against Optical Radiation Generated during Welding and Allied Processes

Process	Approx. Range of Welding Current (AMPS)	Filter Recommended (Notes 1 ,2, 6)
Manual Metal Arc Welding – covered electrodes (MMAW)	Up to 100 100-200 200-300 300-400 Over 400	8 10 11 12 13
Gas Tungsten Arc Welding (GTAW) – (TIG)	Up to 100 100-200 200-250 250-350 Over 350	10 11 12 13 14
Gas Metal Arc Welding (GMAW) (MIG/MAG) (Note 4) Aluminium and Stainless Steel Other than Aluminium and Stainless Steel	Up to 250 250-350 (Note 3) Up to 150 150-250 (Note 3) 250-300 (Note 3) 300-400 (Note 3) Over 400	12 13 10 11 12 13 14
Flux-Cored Arc Welding (FCAW) (Note 4) - With or without shielding gas	Up to 300 (Note 3) 300-400 (Note 3) 400-500 (Note 3) Over 500	11 12 13 14
Plasma Arc Welding, Cutting & Spraying (PAW) and Wire-Arc Spraying (Note 5)	50-100 100-200 200-300 300-400 400 and over	10 11 12 13 14
Air-arc Gouging (Note 4)	Up to 400	12
Gas Welding – Low heat input – Light fusion welds – Heavy fusion welds		3 4 5
Wire Flame Spraying – Except Molybdenum – Molybdenum		2-4 3-6
Flame Cutting and Gouging – Light – Medium – Heavy-close		4 (Note 8) 5 (Note 8) 6 (Note 8)
Aluminothermic Submerged Arc & Electroslag Welders Assistant		6 3 (Note 7) 3 (Note 8)

NOTES:

1. The shade numbers are minimum. If any discomfort is felt, higher shade numbers i.e. darker filters should be used.
2. If the surface temperature of the filter rises above 100°C e.g. when welding preheated sections in a confined space, filters of solid glass or glass laminates with dyed inserts should be used.
3. These processes give off a higher proportion of infrared radiation than others that gives rise to an uncomfortable increase in filter temperature. An auxiliary heat-absorbing filter should be placed between the cover glass and filter glass.
4. Where these processes are fully automatic, shade 3 filters may be used.
5. The appropriate filter should be used for close examination.
6. When these processes are provided with their own shield, lighter eye protection filters may be used. Australian Standards covering eye protection (AS/NZS 1336, AS/NZS 1337 and AS/NZS 1338) should be observed.
7. A darker filter (shade 5) may be required to closely watch the molten pool in electroslag welding.
8. Tinted safety glasses and sunglasses are typically shade 3 and are inadequate for cutting and gouging. Shade 3 is considered to be a minimum requirement for a welder's assistant at some distance and not directly observing the operation. A risk assessment may indicate a higher shade is necessary.

e) Assists in achieving accurate striking of the arc.

f) Reduces fatigue.

g) Improves productivity.

19.3.6.2 Use of self-darkening filters in laser applications

Welding helmets with self-darkening filters are not suitable for use in laser applications as these filters do not protect the wearer from laser radiation (see also AS/NZS ISO 19818.1[8] and AS/NZS IEC 60825.14[9]). There are a number of reasons for this including the fact that response time is not fast enough to provide suitable protection from laser radiation, and, small beams won't always activate the filter sensor.

19.3.7 Welders' Caps

Welders' caps (see Figure 19.3) and balaclavas will provide additional protection for the top of the head from radiation reflected from adjacent surfaces. They should be used in overhead welding. Welders' caps, hoods and balaclavas should be made of heat resistant non flammable material. Welders with long hair should use hoods or nets that cover and hold their hair underneath appropriate caps or head shields.

Welders hoods and balaclavas will also protect the neck from sparks and spatter penetrating clothing below the neck line.

For additional head protection on construction sites, welding helmets should incorporate a safety helmet.

19.4 Protective Clothing for the Body

19.4.1 Purpose

With usual industrial arc and flame processes, it is necessary to wear suitable flame-resistant protective clothing that fully covers the skin to protect the welder's body and clothing against:



Figure 19.3 Examples of welders' caps
(Images courtesy BOC)

a) Heat from the work.

b) Burns and fire that may result from contact with hot components or small globules of hot metal and slag.

c) Ultraviolet light that may burn the skin or deteriorate clothing.

d) Cold winds or rain.

e) Accidental contact with the welding circuit.

With allied processes e.g. grinding, suitable protection for the particular hazards involved are also essential (Table 19.1).

Protective clothing for welding personnel conforming with the requirements of AS/NZS ISO 11611[10] provides protection for welders in light duty welding (Class 1) and for heavier duty welding (Class 2). Conforming clothing provides protection against spatter, short flame contact, radiant heat and limited protection against accidental short duration contact with the welding circuit in the normal conditions of welding and ultraviolet radiation.

It is important to note that sweat and other contaminants can adversely affect the resistivity of the fabric and therefore reduce the level of protection provided against contact with the welding circuit.

19.4.2 Type of Work Clothing

The normal working clothing of a welder is generally their own responsibility. Clothing should:

a) Protect all parts of the body from hot particles or objects.

b) Be preferably of wool, flame-resistant cotton drill or compliant with AS/NZS ISO 11611 Level 2[10]. These materials are much safer in fire than most synthetic materials such as nylon or acrylic that melt or readily stick to skin when overheated. Woollen materials have much greater resistance to ultraviolet radiation e.g. from Gas Metal Arc or Gas Tungsten Arc Welding of aluminium and stainless steel.

c) Be free of cuffs or open pockets that could trap molten metal causing local burns or setting fire to clothing.

d) Fit snugly at wrists but be loose fitting when working in hot conditions.

e) Cover tops of footwear.

f) Be maintained in good condition i.e. laundered as required and hole free.

19.4.3 Gloves

Gloves for hot work on metals should:

a) Be worn during all arc, gas or thermal cutting operations to protect the hands and wrists from heat, burns and cuts. Hands are usually the closest part of the body to the heat source.

b) Be of pliable flame-resistant leather or of aluminised type for very hot operations such asconfined heavy arc or oxy-gouging. Rubber shall not be used.

c) Have seams arranged inside to prevent burning of stitches and trapping of hot metal particles.

d) The non-seamed type of glove with reinforcement between thumb and forefinger is preferred.

e) Comply with AS/NZS 2161.3[11] and AS/NZS 2161.4[12] (see Figure 19.4).

f) Marked in accordance with the requirements of AS/NZS 2161.3[11] and AS/NZS 2161.4[12].

g) Be maintained in good condition and not used for other tasks involving the use of solvents or hydrocarbons.

h) Be replaced when seams come apart, become less pliable, or contaminated with solvents or hydrocarbons.

19.4.3.1 Protection Against Mechanical Risks

Gloves for hot work on metals should comply with the minimum requirements of AS/NZS 2161.3[11] i.e. have level 1 compliance in:

a) Abrasion resistance

b) Blade cut resistance

c) Tear resistance and

d) Puncture resistance



Figure 19.4 Welding gloves compliant with AS 2161 parts 3 and 4[11,12]
(Image courtesy BOC)

19.4.3.2 Protection Against Thermal Risks (Heat and Fire)

Gloves for hot work on metals should comply with the minimum requirements of AS/NZS 2161.4[12] i.e. have level 1 compliance in:

a) Burning behaviour

b) Contact heat

c) Convective heat

d) Radiant heat

e) Small splashes of molten metal

f) Large quantities of molten metal

19.4.4 Safety Footwear

In most industrial situations where welding is used, there is a risk of injury to feet or toes from a number of causes, including:

a) Fractures – from falling objects.

b) Burns – molten or hot particles penetrating or entering footwear (see 19.4.5).

c) Cuts – intrusion of sharp objects through soles.

To provide adequate protection it is recommended that protective footwear be selected in accordance with AS/NZS 2210.1[13]. Additional requirements are specified within AS/NZS 2210.3[14].

> **NOTE**: *For safety footwear with steel toe caps, the steel cap should never be exposed, especially when conducting electric welding or related processes involving an electrical current flow.*

19.4.5 Additional Protection

Aprons, sleeves, shoulder covers, leggings or spats of pliable flame-resistant leather or other suitable materials may also be required in positions where these areas of the body will encounter hot metal, e.g. overhead welding (see Section 19.3.7 for caps) or if leaning on hot metal, or sitting at a bench where molten metal may land in the lap.

Spats or similar protective equipment should preferably be worn over laced safety footwear to prevent spatter and sparks penetrating into the laced region or being trapped within boot.

19.4.6 Clothing Condition

Clothing should be of appropriate industrial grade and heat resistant (see also AS/NZS ISO 11611[10]). Whilst correct industrial grade clothing in sound dry condition

and correctly fitted can be shown to provide adequate electrical protection of welders, any deterioration in condition or addition of moisture (e.g. sweat) can render a garment sufficiently conductive to present a risk of electric shock or electrocution. Hence it is incorrect to assume that clothing is providing any form of protection from electric shock. Moisture level must be kept as low a reasonably practicable.

All protective clothing including gloves and footwear should be in good condition. Clothes, particularly welding gloves, should be dry and free of tears or cuts. Steel toecaps must not be exposed.

19.5 Screens and Curtains

All electric welding operations should be screened to prevent the ultraviolet (UV) rays of the arc from affecting other persons working in the vicinity. Where the work is carried out at fixed benches or in welding shops, permanent screens or curtains should be erected. Where the nature of the work is such that these are not practicable, temporary screens should be used to limit the radiation.

All screens should be opaque or of appropriate translucent materials, of sturdy construction to withstand rough usage, and of material that will not readily be set alight by sparks or hot metal.

They should not, however, be so heavy or cumbersome as to discourage their use. They should permit ventilation under and over; 300mm bottom clearance is usually adequate.

The design and construction of the screen should conform to AS/NZS ISO 25980[15] and they should be selected in accordance with AS/NZS 1336[4].

19.6 Respiratory Protection Devices

19.6.1 Introduction

In situations where ventilation systems are not effective in reducing fume levels, respiratory protection in accordance with AS/NZS 1715[16] is required to provide a combination of controls for best protection. The following general requirements should be considered when selecting respiratory protective devices.

a) They are carefully selected for each application (expert occupational hygiene advice may be required). A common challenge is fitting respiratory protection devices under welding face pieces and helmets, and specifically designed variants may have to be used, e.g. PAPRs which incorporate a UV protective face shield. All devices used should conform to AS/NZS 1716[17] and be used in accordance with AS/NZS 1715[16].

b) Tight fitting face pieces (ie. negative pressure types including disposable half-face or full-face peices) must closely fit the face. These respirators must not be worn by individuals with beards, long moustaches, sideburns, or with stubble growth. They must only be worn on clean-shaven faces. A loose fitting positive pressure type respirator (e.g. PAPR) should be used instead.

c) All respirators must be clean and in good condition before use. Re-useable types must only be transferred between persons if they have been adequately washed and disinfected.

   NOTE*: The operation of PAPRs should be verified before use and all parts inspected on a regular basis for damage (see Figure 19.8).*

d) All respirators should be stored in a clean area such as a closed cupboard in a suitable storage container/ box, including when not in use.

e) Training in correct use of respiratory protection devices is required.

19.6.2 Respirator Types

19.6.2.1 General

There are many different types of respirators. At a high level guide, the main types of air purifying and air supplied respirator.

Air purifying respirators have a filter or cartridge that the inhaled air passes through and captures the contaminant so the wearer can breathe in filtered air. They can be negative or positive pressure. These types of respirators do not provide protection in an oxygen deficient atmosphere or give protection for types of contaminants.

Respirator types available include:

a) *Disposable particulate filter*: Suitable to capture mechanically and thermally generated particulates These may also have carbon component for nuisance level gas/vapour exposures. Disposable types incorporating carbon specifically designed for welding are also commercially available.

b) *Reusable half or full facepiece*: These can come in various sizes and in single or dual filter configurations. They can come with particulate and gas/vapour filters for many common workplace and welding contaminants.

c) *PAPR welding helmets*: PAPR welding helmets are loose fitting (see Figures 19.7 and 19.8) and provide increased protection to the welder with a

Required Minimum Protection Factor (RMPF) of 50 for cleaner air and improved comfort all day long. This means the welder will breathe air 50 times cleaner than they would breathe unprotected. The PAPR draws air in from behind the welder through layers of filtration and delivers clean air at positive pressure into the welding helmet and directly into the welder's breathing zone, excluding the inflow of weld fume. The PAPR filters and air hoses should be periodically inspected and replaced as necessary (see Figure 19.8), and air flow velocities regularly checked using the manufacturer's instructions and equipment provided with the PAPR unit.

19.6.2.2 Air-Purifying Filters/Cartridges

Air-purifying filters/cartridges can be as follows:

a) *Particulate respirators*: A variety of particulate respirators are available conforming to P1 or P2 class filtration efficiency as defined in AS/NZS 1716 (see also 19.6.3.2). These include disposable respirators (or "masks"), half face and full-face pieces, and PAPR respirators fitted with particulate type filters. These should be selected to protect the wearer against harmful inhalation of dusts, solid particles and metallic fumes (see Figure 19.5). For welding operators, respirators with class P2 filters and required and should be worn.

b) *Gas/vapour cartridges*: These may be attached to half or full-face respirators or PAPR fitted with a suitable cartridge to remove various categories of toxic gases and vapours. Reference should be made to AS/NZS 1715[16] and AS/NZS 1716[17] for information on the various categories of gas filter and the degree of protection provided by each.

c) *Combined particulate and gas/vapour respirators*: These may be half (see Figure 19.5) or full-face or PAPR respirators fitted with suitable combination type filters to remove both particulates and defined categories of gases and vapours.

19.6.2.3 Air-Supplied Respirators

Air-supplied respirators provide the wearer a source of fresh air, which is independent of the working environment through an air-line or by the person carrying an apparatus that provides the air. These can include:

a) *Airline respirators*: These may be of full-face piece, hood or helmet type (see Figure 19.6). A common feature of each of these is the supply of clean breathable air at suitable pressure from a remote source e.g. a compressor. Workshop compressed air, after filtering to remove oil droplets and in-line contaminants, is usually suitable for breathing. Confirmation and assessment of the breathable air quality is required.

b) *Self contained breathing apparatus* (SCBA): This equipment is entirely self-contained with an air cylinder and the user is not dependent on an air compressor.

c) *Escape type SCBA*: These incorporate a small cylinder of compressed air that may be turned on and used to escape from an atmosphere immediately hazardous to life if the working air supply fails.

Remember air-purifying respirators do NOT supply oxygen and therefore must not be used in locations



Figure 19.5 **Half facepiece respirator with combination particulate and gad/ vapour cartridge respirator**
(Image courtesy BOC)



Figure 19.6 **Airline helmet**
(Image courtesy BOC)

where an oxygen deficiency may be present e.g. in confined spaces. Atmospheres should be checked for oxygen content as well as to ensure that they are not flammable or explosive.

> **WARNING**: *Unventilated welding helmets are ineffective at preventing weld fume exposure exceeding the WHS standards in the welder's breathing zone without the application of external control measures (see Chapter 17).*

19.6.3 Selection of Equipment

19.6.3.1 Selection of Equipment General

The following factors should be considered when selecting respiratory protection devices:

a) Only equipment that conforms to AS/NZS 1716[17] should be used.

b) It is strongly advised that expert assistance be sought in selecting respiratory protective devices appropriate to the intended service. Such advice may be sought from local WHS Authorities, occupational hygienists. In some states, legislation requires personal protective equipment to be of an approved type.

c) Where filter type devices are used, particular care is required in selecting appropriate filtering systems according to the airborne contaminants present, and the concentration of those airborne contaminants in the air. They must be capable of removing a range of particulates and gases and maintain adequate permeability to air so that breathing does not become difficult.



Figure 19.7 Powered air purifying respirator (PAPR) helmet
(Image courtesy Apex Welding Safety)

d) To be effective, respiratory devices must closely fit the user's face. Beards, moustaches etc. interfere with the closeness of fit and the 'seal' between the respirator and the skin on the face. Fit testing as described in AS/NZS 1715[17] is required to ensure a satisfactory fit is achieved, for any tight fitting negative pressure respirators. It is not required for positive pressure respirators such as PAPRs or air-supplied loose fitting helmets.

e) In atmospheres immediately hazardous to life, self-contained breathing apparatus or airline respirators with emergency escape device is required.

f) Airline respirators may only be used in atmospheres immediately hazardous to life if fitted with es-cape type SCBA for use in event of failure of the airline or compressor.

g) In areas containing toxic fumes or dusts not immediately hazardous to life, follow the recommenda-tions of AS/NZS 1715 to determine the correct respirators required to achieve sufficient protection.

Additional guidance on the selection of respiratory protection can be found at the AIOH Respfit website (www.respfit.com.au) using the respirator selection tool. The AIOH Respfit program also provides infor-mation and accreditation for persons who conduct respirator fit testing to ensure the testing is con-ducted by a competent person. Additional information can also be found on the AIOH's Breathe Freely website https://www.breathefreelyaustralia.org.au/.

19.6.3.2 Revision of Standards

In 2025, AS/NZS 1715[16] and AS/NZS 1716[17] commenced the transition process to be replaced by locally adopted AS/NZS ISO standards with the superseding process being completed by 2030. During this time it is expected that new ISO products will become available. Information regarding how the products work and their limitations will become available.

Importantly, manufacturers of respiratory protective devices and filters are required to have their product tested for conformance with these standards (as appropriate) and accordingly specific designation detail may vary from that shown in the example designations in this section.

The relevant standards are as follows:

(i) AS/NZS 1715[16] to be replaced by the SA/SNZ TS ISO 16975 Selection use and maintenance series including AS/NZS ISO 16975.3 Fit testing[18]; and,
(ii) AS/NZS 1716[17] to be replaced by a range of standards including:

A. Standards relevant to end users: AS/NZS ISO 16972 Vocabulary[19] and SA/SNZ TS ISO 16973 Classifications[20]; and,
B. Standards relevant to manufacturers: AS/NZS 16976 Human factors series[21], AS/NZS 17420 Performance series[22], and the AS/NZS ISO16900 Test method series[23].

It should be noted that the current AS/NZS 1716 P2 filter has a similar particle filter efficiency to the new F2 filter and similarly the P3 filter aligns between the F3 and F4 filter in terms of filter efficiency.

The new standards define a range of performance factors that define the filter and what it is attached to, and the combination capabilities under SA/SNZ TS ISO 16973. These range as follows:

- Protection class – PC1 to PC6
- Work rate – W1 to W4
- Respiratory interface class based on area of body covered i.e. a - mouth to head, complete body, and, whether loose fitting (L) or tight fitting-(T)
- Particle Filter Efficiency – F1 to F5
- Special Application designation (where relevant) e.g. WE for welding
- Gas filter class – OZ, NOX etc.

Specific performance classes as defined in SA/SNZ TS ISO 16973[20] can be summarised in the example for a P2 filter as shown in Table 19.3.

An example comparative AS/NZS 1716 P2 filter equivalent designation suitable for welding is PC2 W1 bT F2 WE. If ozone filtration capability was included, the designation would be similar to PC2 W1 bT F2 OZ1 WE. A PAPR fitted with a P3 or equivalent filter compliant with AS/NZS 1716[17] and loosely fitted over the face may likely have a designation of either PC3 W1 cL F3 WE or PC3 W1 cL F4 WE or better, depending on its performance class per its testing results. Being a positive pressure device, it should be noted that leakage will be minimal even if loose fitting (normal for PAPRs).

The ISO standards have listed Protection Levels, however this is an area that is being reviewed. It is expected these will be amended to better reflect real-world performance in due course.

Users should be aware that filters with higher filter ratings (higher suffix numbers) generally have an increased breathing resistance at lower work rates.

19.6.4 Maintenance of Equipment

19.6.4.1 General

Appropriate maintenance of fume control equipment is essential to ensure it operates correctly and as intended on an ongoing basis. In the absence of manufacturer's instructions, the following are recommended:

a) All equipment should be checked visually for defects and damage prior to use.
b) Powered air purifying respirators – see Figure 19.8. Note that the PAPR's air hose is susceptible to piercing from spatter and in some situations, creasing and cracking. Filter packs also need to be periodically checked and changed, and the air flow regularly checked.
c) On-tool Exhaust Systems – see Figure 19.9.
d) Fume Exhaust Hoods – see Figure 19.9.

Table 19.3 Example performance class for a P2 filter

Performance	Class	Comment
Protection class	PC2	5% leakage
Work rate	W1	Moderate or light work
Respiratory Interface	bT	Tight fitting over mouth & nose
Particle Filter Efficiency	F2	≥ 95.00%
Special Application - Welding	WE	—
Gas filter – Ozone	OZ1w1	—

Captured weld fume, if exhausted to the workshop, must be suitably filtered, preferably in conformance with class W3 of AS/NZS 21904.1[24] (i.e. 99% filter class efficiency), or equivalent. Some systems may also be fitted with a supplementary final stage High Efficiency Particulate Air (HEPA grade) filter which will ensure that ultrafine particulates are captured with a 99.95% filter class efficiency.

Alternatively, captured weld fume may be exhausted to atmosphere external to the workshop away people such that it cannot be recycled into any building or within close proximity to any person. Irrespective, it is recommended that captured weld fume be filtered prior to being exhausted to atmosphere to remove particulates to at least the equivalent of a filter class efficiency of 95% for all 0.3µm particulates (e.g. EN 1822-1 E11[25]).

19.6.4.2 Cleaning and maintaining PAPR systems

Cleaning PAPR systems involves cleaning both the helmet and respirator components, and reference should be made to the supplier's guidelines. The following recommendations have been reproduced, courtesy of Apex Welding Safety (AWS).

a) **Safety and general**:

(i) Do not attempt to clean the filters with compressed air as this will likely damage the filters and compromise the level of protection available to the user.

(ii) When inspecting the main filter, check for 'break-through' i.e. particles that have broken through or damaged the reverse side (clean side) of the filter.

WARNING*: Breakthrough will prevent the filter replacement warning system working correctly. These systems are based on the blower motor ramping up when the filter reaches capture capacity (i.e. filter not allowing air through and the filter ramping up to maintain air flow).*

(iii) Identify the hazards associated with the use of chemicals used in the cleaning process and controls required to eliminate or the minimise the risks associated with the hazards identified.

(iv) Review chemical SDS documents prior to use of the cleaning and sanitising solutions recommended in the cleaning and sanitising procedure.

b) **Clean the welding helmet**:

- Disconnect breathing tube from the head-top then disconnect the other end of breathing tube from respirator unit.
- Remove the battery and blower assembly from the waist belt.
- Clean all of the head-top with a sponge/soft cloth with warm 50°C water containing a mild detergent. Do not use detergents containing lanolin or oils, petrol, chlorinated degreasing fluids (e.g. trichloroethylene), organic solvents or abrasive cleaning agents.
- Wipe components cleaned in the above step with a sponge or soft cloth dampened with clean warm 50°C water.
- If required, sanitise components by wiping with a sponge or soft cloth dampened with a hypochlorite solution - 30ml household bleach in 7.5L of water.
- Discard and replace a damaged or significantly stained/dirty face seal or sweatband.
- Discard and replace damaged or significantly scratched inside and outside cover lenses.
- Regular replacement of the pre-filter extends the life of the particle filter and decreases running costs.
- Replace the particle filter when the first indicator becomes red. Otherwise, replace whenever the battery operating time becomes too short, or when the low airflow alarm is triggered.

c) **Clean the blower assembly**:

- Remove the filter cartridges from the blower assembly. Properly dispose of the used filter/cartridge.
- Do not attempt to clean the PAPR filters at any time, they are not user-serviceable.
- Wipe the battery pack with mild cleaning solution. Do not immerse the battery pack.
- To clean the outside of the breathing tube, cover both ends and wipe down with a soft cloth dampened with a warm water and mild detergent solution followed by a wipe with a cloth dampened with clean water.
- Be careful not to let any of the cleaning solution enter into the hose. Air dry in uncontaminated atmosphere with temperature not to exceed 50°C.
- To clean the inside of the tube, follow the instructions above and ensure the inside of the tube is thoroughly rinsed with water before allowing it to air dry in an uncontaminated atmosphere with temperature not to exceed 50°C.
- If required, sanitise components by wiping with a sponge/soft cloth dampened with a

hypochlorite solution (e.g. 30ml household bleach in 7.5 L of water) observing the safety instructions provided on the SDS for hypochlorite solution.

- Reassemble unit as described in the user instructions.

19.7 References

1. Standards Australia, AS/NZS 1337.1, *Personal eye-protection Part 1: Eye and face protectors for occupational applications*
2. Standards Australia, AS/NZS 1338. (series), *Filters for eye protectors Part 1: Filters for protection against radiation generated in welding and allied operations*
3. Standards Australia, AS/NZS 16321 (series), *Eye and face protection for occupational use* (ISO 16321 series, modified)
4. Standards Australia, AS/NZS 1336, *Recommended practices for occupational eye protection in industrial environments*
5. Sacca S C. et al, *Experimental Investigations on the Effect on Radiations Produced by a Welding Arc on Eyes with Contact Lenses*, IIW Doc VII-1271-85, (P9-45-85)
6. Standards Australia, AS/NZS 1338. (series), *Filters for eye protectors Part 2: Filters for protection against ultraviolet radiation*
7. Standards Australia, AS/NZS 1338. (series), *Filters for eye protectors Part 3: Filters for protection against infra-red radiation*
8. Standards Australia, AS/NZS ISO 19818.1, *Eye and face protection — Protection against laser radiation Part 1: Requirements and test methods*
9. Standards Australia, AS/NZS IEC 60825.14, *Safety of laser products Part 14: A user's guide*
10. Standards Australia, AS/NZS ISO 11611, *Protective clothing for use in welding and allied processes*
11. Standards Australia, AS/NZS 2161.3, *Occupational protective gloves Part 3: Protection against mechanical risks*
12. Standards Australia, AS/NZS 2161.4, *Occupational protective gloves Part 4: Protection against thermal risks (heat and fire)*
13. AS/NZS 2210.1:2025, *Safety and occupational footwear Part 1: Guide to selection, care and use*
14. Standards Australia, AS/NZS 2210.3, *Personal protective equipment, Part 3: Safety footwear (ISO 20345:2011, MOD)*
15. Standards Australia, AS/NZS ISO 25980, *Health and safety in welding and allied processes — Transparent welding curtains, strips and screens for arc welding processes*
16. Standards Australia, AS/NZS 1715, *Selection, use and maintenance of respiratory protective equipment*
17. Standards Australia, AS/NZS 1716, *Respiratory protective devices*
18. Standards Australia, SA/SNZ TS ISO 16975 (series) *Respiratory protective devices — Selection, use and maintenance*
19. Standards Australia, AS/NZS ISO 16972, *Respiratory protective devices — Vocabulary and graphical symbols*
20. Standards Australia, SA/SNZ TS ISO 16973, *Respiratory protective devices — Classification for respiratory protective device (RPD), excluding RPD for underwater application*
21. Standards Australia, AS/NZS 16976 (series), *Respiratory protective devices — Human factors*
22. Standards Australia, AS/NZS 17420 (series), *Respiratory protective devices — Performance requirements*
23. Standards Australia, AS/NZS ISO 16900, *Respiratory protective devices — Methods of test and test equipment*
24. Standards Australia, AS/NZS 21904.1, *Health and safety in welding and allied processes — Equipment for capture and separation of welding fume Part 1: General requirements (ISO 21904-1:2020, MOD)*
25. European Standard, EN 1822-1, *High efficiency air filters (EPA, HEPA and ULPA) — Part 1: Classification, performance testing, marking*

Table 19.8 Powered air purifying respirator (PAPR) checklist

Item		Description of Inspections to be Carried Out
Daily/Pre-Start	Visual check	• Check for any visible damage or wear. Ensure all parts, including the helmet, facepiece and hoses are in good condition. • Ensure all components are free from obstruction & debris. • Check outer hose sheath for damage and pinholes from weld spatter etc. If holes or damage are present, check inner hose for leaks e.g. perform alarm check and airflow check. • Check that hose connections are secure.
	Battery check	• Check that battery is fully charged prior to use. • Check that the battery is free of damage. • Check that the battery is properly installed and secure.
	Filter and cartridge check	• Inspect condition of main filter, pre-filter, and spark filter mesh. Replace if visibly clogged, pierced or damaged. Do NOT attempt to clean PAPR filters, they are not user-serviceable. • Check that the correct filter and/or gas/vapour cartridge is installed. • Check that filters and cartridge are in-date and have not expired. Replace if expired.

	Alarm check	• Switch on belt unit and block the end of the hose by hand until the alarm sounds or visual warning is given:
		  • unblock the hose and the alarm/warning should cease.
		  • if warning/alarm is not activated, remove hose from belt unit and check for leaks. Replace hose if leaking.
		• Check any alarms or warnings for correct operation.

	Airflow check	• With correct filters/cartridge installed, turn on PAPR and check that it is operating.
		• Detach the air hose from the helmet and with the belt pack set to its lowest setting, use an airflow meter to measure the air flow at the helmet end of the hose. If the measured air flow is less than the minimum specified:
		  • check the hose for leaks, replace if leaking;
		  • replace the filters/cartridge;
		  • repeat the test. If minimum airflow cannot be achieved, withdraw unit from service and send for repair.

	Headpiece check	• Ensure all clear cover lenses are clean. Replace if scratched or damaged. • Check that the face seal is intact and undamaged. • Check that the headpiece fits properly and forms a good seal.
Weekly	Inspect hose	• Check inside of hose for dirt. Replace hose if the inside is dirty. • Check the hose for leaks by removing the hose from the outer sheath and stretch to look for holes, cracks and creases. Replace hose if leaking.
	Clean helmet	• Wipe exterior with damp cloth to remove dirt and dust. Check inside of helmet, air vents and face seals, clean if required.
	Face seals	• Check face seal for damage or excessively dirty. Replace as necessary.
	General	• Check all components for damage, cracks, wear, air leaks, etc. Replace as necessary.
Annual	General Service	• Clean and sanitise the helmet and PAPR system, replacing all filters, helmet face seal, hose, and hose cover, helmet cover lenses (if damaged or scrtched), helmet sweatband. • Check battery for damage and ability to retain charge for the minimum specified duration. Replace if required. • Replace battery if charge cycles have exceeded 500 cycles.
Notes • Some PAPR suppliers offer an annual maintenance, sanitisation and inspection service. • Record details of checks performed.		

Table 19.9 Fume extractor checklist

Item		Description of Inspections to be Carried Out
Daily/Pre-Start	Visual check	• Check vacuum and extraction hoses, nozzles and enclosures for visible damage or wear. Ensure all parts, especially hoses, are in good serviceable condition. • Ensure all components are free from blockages, obstruction and debris. • Check that all connections are secure.
	Filter check (where fitted)	• Inspect condition of the filter. If visibly clogged and manufacturer's instructions permit, clean using dry oil-free compressed air, or replace. Replace if pierced or damaged. **WARNING***: Particulates collected are hazardous, PPE must be worn by the operator to prevent inhalation. Do NOT clean in the vicinity of other personnel.* • Check that the correct filter is installed. • Check filter media and housing for signs of breakthrough, by-pass and/or build-up of surface deposition. • Check that filter is in-date and has not expired. Replace if expired.
	Operation and airflow check	• Switch extraction unit on and verify air flow on the welding gun /torch (on-gun extraction only) or at the extraction hood/inlet (hooded extraction only). • Verify air flow at the air outlet on the unit (portable units only). • Check operation and ease of movement of moveable ducts and flexible arms (hooded extraction only).
	Air supply (self-cleaning equipment only)	• Check suitable air supply is connected, air is dry and oil-free, and compressor is operating. • Initiate the self-cleaning function as per the manufacturer's instructions.
	Dust and fume collection	• Check contents of dust/fume collection container/tray/bin. • If required, empty fume collector into suitable bag or container and seal. Dispose of dust/fume in conformance with local regulations. **WARNING***: Particulates collected are hazardous, PPE must be worn to prevent inhalation. Do NOT empty in the vicinity of other personnel.*

Weekly	Inspect extraction arms and hoses	• Check extraction hoses and arms are free of damage, cracks and air leaks. Replace as necessary.
		• Check shielding gas flow rate (on-gun extraction systems only).
		• Measure the extraction volume flow rate and verify it is within manufacturer's specified limits.
		  • measure at the extraction nozzle (on-gun extraction).
		  • measure the face velocity at the extraction hood (hooded extraction).

	Filter(s)	• Check back-pressure drop across the filter media and compared with specification. Replace filter(s) if non-compliant. • Verify operation of the self-cleaning function as per the manufacturer's instructions (self-cleaning systems only).
	General	• Check power cable and connections, verify that electrical safety test tag is in-date. • Check all components for damage, cracks, wear, leaks, etc. Replace as necessary. • Empty collector container/tray/bin (see above).
Annual	General Service	• Check all hoses including compressed air hose, replace is damaged, cracked or there is evidence of deterioration or perishing. • Replace filters if expired or if in use for more than 12 months.

Notes

- To prevent hazardous materials coming into contact with the operator's hands, body, eyes and airways, suitable PPE including P2 or P3 masks must be worn when emptying dust/fume trays or containers, or cleaning filters with compressed air. Do not perform these operations where there is poor ventilation, strong air flows or other personnel are nearby.
- Power cables for portable fume equipment should be tested and tagged (see AS/NZS 3760)
- Record details of checks and tests performed.

20. Welding and Cutting in Confined Spaced

20.1 Introduction

Working in a confined space is controlled by jurisdictional WHS regulators and their WHS regulations in each State and Territory, and in accordance with Australian Standard AS/NZS 2865[1].

> **Note**: *Liquid engulfment referred to in this Chapter is excluded from Victorian regulations. Additional information can be found in the WorkSafe Victoria Compliance Code publication titled Confined Spaces.*

20.1.1 Identifying a Confined Space

The definition of a confined space can vary, but typically refers to an enclosed or partially enclosed space that is not intended or designed primarily for human occupancy, within which there is a risk of one or more of the following:

a) An oxygen concentration outside the safe oxygen range;

> **Note**: *AS/NZS 2865[1] defines the safe oxygen range as a concentration of oxygen in the atmosphere having a minimum of 19.5% by volume and a maximum of 23.5% by volume, under normal atmospheric conditions.*

b) A concentration of airborne contaminant that may cause impairment, loss of consciousness or asphyxiation;

c) A concentration of flammable airborne contaminant that may cause injury from fire or explosion;

d) Engulfment in a stored free-flowing solid or a rising level of liquid that may cause suffocation or drowning.

In some jurisdictions, the definition of a confined space may include reference to a restricted means of entry and exit.

Notes:

1. *Enclosed or partially enclosed spaces that may meet the definition criteria for a confined space are:*
   a) *Storage tanks, tank cars, process vessels, boilers, pressure vessels, silos and other tanklike compartments;*
   b) *Pipes, sewers, shafts, degreaser and sullage pits, ducts and similar structures; and*
   c) *Any shipboard spaces entered through a small hatchway or entry point, cargo tanks, cellular double bottom tanks, duct keels, ballast and oil tanks, and void spaces.*
2. *Appropriately sized entry and exit points are important for the safe entry and exit or retrieval of a person(s) in an emergency, however, not all confined spaces have a restricted means of entry and exit.*
3. *Most enclosed or partially enclosed spaces are intended or designed primarily for human occupancy, e.g. offices and workshops where adequate ventilation and lighting, safe means of access and egress, etc. are provided. From time to time they may have atmospheric hazards produced by task-related activities such as welding. Such task-related hazards are not covered by this Standard and other safety systems apply.*
4. *Some enclosed or partially enclosed spaces have atmospheric contaminants that are harmful to persons but are designed for persons to occupy e.g. abrasive blasting or spray painting booths. Enclosed or partially enclosed spaces that are intended or designed primarily for human occupation and have systems such as gaseous fire extinguishing systems (see AS 4214[2]) or inert gas systems for beverage dispensing (see AS 5034[3]) installed, are not confined spaces.*

In such cases, other safety systems such as relevant legislation, Standards or Codes of Practice apply.

5. *A rising level of a liquid in an enclosed or partially enclosed space may cause engulfment through the inability of a person to readily exit the space. Drowning in a reservoir, dam or tank where the level of liquid is static is not considered to be drowning from engulfment.*

20.1.2 Atmospheric Hazards and Engulfment Hazards of Confined Spaces

Confined spaces can present a risk from atmospheric hazards or engulfment. These may include the following:

a) Oxygen concentration in the atmosphere below 19.5% in the confined space, which may be caused by:
   i) Slow oxidation reactions of either organic or inorganic substances e.g. rusting;
   ii) Rapid oxidization e.g. a fire;
   iii) Displacement of oxygen in the atmosphere by other gases; or
   iv) Absorption by stored substances.

b) Oxygen enriched atmospheres, with oxygen concentration greater than 23.5% by volume. Atmospheres with oxygen enrichment have an increased risk of fire or explosion, particularly when flammable contaminants are present. Causes of oxygen enriched atmospheres in confined spaces include:
   i) Inadvertent purging with oxygen;
   ii) Oxygen injection systems (used in sewerage systems); or,
   iii) Using a cutting process such as oxy acetylene which can rapidly increase the oxygen content.

c) The presence of contaminants in the atmosphere or on surfaces. The sources of contaminants encountered may include:

i) The manufacturing process;

ii) The substance stored or its by-products (e.g. petroleum products, or disturbing decomposed organic material that may liberate toxic substances such as hydrogen sulphide); or,

iii) Hazardous services connected to the confined space (e.g. gases, vapours, fumes, solids, liquids, sludge, particulates etc).

d) Free-flowing solids stored in the confined space, e.g. grain, sugar, flour, sand, coal or fertilizer.

NOTE*: Some stored materials can form a crust or bridge when a container is emptied from below, leaving the top layer in place e.g. grain, sand etc. Workers walking on the crust or bridge may be engulfed if the crust cracks or dislodges and the bridge collapses (see Figure 20.1).*

e) An increase in the level of a liquid in the confined space.

20.1.3 Task-related Hazards and Other Occupational Hazards

The tasks a person is required to conduct may expose them to risks from the hazards associated with the occupational environment and the task(s) being conducted. These task-related hazards may include the following:

a) A reduction in the oxygen concentration in the atmosphere to below 19.5% by volume in the confined space. This may be caused by fire or respiration, or leaking gas cylinders (containing gas that displaces oxygen). The use of air-LPG burners for preheating will rapidly deplete oxygen.

b) Oxygen enriched atmospheres with oxygen concentration greater than 23.5% by volume, which may be caused by:

   i) A leaking oxygen hose or fitting when using oxy-acetylene equipment; or,
   ii) The use of chemicals that release oxygen e.g. hydrogen peroxide; or,
   iii) Using a cutting process such as oxy acetylene which can rapidly increase the oxygen content.

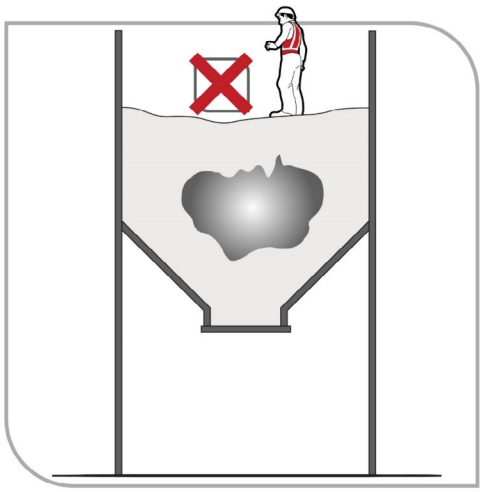


Figure 20.1 Example of bridging which may result in engulfment
Source: Safe Work Australia[4]

c) Airborne contaminants e.g. welding fume, chemicals used for metal preparation, dust, fibres, and lead or mercury fumes.

d) Inability to maintain continuous communication and/or observation between those in the confined space and the stand-by person(s), or other systems of work methods and controls provided for an equal or better safety outcome.

e) Noise, e.g. that caused by hammering or the use of equipment within the confined space.

f) Temperature (either high or low) resulting from the occupational environment or the weather conditions, or where appropriate ventilation is not provided, or appropriate clothing is not worn. This is of particular concern when carrying out hot work which requires and generates heat.

g) Radiation within the confined space e.g. from X-rays, radiation gauges, isotopes, lasers and welding equipment.

h) Manual handling.

i) Unsafe entry and exit or unsafe surfaces.

j) Inadequate lighting.

k) Restricted entry or exit.

l) Openings obstructed by fittings or equipment that could impede rescue.

m) Entrapment from the operation of moving equipment, e.g. being trapped by augers, or crushed by rotating or moving parts such as conveyor belts.

n) The tasks conducted in the confined space e.g. painting with coatings containing toxic or flammable contaminants, welding or brazing with metals capable of producing toxic fumes.

o) Exposed live electrical conductors.

Particular attention should be given to the task-related hazards created by a work team(s) in, on or near the confined space that may affect other work team(s) within the confined space (refer to AS/NZS 2865[1]).

Many confined spaces are also electrically hazardous environments, in which case the requirements of Sections 14.6 or 14.7 apply. If confined spaces are hot and humid, the requirements of Chapter 23 also apply.

When working in confined spaces or under cramped conditions, the precautions required during normal welding require additional attention. For example, additional care is required in respect of hazardous atmospheres where flammable, toxic or asphyxiating gases may be encountered. Always check the previous contents of the confined space when flammable, explosive or toxic materials are suspected. Always check that oxygen has not been depleted by excessive rusting of steel or snowflake corrosion of aluminium. Always check that explosive, toxic or oxygen-displacing gases do not build up due to leakage etc. Gas detection devices for checking oxygen content, flammability, explosivity and for identifying toxic gases are available commercially.

20.2 Supervision, Permits and Precautions

a) *Permits*: In all circumstances where such welding is required, a responsible person such as a safety officer should supervise the preparations for work and issue suitable permits. A risk assessment must be undertaken to identify all hazards, assess the risks and put controls in place before issue of a permit.

b) *Testing*: The atmosphere and any materials present in a confined space should be examined and if necessary tested in respect of toxicity and flammability before working. Where required, the cleaning and safe working procedures given in Chapter 21 should be carried out i.e. where the contents or previous contents are known or suspected to be flammable, explosive or toxic.

20.3 Ventilation, Shading and Thermal Insulation

20.3.1 Ventilation

The following points should be noted:

a) *Local exhaust ventilation* is a prerequisite in confined space welding and cutting.

b) The specific type of ventilation depends essentially on the size of the confined space and welding process being carried out and required cooling.

c) All air, replacing that withdrawn, must be clean and respirable.

d) *Oxygen* or oxygen-enriched gases must *never* be used for ventilation.

e) If it is impracticable to provide adequate ventilation, suitable air supplied personal respiratory protection (see Section 19.6) must be used.

NOTE*: PAPRs may be unsuitable for use in confined spaces as their filters can be quickly clogged in the event of poor or restricted ventilation and a build-up of fume, and oxygen levels cannot be ensured. Air-supplied respiratory protection is preferred.*

20.3.2 Shading

In a confined space or vessel in sunshine, shading (tarpaulins etc.) should be used to reduce heat stress (see Section 23.2).

20.3.3 Thermal Insulation

If preheat is needed, insulate all heated parts not being welded to reduce heating of airspace occupied by welder and to reduce risk of burns. This insulation must not break down to give toxic fumes. Additional ventilation may be needed to cool personnel.

20.4 Atmospheric Testing and Monitoring

Atmospheric testing should include testing by calibrated and well maintained instruments:

a) Oxygen concentration.

b) Concentration of flammable airborne contaminants: and

c) Concentration of airborne contaminants.

Refer to local regulations and Codes of Practice[4], and AS/NZS 2865 Section 3 and AS/NZS 2865 Appendix I[1] for detailed guidance on implementation of confined space management.

Consideration should also be given to atmospheric testing and monitory in the areas close to the access point for the confined space, particularly where there is a possibility of contaminant leakage.

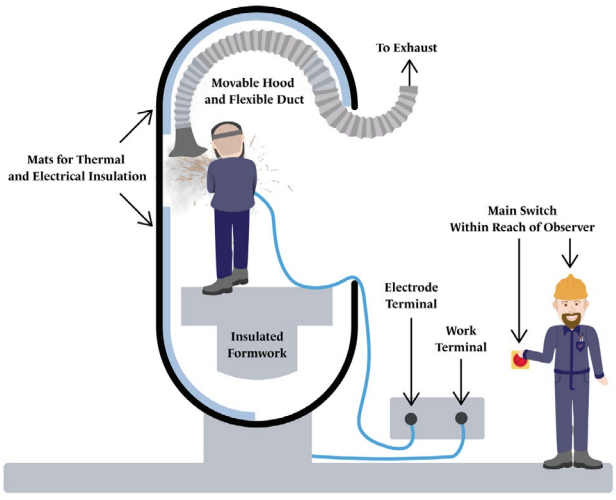


Figure 20.2 Confined space welding
NOTE: Work lead should be attached to directly to the workpiece

20.4.1.1 Gas Monitors

Gas monitors used for the purpose of atmospheric monitoring within a confined space should be maintained and used in accordance with the manufacturer's instructions and warnings (refer to AS/NZS 60079.0[5] and AS/NZS 60079.11[6]).

20.4.1.2 Challenge Testing

Gas monitors should be challenge tested on a routine basis using premixed calibration gases to ensure their accuracy and sensitivity across the range of use. Detectors can become contaminated ("poisoned") leading to potential errors in readings.

> **Note***: Challenge testing requires the instrument to correctly determine the concentration of a premixed "calibration gas" at appropriate concentration close to the value being measured.*

20.5 Electric Shock

Because of the cramped conditions and probability of the welder sweating excessively, the risk of electric shock is greatly increased and deaths have occurred in these conditions in Australia. In addition to the normal safe operating procedures outlined in Chapter 14, the following measures should be taken:

a) All electric welding in confined spaces should be managed in accordance with the requirements of AS 1674.2[7] Category C environments. A welding safety observer is a dedicated role whose sole responsibility is to monitor the welder's activity and is capable of responding in an emergency (AS 1674[7]). This welding safety observer cannot be the Confined Space Stand-by person or perform any other role if the additional role compromises their ability to perform their role as the welding safety observer.

b) *Power sources* are to be left outside the confined working space and should preferably be DC with an active VRD.

c) *Power supply hazard reducing devices* that eliminate or restrict the no-load voltages to a value as low as practicable should be used (see AS 1674.2[7]).

d) *Electrical connection* to electrodes, work and equipment should be fully insulated and thoroughly checked.

e) *Means for cutting off power* to the welding unit should be installed and readily accessible. Alternatively, due to the proximity of the mains switch or the power source outside the confined space entry, a secondary HRD such as in line

emergency cut-out switch located in the electrode lead, is a good option to de-energise the power supply to the electrode holder. The emergency cut-out switch can be located inside or outside the confined space entry and is operated by the competent welding safety observer – prior to the welder operator changing the electrode or in an emergency situation, thereby removing any potential electric shock risk to the welder contacting a "live" electrode.

f) *Insulating mats* or layers of a suitable material to insulate the welder from the walls of the vessel should be provided (Figure 20.2).

g) *Electrical lighting* and other electrical equipment (e.g. portable electric grinders) used in the confined space must be fully or double insulated and in good condition with heavy-duty cables connected to RCD-protected circuits. Preference should be given to pneumatic or battery powered equipment.

h) *High frequency* should not be used in confined spaces because ordinary insulation is ineffective against high frequency.

Scratch or lift-arc starting in GTAW (TIG) starting is preferred where this process is used in confined spaces.

It is not recommended that HF be used in confined spaces. Wherever HF is used, the circuit must be such that HF current will not create a danger for the welder or other personnel e.g. inside confined spaces with metal walls. Additionally, precautions should be made to avoid interference by electromagnetic fields created by HF currents and voltages with other equipment (see AS CISPR 11[8]).

Improved technology in power sources such as lift arc GTAW enables easy starting and stable arc conditions without the need for high voltage pilot arcs, effectively eliminating the hazard.

NOTE*: Canadian Standard CSA W117.2-19[9] warns that persons with metal implants should be aware that at least one case (2 persons using the same welding machine) has been reported in which the welder experienced a burning sensation around the metal implant while using a high frequency welding process.*

20.6 Flame Cutting, Welding or Preheating

Where gases are required for cutting, welding or preheating, precautions are required to ensure a build-up of toxic or flammable gases cannot occur. The following precautions should be observed:

a) *Gas cylinders* are to be kept away from the working area and preferably outside the confined space.

b) *Blowpipes* should be lit outside to avoid gas and heat build-up inside the confined space.

c) *Torches and pressure hosing* connected to the supply are not to be left inside the working area when not in use. Very slow leaks of oxygen or fuel gas can allow an explosive atmosphere to build up rapidly.

d) *Flame cutting* may result in a build-up of oxygen level due to only a small portion of the oxygen from the cutting jet being consumed in the cutting operation. Ventilation is required to ensure that the oxygen levels do not increase.

NOTE*: The presence of an oxygen enriched atmosphere can compromise the flame resistance of clothing being worn by personnel working in the confined space, making normally non-flammable or flame resistant materials highly flammable without warning.*

e) *Preheating* using a gas flame that is not supported by oxygen, such as a naturally aspirated LPG flame, will rapidly deplete the oxygen level in a small confined space. Ventilation is required to ensure that the oxygen levels do not decrease.

f) *Build-up of asphyxiant gases* will accompany any gas cutting or heating activity carried out in a confined space. Ventilation is required to ensure that the asphyxiant gas levels do not increase.

20.7 The Welder

Working under confined space conditions increases the fatigue experienced by the welder and can therefore reduce their concentration level. This situation is more serious in hot conditions that can arise from either preheating or build-up of heat during welding. Additional care in selection of working clothing and protective clothing is required (see also Chapter 19):

a) Flame resistant protective clothing, e.g. compliant to AS/NZS ISO 11611 Level 210 or wool is required to be worn;

b) Clothing soiled with readily combustible materials such as oil or grease, should not be worn;

c) Gauntlet gloves in good condition without metal rivets should be worn. They should be of flame resistant material and be kept dry;

d) Footwear should be robust, watertight and of the non-nailed type. Steel toecaps are recommended, but metal should not be exposed;

e) Protection from reflected radiation from the walls of the vessel is required to prevent burns to the back of the neck;

f) Rest periods should be allowed for. This may be achieved by using several welders in turn;

g) Special provision will be required where very hot conditions are experienced (see Chapter 23).

20.8 Emergency Removal of Personnel from Confined Space

Where access to the confined space is limited e.g. through a manhole, provisions are required to be made to allow rapid removal of the welder in an emergency. These include:

a) *Safety harnesses* with lifelines are recommended (e.g. Figure 20.3) and are a legal requirement in some instances. Care is required to ensure the welder's body will not jam in small exits;

b) *A helper or observer* with a pre-planned rescue procedure and suitable training should be stationed outside to observe the welder at all times and to be capable of putting rescue operations into effect;



Figure 20.3 Welder secured by a retractable harness

c) *The observer* must be aware that an unprotected person must not enter a space where another person has collapsed before taking appropriate precautions.

20.9 Typical Check List

The following sequence of checks is recommended for confined space work:

a) Pre-Entry

i) Work selection and planning

ii) Hazop, Task-based Risk Assessment, develop control measures

iii) Risk Assessment control measures must consider:
- Atmosphere (purging or ventilation)
- Flammable gases and vapours
- Fire and explosion
- Activity and recognition of potential hazards (both inherent and what will be introduced by the hot works or welding)
- Additional observer type roles required (e.g. larger confined spaces may require additional weld-ing safety observers or firewatchers inside the space).

iv) Identify all sources of external energy and stored energy

v) Isolate the confined space from all sources of external energy and stored energy

vi) Prepare a Confined Space Access Permit

vii) Implement control measures for the work

viii) Worker information, training and instructions (see AS/NZS 2865[1]) including:
- Confined space training
- Recognition and nature of all hazards associated with the confined space and the proposed work
- Nature of the work
- Need for and appropriate use of risk control measures
- Selection, fit, use, wearing, testing, storage and maintenance of any PPE
- Contents of any relevant confined space entry permit, and confined spaces
- Emergency procedures

ix) Responsibilities of responsible person

x) Sign onto the Confined Space Access Permit

b) Entry

i) Isolation of confined space

ii) Confined space signage to be placed at the entrance

iii) Precautions at entrance to confined space

iv) Implement control measures

v) Standby person in place

vi) Sign onto the access sheet

vii) Initial testing and recording of confined space atmosphere

viii) Comparison of initial test results to establish ventilation or personal protection

ix) Ventilation and provide personal protective equipment

c) During Entry

i) Continuous or period monitoring of confined space atmosphere

ii) Assure safe workplace practice is followed

e) After Entry

i) Re-issue permit after prolonged absence if conditions change

ii) Confirm that all persons and equipment are accounted for

iii) Review the operation and comment on unsatisfactory aspects

iv) Acceptance of completed job

f) Exit

i) Sign off from the access sheet

ii) Re-validate confined space control measures after a prolonged absence or if conditions change

g) Completion of Work

i) Sign off from the Confined Space Permit

ii) Confirm that all persons and equipment are accounted for

iii) Review the operation and comment on unsatisfactory aspects

iv) Acceptance of completed job

v) Person in Control to return the CS Permit

vi) Keep and maintain copies of the Risk Assessment and Confined Space Access Permit

See Appendix F for an example of a form for a Confined space entry permit.

20.10 References

1. Standards Australia, AS/NZS 2865, *Confined spaces*
2. Standards Australia, AS 4214, *Gaseous fire-extinguishing systems*
3. Standards Australia, AS 5034, *Installation and use of inert gases for beverage dispensing*
4. Safe Work Australia, Model Code of Practice, *Confined spaces*
5. Standards Australia, AS/NZS 60079.0, *Explosive atmospheres, Part 0: Equipment — General requirements*
6. Standards Australia, AS/NZS 60079.11, *Explosive atmospheres, Part 11: Equipment protection by intrinsic safety "i"*
7. Standards Australia, AS 1674.2, *Safety in welding and allied processes Part 2 Electrical*
8. Standards Australia, AS CISPR 11, I*ndustrial, scientific and medical equipment — Radiofrequency disturbance characteristics — Limits and methods of measurement (CISPR 11:2015+AMD1:2016 (ED.6.1) MOD*
9. CSA Group, CSA W117.2, *Safety in welding, cutting and allied processes*
10. Standards Australia, AS/NZS 11611, *Protective clothing for use in welding and allied processes*



21. Welding or Cutting in or on Containers

21.1 Introduction

For the purposes of this Chapter a container includes any piping, vats, tanks, drums, vessels. Welding or cutting in or on or near containers may present hazards not commonly encountered in welding or cutting operations. For example, hazards could arise from the flammability, toxicity and explosive characteristics of contained liquids, gases or solids or from their release. Welding of components under internal pressure also poses obvious hazards to the operator and those in the vicinity (see Chapter 22).

Where containers are known or suspected to have contained flammable or toxic substances, the provisions of Section 21.3 must be carried out prior to welding.

Where the work represents a confined space situation, the provisions of Chapter 20 are to be adhered to. The requirements of AS 1674.1[1] should be met.

21.2 Supervision and Approval

21.2.1 Permits

a) In all situations where such work is to be carried out, a responsible person such as a safety officer should supervise all preparations for the work and issue the necessary work permits.

b) Permits need to be issued in the following circumstances:
   i) To carry out hot work on the outside of a container, large or small
   ii) To enter the confined space of a vessel, i.e. requiring a gas free permit
   iii) To carry out hot or cold work inside a vessel

21.2.2 Gas Freeing Area

Unless a building has been designed and approved for such work, all "gas freeing" must be performed outdoors, remote from all sources of ignition (in the case of combustibles) or sufficiently isolated to protect personnel in the immediate vicinity. The following points should be noted:

a) Gas freeing areas should be clearly identified.

b) The container should be positioned where vapours will not drift indoors, towards sources of ignition (in the case of combustibles) or endanger personnel in the case of toxic or asphyxiating gases.

c) Many vapours are heavier than air and will accumulate in low areas.

d) Safe distances need to be established from sources of ignition in the case of combustibles and air contamination requirements in the case of toxic gases, etc.

e) Where water or steam is used, the work area must have a sealed area complying with statutory and environmental requirements.

f) Gas free status atmospheres for safe entry must be checked by instruments that are used by experienced and qualified personnel. Unless skilled personnel are used, there is a likelihood of dangerous consequences due to malfunctioning of the instrument.

21.2.3 Other Considerations

a) Identification of contained materials or previously contained materials and assurance that safe conditions apply is required prior to issuing of work permits (see Chapter 20 and Section 21.3).

b) Fire precautions outlined in Chapter 16 should be adhered to even if the relevant precautions noted in Section 21.3 have been carried out.

c) Interruptions to work that involve a reasonable elapsed time require an assessment of the conditions to ensure that it is safe to recommence work.

21.3 Welding or Cutting Containers That Have Held Combustibles

21.3.1 Introduction

The obvious hazard associated with welding or cutting containers that have at *any time* contained combustible liquids or gases is the risk of explosion or fire. Additionally, precautions are required where the contained material is such that a toxic gas or dust could be released or formed during cleaning, purging or welding or cutting operations.

The following provides basic guidance in identification and avoidance of possible hazardous situations. More detailed information is provided in AWS F4.1[2].

21.3.2 Identification of Hazard

It is important to identify completely the type of liquid, gas or other flammable material that has been or remains in the container. This provides assistance in determining appropriate means of avoiding fire, explosion or other health risks. The more common hazardous situations are noted below:

a) If the previous contents of a container to be worked on are unknown, it should be treated as having contained a combustible toxic substance however long it may have remained empty.

b) Petroleum products and other volatile liquids release vapours at atmospheric pressure that may remain after a container is emptied particularly in lapped or fillet welded joints.

c) Containers that have contained plastic products, heavy oils or tars or have been coated inside or outside with plastic or paint may fill with explosive vapours when the metal is heated by welding, cutting etc. The welding or cutting may then provide the spark that sets off an explosion.

d) Hydrogen may be present in metal containers that have held an acid, due to reaction between the metal and acid.

e) Deposits of sludge, scale, traces of gum, resin, varnish, bitumen or similar non-volatile oils or solids may release flammable or explosive gases when heated in welding or cutting operations.

f) Explosive conditions may exist if a container has held a flammable or explosive solid and finely divided particles of this matter are present in the form of dust. Examples are wheat silos or coal storage bins (see Section 16.3).

21.3.3 Basic Precautions

The following lists the basic precautions to be met when welding or cutting on containers that hold or have previously held combustibles.

a) Appropriate chemical analysis carried out by qualified personnel should be used to identify any doubtful situations. Even small amounts of residual gas-forming substances can cause a serious explosion.

b) Sight or smell CANNOT be used to determine if safe working conditions apply and could prove fatal through the inhalation of toxic vapours.

c) Cutting, welding or heating should only be carried out by experienced welders directly supervised by a person who fully understands the hazards involved.

d) Cleaning by methods appropriate to the size of the container and nature of its contents is required prior to cutting or welding except where the hazard can be avoided by other methods (see Section 21.3.4).

e) Ventilation during cleaning should be such that any flammable gases are quickly and safely dispersed. Open air cleaning is preferred. Note that some gases (e.g. vapour from petroleum products) are heavier than air and will tend to collect at floor level.

f) Ignition sources listed below can be dangerous:
   i) Flame or arc from welding and cutting, hot metal, smoking, matches or a lighter
   ii) Electrical discharge from equipment not approved for hazardous areas
   iii) Defective electrical equipment
   iv) Portable equipment (electrical)
   v) Electrical power tools (e.g. drills, grinders etc)
   vi) Hot-air guns or heating torches
   vii) Hot engine exhaust
   viii) Friction or impact sparks (grinding or abrasive disk cutting)
   ix) Spontaneous combustion (oily rags)
   x) Auto ignition from vehicle
   xi) Static electricity including discharge for synthetic clothing or footwear
   xii) Lighting – electrical

g) Chisels, hammers etc. made of steel should not be used for cleaning or scraping of residues as sparks can be generated and ignite gases. Wooden or bronze mallets and scrapers of non-sparking material are preferred e.g. copper beryllium tools.

h) Internal piping, baffles, trays etc. should, where possible, be removed and drained to facilitate cleaning.

i) Residue removed from containers should

immediately be stored in a safe place.

j) Compartments within a container should all be treated in the same manner, even if only a localised portion of the container is to be worked on.

k) Rendering of materials to a non-explosive or non-flammable condition may, under certain circumstances, provide an alternative to cleaning (see Section 21.3.6).

l) Solvents may in themselves constitute a hazard in a welding environment and advice should be sought before their use.

m) Washing with either hot or cold water is not generally an acceptable method of cleaning as many materials are not soluble in water. Exceptions are noted in Section 21.3.4.

n) Waste material should be disposed of safely.

21.3.4 Cleaning Procedures for Small Containers

There are a number of methods in common use for the cleaning of small containers. Brief details are given below and more complete information can be found in reference 30.

Cleaning of a vessel is necessary in all cases. It should be supplemented by filling the container with water or an inert gas prior to and during the hot repair work (see Sections 21.3.5 and 21.3.6).

21.3.4.1 Water Washing and Rinsing

a) *Application*: Only suitable for substances known to be readily soluble in water, e.g. acids, caustic, acetone, alcohol.

b) *Basis*: Water soluble contaminants are rendered safe by dilution in water.

c) *Method*: Complete filling and draining of containers a number of times with appropriate testing of the drained liquid.

d) *Caution*: Dilute acids frequently react with metals to produce hydrogen when concentrated acids will not. All traces of acid must therefore be removed by repeated flushing.

21.3.4.2 Hot Chemical Solutions

a) *Application*: Suitable for containers that are not entered by workmen and that have contained petrol, domestic heating oils and other light petroleum by-products.

b) *Basis*: Hot chemical solutions emulsify contaminants so they can be removed by water rinsing.

c) *Method*: A two-stage cleaning process is generally used that involves thorough flushing of the container with water to remove any remaining sludge, scum or liquid followed by cleaning with a hot solution of detergent. The cleaning procedure involves:

i) Dissolve chemicals in small quantities of boiling water and pour into container. Typical chemicals used are sodium silicate or trisodium phosphate; the amount required being determined by the size of the container.
ii) Fill container with fresh water.
iii) Make a steam connection either to a separate drain connection at the bottom of the container or by a pipe through the filling connection or vent and leading to the bottom of the container.
iv) Maintain solution at 75° to 90°C.
v) During steaming, add sufficient water at intervals to allow discharge and continue steaming until the overflow is clear.
vi) Drain container and carry out an appropriate gas test before issuing work permits.
vii) Caution: Personnel should guard against injury from either steam or caustic cleaning compounds by wearing suitable protective clothing. The chemicals used in cleaning should be such that corrosion of the container cannot occur.

21.3.4.3 Steaming

a) *Application*: As for hot chemical method.

b) *Basis*: Steaming provides heat to vaporise and remove contaminants.

c) *Method*:

i) Where practicable, the inside surfaces should be flushed with a 25% caustic solution and the container thoroughly drained prior to steaming.
ii) For containers with two openings, live steam

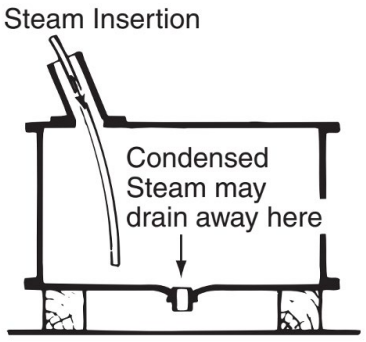


Figure 21.1 Arrangements for steam cleaning a container

should be blown through the drainage hole. When the container has only one opening it should be positioned so that condensed steam can drain away whilst steaming continues.

iii) *Low Pressure should not be used* as this will not provide sufficient cleaning action. Steam pressure should be controlled by a valve positioned at the head of the filling hose, or pipe. The arrangement must not be able to over-pressurise the container.

iv) Continue steaming until the container is free of odours and sufficiently hot to allow steam to freely flow out of the container vent and all parts of the container are hot.

v) Flush container with boiling water and drain.

vi) Inspect the inside of the container to ensure it is clean. This may require the use of mirrors to reflect light into the container.

vii) Carry out appropriate gas tests before issuing work permits.

viii) Figure 21.1 illustrates suitable arrangements for steam cleaning methods

d) *Caution*: Metal nozzles on the steam line should be non-sparking types to prevent accidental ignition of flammable gases. Metal nozzles should be electrically bonded to the container and the container also grounded to prevent a build-up of static electricity. Protective clothing including that necessary to protect the operator's head and hands is required in steam cleaning. Any light sources used for inspection purposes should be of a type approved for use where flammable vapours are present.

21.3.5 Water Filling Treatment

a) *Application*: It is advisable to use either this method or the inert gas treatment (Section 21.3.6) to supplement the cleaning methods described. Dependent upon the contents of the container and if the container is in a non-hazardous location, it may be approved as the sole method required before commencing hot work.

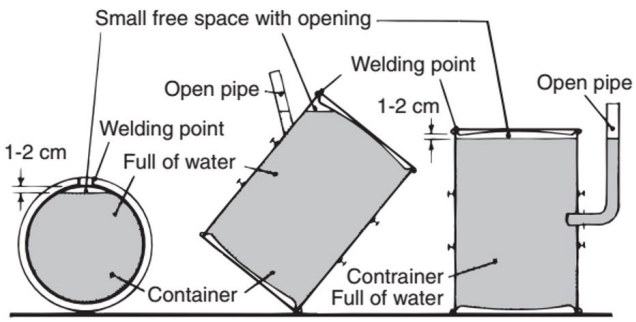


Figure 21.2 Arrangements for water filling

b) *Basis*: Water is used to reduce the vapour space to a minimum. There may still be flammable vapours within the space, but the volume of gas has been reduced as much as practicable. Inert gas is then introduced into the remaining space to displace the remaining air and eliminate all oxygen.

c) *Method*: The container is filled with water to within a few centimetres of where welding or cutting is to be carried out (Figure 21.2). Vents or openings are required to allow the release of heated air or vapour from the container.

d) *Caution*: Approval of this method as a single means of protection requires written approval of a responsible officer.

21.3.6 Non-flammable Gas Purging – Inerting

a) *Application*: As for water filling treatment (see Section 21.3.5 above).

b) *Basis*: Use of this method requires that flammable gases and vapours are rendered safe within the container by diluting them sufficiently with a non-flammable gas (the lower explosive limit (LEL) and lower flammable limit (LFL) for any flammable species depends on the oxygen concentration). The aim is to reduce the oxygen concentration to well below the minimum oxygen level necessary to support combustion, known as the limiting oxygen concentration (LOC) or minimum oxygen concentration (MOC). When the oxygen concentration is well below the LOC, flammable gas or fuel vapour can be safely generated by hot work on the container because the possibility of internal explosion has been eliminated.

> **Note***: Limiting oxygen concentration, (LOC), also known as the minimum oxygen concentration, (MOC), is defined as the limiting concentration of oxygen below which combustion of a particular flammable species is not possible, independent of the concentration of fuel. It is expressed in units of volume percent of oxygen. The LOC varies with pressure and temperature. It is also dependent on the type of inert (non-flammable) gas.*

c) *Suitable Gases*: Carbon dioxide added as dry ice or in gas form and nitrogen are the most commonly used inerting gases. Oxygen or mixtures thereof



are dangerous. Shielding gases based on argon and carbon dioxide (possibly with up to 2.5% O_2) commonly used in welding are usually suitable for inerting a space and may be used for convenience.

> **Note**: *Whilst argon based shielding gases may be readily available and accessible in a welding workshop, they will generally be more expensive than alternatives such as nitrogen or carbon dioxide.*

d) *Method*:
   i) The only openings in the container should be a drain and a vent.
   ii) The container should be drained. If this is not practicable, the fluid level should be lowered to well below the area to be worked on.
   iii) Where possible, the portion of the container to be worked on should be uppermost.
   iv) Introduce inert gas in the amount required. A person who has thorough knowledge of this type of work must be responsible for the determination of the correct amount. Figure 21.3 (a) and (b) illustrates a typical arrangement for introduction of an inert gas. Ensure there is sufficient inert gas on hand to continue purging until the hot work is completed and the container is fully cooled.
   v) Tests of the contained gas must be carried out prior to and during work where extended work periods are required. A person who has thorough knowledge of this type of work must control continuous atmospheric monitoring of the concentration of oxygen within the container during the initial inerting and throughout the duration of the hot work.
   vi) The target oxygen level must be below the LOC for the gases or vapours that could be present in the container. Refer Table 21.1 for guidance on LOC for a number of flammable substances.

> **Note**: *In many industries, an LOC of 2% is used, which is 40% of the LOC for hydrogen, since hydrogen has the lowest LOC value of any flammable substances.*

e) *Caution*: Where solid carbon dioxide (dry ice) is used, protection is required to avoid bodily contact, as "burns" will result. Where solid carbon dioxide is used, openings should be fitted with non-return valves to prevent undue loss of gas or excessive pressure building up. Analysis of contained gas immediately before and during hot work is essential as hot work may release dangerous vapours. Gases emitting from the inerted container must be ducted away to a safe gas freeing area.

> **Note**: *Gas detectors must be suitable for monitoring oxygen at the target concentration.*

21.3.7 Large Vessels, Tanks etc.

a) *Methods*: These are essentially as described for small containers although of course on a very much larger scale.

b) *Caution*: Particular care is required where work is required to be carried out inside a container where there is a risk of the atmosphere being flammable,

Table 21.1 Typical Values of LFL (air), UFL (air), LOC (N air) and LOC (CO_2-air)

Flammable Substance	LFL (air)	UFL (air)	LOC (N-air)	LOC (CO_2-air)
Hydrogen	4.0	75.0	5.0	6.0
Carbon Monoxide	12.5	74.2	5.5	5.5
Methane	5.0	15.0	12.0	14.5
Natural Gas	4.5	15.0	12.0	14.5
Propane	2.1	9.5	11.5	14.0
Butane	1.6	8.4	12.0	14.5
Petrol	1.4	7.6	12.0	14.5
Kerosene	0.7	4.8	11.0	13.0

toxic or both. No welder should be required to enter such a vessel or tank until it has been certified to be:

i) Safe for entry; and,
ii) Safe to work in with an arc, flame or any ignition source

The precautions applicable to welding in confined spaces apply to this situation (see Chapter 20).

21.4 Welding on Containers and Piping Under Internal Pressure

See Chapter 22.

21.5 Welding on Closed Sections

On any occasion when hot work is contemplated on a closed section a thorough hazard identification and risk assessment should be carried out. A number of quite serious incidents have resulted from hot work being carried out on closed sections that created a fire or explosion. The fuel has been:

a) Hydrocarbons such as lubricating or hydraulic fluids that have seeped into the space due to cracking;

b) Hydrogen evolved by bacterial action on moist and/or rusty steel ballast within a closed space;

c) Hydrogen and carbon monoxide gas produced from incomplete combustion of a preheating flame.

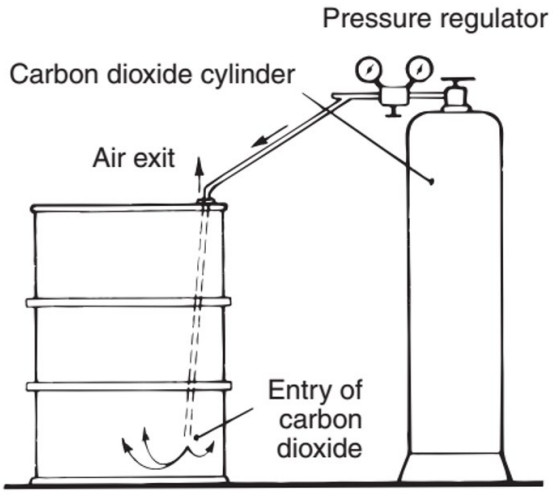
In all cases there was no expectation that there was anything flammable on the other side of the metal where the hot work was being carried out.

21.5.1 Purging with Inert Gas

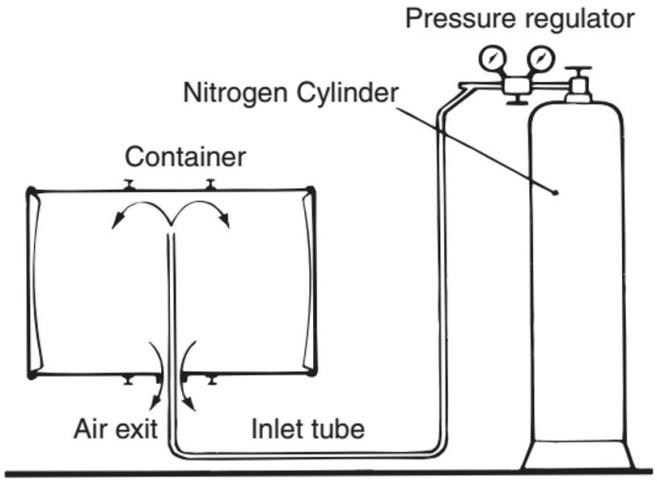
Before commencing hot work on a closed space, it is recommended that openings be made at the upper and lower extremities of the space to enable venting to the atmosphere and purging the space with inert gas. New equipment such as box section booms should be supplied with purging holes, typically sealed with a removable screwed plug. Where there is no provision for purging and venting, the initial penetration of the space must be made with caution, as there may be flammable material on the other side.

21.6 References

1. Standards Australia, AS 1674.1, *Safety in welding and allied processes, Part 1: Fire precautions*
2. American Welding Society, AWS F4.1, *Safe practices for the preparation of containers and piping for welding, cutting, and allied processes*



a) Protection by filling with carbon dioxide (heavier than air)



a) Protection by filling with nitrogen to displace dangerous vapour

Figure 21.3 Procedure for inert gas protection



22. Welding and Cutting on Pressurised Equipment

22.1 Introduction

This section gives a general overview of this topic and additional job safety and is recommended before performing this work safely.

Pressure vessels, pressure piping and pipelines often require to be welded whilst they are in operation.

Such welding operations commonly referred to on pressure piping and pipelines as hot tapping, require careful establishment of welding procedures and in particular, techniques of welding that closely control heat input. Depending on material properties, wall thickness, contents, pressure, temperature and flow rate there is a distinct risk that metal in the vicinity of the weld will become softened allowing the pressure to cause bulging and possible bursting. Conversely, in the event of insufficient heat input there is a risk of developing hydrogen cracking in or adjacent to the welds. There may also be a possibility of internal explosion and or degrading of the contents.

Welding on vessels, piping and pipelines is a highly skilled operation requiring proven welding procedures and practices, trained welders, very strict controls and safety requirements particularly the control of heat input.

AS/NZS 2885.2[1] has information relating to hot tapping. Certain conditions prevent the use of hot tapping operations and this is primarily dictated by pressure and the contents of the pipeline.

Some fluid contents could decompose under the heat input from welding to form explosive mixtures. A detailed knowledge of the fluid content and evaluation by a process expert (Chemical / Process Engineer) must be undertaken prior to commencement of any work.

The lining coatings and residues inside a pipe that will be affected by the heating operation could have a detrimental effect on the hot tap weld resulting in degradation in weld metal properties and cracking. Particular contents could break down under heat and hence the product could be affected.

22.2 Precautions

When welding on pressurised equipment such as boilers, pressure vessels, piping or pipelines (hot tapping), the following requirements apply:

a) Conformance with appropriate statutory regulations (see Appendix A).

b) Written specifications for safe procedures must be available and followed.

c) All work must be carried out under direct supervision of persons specifically responsible for such operations.

d) All operators must be competent, trained personnel who have been informed of the risks involved and the methods of avoiding problems.

e) In hot tapping, welding should be carried out in accordance with the requirements of AS/NZS 4645.2[2] and AS/NZS 2885.2[1]. Weld Australia's Technical Note 20[3] gives further information on this subject.

f) For critical applications an appropriate documented risk assessment should be performed including justification for why the hot tap is essential and the means to fully control the risk.

g) The application of high intensity localised energy during hot work procedures can generate dangerous volume changes and rapidly increasing pressures due to liquid to vapour and solid to vapour reactions.

22.3 Procedures

The main points to be considered in establishing safe welding or cutting procedures are:

a) Assessment of the thickness and integrity of the material in the area to be welded. This includes accurate knowledge of the material type.

b) Welding conditions must be such that the weld will not embrittle the parent metal and result in hot or cold cracking.

c) Welding conditions should be such that there is no risk of blowing through the pipe wall.

22.4 References

1. Standards Australia, AS/NZS 2885.2, *Pipeline systems — High pressure, Part 2: Welding*
2. Standards Australia, AS/NZS 4645.2, *Gas distribution networks Part 2: Steel pipe systems*
3. Weld Australia, Technical Note 20, *Repair of steel pipelines*



23. Welding and Cutting in Hot or Humid Conditions

23.1 Introduction

Adverse health effects occur when the human body is unable to dissipate heat at a satisfactory rate and core body temperature rises. International standards for working in hot conditions are aimed at keeping the core body temperature below 38°C since the risk of serious heat induced illness increases above that temperature. Heat is continuously produced within the body by metabolic processes in proportion to the rate of physical activity and this metabolic heat is usually the main contributor to raised body temperature. Hot working conditions also contribute to raised body temperature and are encountered with excessive exposure to the sun and when working with preheated steels or near furnaces. In some situations, essential work may be done at preheat temperatures up to 250°C provided that work is carefully planned, an adequate risk assessment is done, appropriate personal protective equipment is used, and an observer is constantly present. The ability to evaporate sweat is one of the main ways of regulating body temperature. Heat problems are exacerbated when working in heavy clothing or hot confined spaces.

23.2 Heat Stress

23.2.1 Effects of Heat Stress

The risk of heat stress increases as the body temperature rises above 38°C. Heat stress may:

a) Cause discomfort.
b) Cause excessive sweating thus increasing the risk of electric shock.
c) Cause dehydration and exhaustion.
d) Reduce concentration.
e) Aggravate pre-existing medical conditions.
f) In extreme cases, cause heat stroke that can be fatal.

These effects can also distract attention from safe working procedures and contribute to accidents.

Symptoms of heat stress should never be ignored, and steps taken immediately to cool the body.

Heat stress can rapidly progress to heat stroke (body's core temperature rises above 40°C) within minutes. Heat stroke is a life-threatening emergency, and immediate medical intervention is required to prevent permanent damage to the brain, kidneys, heart and muscles, which can be fatal.

In both cases, first aid treatment aims to quickly cool the body's core temperature.

23.2.2 Contributing Factors

The major factors that contribute to heat stress are:

a) Physical effort required and duration of work.
b) Ambient environmental temperature (indicated by dry bulb thermometer).
c) Radiant temperature of the surroundings.
d) Relative humidity (indicated by wet bulb thermometer).
e) Type of clothing worn.
f) Poor air movement.
g) Duration of exposure.

Indices of heat stress are complex and not universally applicable since individual workers vary greatly in their ability to perform work in hot conditions. Individual characteristics that affect heat-work tolerance include age, physical fitness, weight, medical conditions and acclimatisation. Therefore, whenever a heat stress situation is suspected or anticipated, precautions should be taken. Work in hot conditions should be self-paced to accommodate individual workers' abilities. When work is required in extreme heat conditions, the professional advice of an occupational physician or occupational hygienist should be sought.

23.2.3 Minimising Heat Stress

Measures to minimise heat stress depend on reducing heat load, promoting the loss of body heat, maintaining adequate hydration and preventing adverse physiological effects. These measures include:

a) Frequent rest periods to prevent fatigue – self paced or based on international heat stress indices such as wet bulb globe thermometer temperature (WBGT).

b) Replacing fluid loss due to sweat by taking frequent drinks of cool (not cold) water. It should be noted that thirst is not a satisfactory indicator of adequate hydration. Reference can be made to a urine colour chart[1] (see. Figure 23.1), however be aware that some nutrient drinks and vitamin drinks can artificially colour urine which masks indication of dehydration. Salt tablets and electrolyte solutions are not recommended.

c) Suitable clothing for the task. A loose fitting, lightweight overall is preferred to minimise radiant heat input while permitting air movement and sweat evaporation. If heavy protective clothing or enclosed body suits are necessary for protection from very hot or toxic environments the ability to lose body heat is severely compromised and work rates and exposure time must be limited.

d) Adequate air movement by good general ventilation, pedestal or fixed fans and spot cooling with cool air if indicated.

e) Shade should be provided for hot outdoor work whenever practicable (Sunshades).

f) Heat radiation shields and insulation on preheated work.

g) Worker acclimatisation if extended periods in hot working conditions are experienced.

h) Administrative procedures such as scheduling strenuous work for the cooler parts of the day.

Simple assessment tools are readily available for welders and all personnel to use including calculators designed for use online via WorkSafe Queensland's website, and from the AOIH Basic thermal risk application for use on mobile telephones and via a computer spreadsheet.

The AIOH have also published a guide to managing heat stress[2].

23.3 Extreme Conditions with High Preheat in Confined Space

Whenever work is regularly required in extreme hot environments professional advice should be obtained whenever possible. Specialised heat resistant clothing, possibly air or water cooled, and very limited work periods under careful supervision and with rescue resources may be necessary.

More commonly, welding on preheated manholes or nozzles is achieved by conventional welding equipment but with the preheated surfaces completely insulated by 100 mm of fibre insulation and large volumes of cooling air passed over the welder. Additional insulation may be needed under the welder's feet.

23.4 Risk of Electrocution

Hot conditions increase the risk of electrocution because clothing and equipment may become soaked in perspiration. The risk is increased in closed environments, such as tanks or vessels, particularly when these are exposed to the sun's heat. To minimise this risk:

a) Take frequent rest periods, during that time dry off equipment and clothing.

b) Frequently change or alternate gloves and protective clothing to avoid perspiration accumulating. Keep clothing and equipment dry and free of damage.

c) Ventilate or air-condition the work area.

d) Cool the face with an air fed welding mask.

e) Use BOTH welding gloves and sufficient appropriate protective clothing. DO NOT change electrodes with bare, perspiring hands. DO NOT expose skin to keep cool.

f) Use an in-line safety cut out switch (or similar) to ensure 0 volts .at the electrode holder when changing electrodes.

g) Use a voltage-reducing device (preferably with an OCV of 12V D.C. or less) used as described in 14.6. The use of A.C. or High Frequency (HF) welding power sources must be avoided.

h) If clothing becomes saturated with perspiration, it must be changed. The need for a changing room and fresh clothing must be anticipated.

i) Implement confined space working procedures when indicated.

Hot or humid conditions (see Chapter 14) require precautions necessary for Category C environments (see AS 1674.2[3]). Category C should be the default position unless extraordinary measures have been implemented to ensure Category B or Category A conditions are maintained. See also Chapters 4 and 14 of this Technical Note and Weld Australia's Technical Note 22.

23.5 References

1. Healthdirect Australia, *Urine colour chart*, 2024
2. Australian Institute of Occupational Hygienists (AIOH), *A Guide to Managing Heat Stress*, 2025
3. Standards Australia, AS 1674.2, *Safety in welding and allied processes Part 2: Electrical*

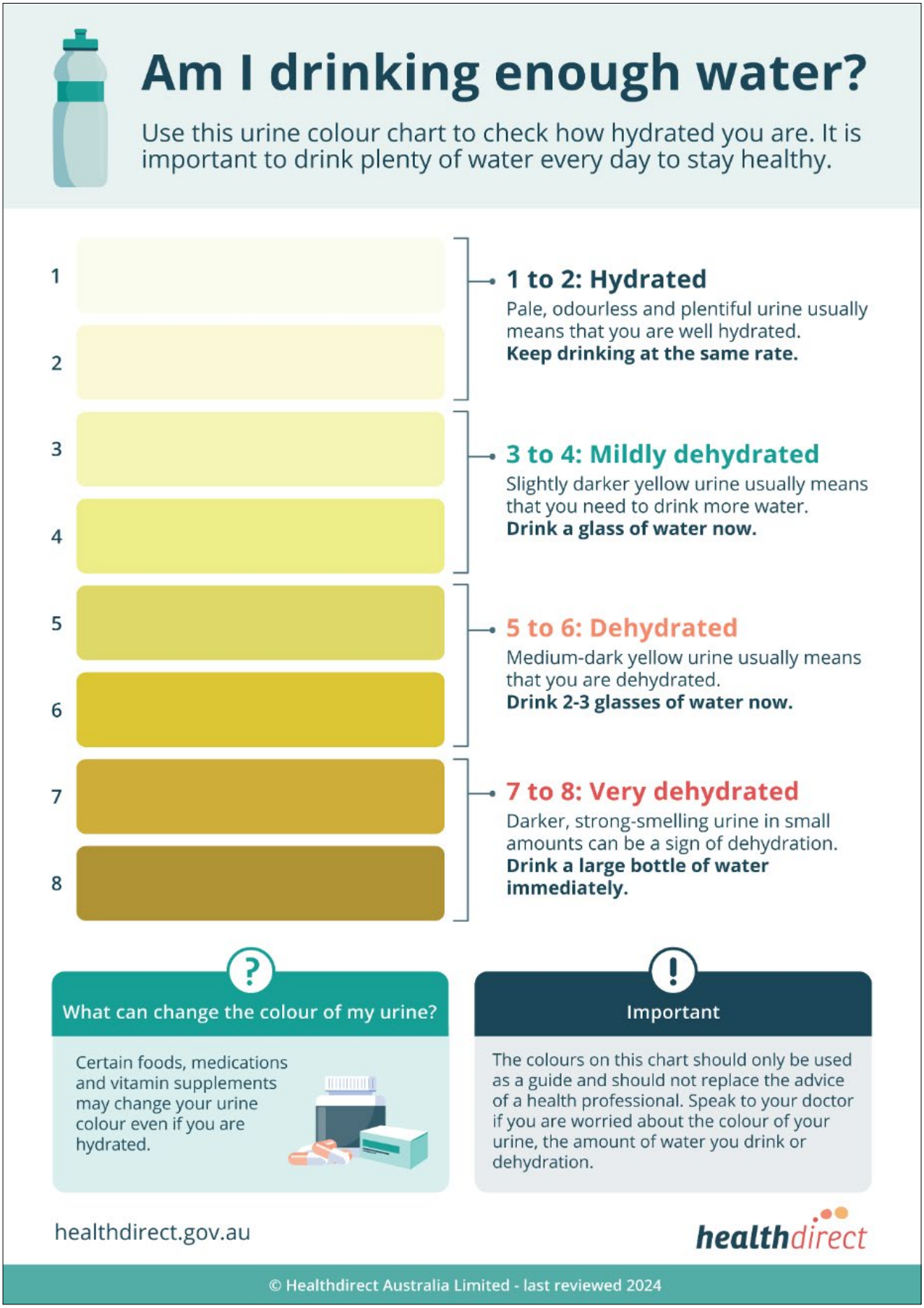


Figure 23.1 **Example of a urine colour chart**[1]
Source: © 2024 Healthdirect Australia Ltd. All rights reserved



24. Welding in Refineries and Chemical Plants

24.1 Introduction

Welding or flame cutting in refineries or chemical plants raises many hazards that will not be encountered in the great majority of welding applications. The hazards generally arise from the characteristics of the environment, e.g. the presence of toxic, flammable or explosive liquids, gases or materials. In some chemical plants, highly corrosive fluids may also be present that give rise to serious burns when in contact with the skin.

Refineries and chemical plants have stringent and effective regulations that must be adhered to in order to minimise the risks of injury or damage to plant and equipment. In this section, some of the more fundamental aspects of safe working in such environments are briefly described. Other sections of this Note give information that will assist in the adoption of safe working procedures in a variety of circumstances that may apply in refineries and chemical plants (see Chapters 20, 21, 22, 23, 25 and 27).

Site regulations with respect to smoking, only being allowed in clearly designated areas and other special practices should be clearly communicated and understood by all permanent, contract and casual workers

24.2 Precautions with Toxic or Flammable Liquids or Gases

a) Welding and cutting can only be carried out in areas where vapours or liquids cannot collect in sufficient quantities to cause problems.

b) Welding and cutting cannot be carried out in areas where falling hot sparks can contact flammable or combustible materials.

c) Gases can travel relatively long distances dependent upon their density, the terrain and wind conditions, resulting in special care being required.

d) In working in confined spaces where there could be a risk of ingress of flammable liquids or gases, all connections should be positively isolated i.e. blanked off. Closure of one valve should not be relied upon as it could leak or be accidentally opened. Complete removal of the connection, use of spectacle plates or double valves with locking capabilities and an intermediate air gap is generally advisable.

e) In dangerous areas, it is essential that two people are present, and that fire extinguishers or appropriate firefighting equipment be available for immediate emergency use.

f) Responsibility for welding operations should be clearly defined in all dangerous areas of the plant.

g) Where any doubt exists as to the presence of explosive or flammable liquids or gases, instruments should be used for testing i.e. combustible gas detectors, hydrogen sulphide meters, carbon monoxide meters.

h) All sub-contractors must be under strict control and comply with all safety requirements. "Hot-work permits"[1] must be obtained where there is a source of ignition i.e. welding, electric drilling, grinding and oxy cutting.

i) Welding on epoxy or coated pipe creates noxious fumes and toxic gases.

j) Oxygen levels in breathing air should be between 19.5 and 23.5% before entry into confined areas. Oxygen levels above this maximum may increase the risk of some materials overheating and igniting. Oxygen levels below this minimum level create a risk of illness or death.



k) A "Safe entry permit" is required before entry to ensure atmospheric checks have been made[2].

l) The requirements of AS 1674.1[1] should be met.

24.3 Fire Precautions – General

In addition to those listed in Section 24.2 the following general precautions apply (see also Chapter 16).

a) Safe practices must be defined for specific areas or conditions and must be strictly adhered to e.g. non-sparking tools will be required for work in areas where flammable vapours could still be present (considered good practice, but not necessarily followed on all sites).

b) Flammable materials such as oily rags, wood fibres and the like must be kept free from welding areas where spontaneous combustion or ignition may result. Such materials should be disposed of in a safe manner.

c) Stub ends of electrodes should be safely disposed of.

d) Welding cables and joints must be carefully inspected to ensure they do not overheat in areas that could cause fire e.g. near paper, wood or dry grass.

e) Welding and other cables should be run so that they do not constitute a tripping hazard, or have the insulation damaged by contacting hot equipment, effluent from vents, aggressive solvents or hydrocarbons and mechanical means.

f) In welding or cutting, materials must be cleaned of oil or flammable compounds to avoid the possibility of fire, as well as to obtain good weld quality.

g) Explosive conditions can occur when welding or cutting on pipes in conditions where residual product may decompose under heat or corrosion product remnants spontaneously ignite. In some circumstances cold cutting techniques may be required.

h) Aerosol NDE consumables can be hazardous when used in confined locations; the propellants tend to be flammable hydrocarbons. Therefore, in poorly vented conditions they can present a threat of asphyxiation or a risk of explosion on resumption of the welding operation.

i) Only "intrinsically safe" testing equipment should be used in the area.

24.4 Plant and Personnel

See also Chapters 3, 4, 22, 27.

a) Particular care is required for the safety of fellow workers as well as the plant itself.

b) Work current path must not be made through equipment but via the appropriate welding cables.

c) In refineries and chemical plant, special steels may be used on high pressure and high temperature equipment or where corrosive liquids or gases are present. Inadvertent arc strikes may seriously affect the integrity of such equipment and special care is required.

d) Welding in or on machinery will require special procedures in order to avoid hazards (see Chapter 28). The welder, when repair welding, should be alert to potential undetected problems on equipment such as thinned or distorted components. Where such conditions are found they should be reported to the appropriate supervision.

e) Any welding problems detected during welding that could be caused by incorrect materials or conditions should be reported.

f) The welders should be adequately informed of any special process related requirements affecting welding technique prior to undertaking the weld e.g. the need for the low hydrogen “hot pass” to be completed before the cellulose root run has cooled, or complete removal of weld slag in some service requirements.

g) Field radiography can be a potential hazard in a busy refinery environment. The site safety officer / welding supervisor must be assigned the responsibility to ensure that the radiation site is kept clear of personnel for the duration of the radiography session (normally undertaken out of hours, or for small jobs, during lunch breaks).

24.5 References

1. Standards Australia, AS 1674.1, *Safety in welding and allied processes Part 1: Fire precautions*
2. Standards Australian, AS/NZS 2865, *Confined spaces*



25. Welding and Cutting at Heights or Underneath Construction

25.1 Introduction

Many welding operations involved in site or maintenance welding are undertaken at heights where falls have serious consequences. Additionally, falling objects can obviously cause severe injury to personnel below. As many accidents occur in these situations, attention must be paid to the special considerations that apply.

Legislative requirements apply to safety matters when working at heights and specific State/Territory Government requirements need to be known and implemented. AS/NZS 1891.4[1] gives guidance for the control of risk for people working at heights and fall protection options.

25.2 Electrical Shock

Even minor electrical shock can have a severe result if the welder falls or causes other objects to fall. All of the relevant precautions given in Chapter 14 should be adhered to. Also, AS/NZS 1891.4 details other associated risks that should be considered in these circumstances. AS/NZS 1891.4 Section 2.1.4 covers work in adverse environments. AS/NZS 1891.4 Section 2.1.5 covers work task hazards and AS/NZS 1891.4 Section 2.1.6 covers rescue and first aid provisions[1].

25.3 Head Protection

All personnel working at heights or below construction are required to wear approved safety helmets (hats or caps) complying with AS/NZS 1801[2].

25.4 Falls or Falling Objects

a) Statutory authorities in each state have regulations specifying the construction and use of scaffolding (refer also to AS/NZS 1576[3] and its parts, AS/NZS 1577[4] and AS/NZS 4576[5]). These regulations and relevant standards must be adhered to.

b) Support brackets for scaffolding shall be securely attached to the structure in such a way that tilting is prevented. Where welded connections are used, in constructing or positioning scaffolding, these shall be made by qualified welders, inspected by the job supervisor, and comply with the specific structural application standard e.g. AS/NZS 1554.1[6].

c) Secure loose material on scaffolding to prevent its falling or interference with movement of workmen. Toe boards should be used to further guard against objects being dislodged (AS/NZS 4576 Section 8[5]).

d) Safety belts or harnesses to AS/NZS 1891.4[1] Section 7 and 9 and lines of a type approved by statutory authorities are required where circumstances prevent the use of scaffolding.

e) Ladders and walkways shall be safe and in accordance with statutory regulations. The safe use of ladders, placement, working on, movement, etc. is covered by AS 1657[7] and AS/NZS 1892.5[8].

f) Scaffolding shall be fit for service; AS/NZS 4576[5] Section 8 gives guidance on the load bearing capacity of the working platform.

g) Firewatchers (see AS 1674.1[9]) should be placed below any hot works to monitor potential ignition sources at ground level.

25.5 Rope Access Welding

Rope access systems are occasionally used in conjunction with welding and hot-work activities whilst working at heights. When considered for use, controls must be implemented to protect both the person undertaking the hot works e.g. the welder, and damage to the access ropes and equipment in use including harnesses and rigging.

In addition to the welder/operator having appropriate rope technician skills as recommended by the *IRATA International Code of Practice for Industrial Rope Access*, recommended controls may include, but are not limited to:

a) Positioning of a welding safety observer so that they remain in constant contact with the welder, are able to operate a hazard reducing device as required, and can cut power to the welding torch whilst the welder is changing electrodes, repositioning and in an emergency.

   NOTE*: The Welding Safety Observer may also be the IRATA level 3[10] safety person - as long as the additional role does not compromise either role.*

b) The use of flame retardant barriers to protect the welder or hot works operator and rope access equipment.

c) The use of fall-restraint systems may be necessary to prevent the failure of the primary access rope(s) e.g. non-flammable hard links, steel wire lanyards etc.

d) Requirements for the rescue of the welder or operator in the event of an emergency.

Consideration should be given to implementing similar controls to those required when performing hot work in confined spaces and high risk Category C welding environments.

Refer to AS 1674.1[9] and AS 1674.2[11] for further information.

25.6 Storage of Equipment

a) The minimum equipment necessary for safe working at the required locality should be used.

b) Bins that are properly fastened to supports should be used for electrode stubs and other uses.

c) Care is required in designing and making containers for tools required for use at heights.

25.7 Fire or Burns to Personnel

a) Special care should be taken to ensure that molten metal from cutting or gouging operations will not cause fire or injury hazard below. It will be necessary to prevent such material from falling where people are working below.

b) Consideration should be given to the use of protective shields, nets or screens.

   Note*: When a welder is repairing mining equipment or where there are pressurised hydraulic lines with metal covering, fires can and have occurred from inadvertent contact of the electrode with a hydraulic line. If the line is under pressure, fires can erupt explosively without warning.*

25.8 Lifting of Equipment

a) Personnel should not walk or work directly below any load being lifted or loaded, or within a working distance of a mobile lift.

b) All welding personnel should observe proper lifting rules for the handling of equipment at heights.

25.9 References

1. Standards Australia, AS/NZS 1891.4, *Personal equipment for work at height Part 4: Selection, use and maintenance*
2. Standards Australia, AS/NZS 1801, *Occupational protective helmets*
3. Standards Australia, AS 1576 (series), *Scaffolding*
4. Standards Australia, AS/NZS 1577, *Scaffold decking components*
5. Standards Australia, AS/NZS 4576, *Guidelines for scaffolding*
6. Standards Australia, AS/NZS 1554.1, *Structural steel welding, Part 1: Welding of steel structures*
7. Standards Australia, AS 1657, *Fixed platforms, walkways, stairways and ladders — Design, construction and installation*
8. Standards Australia, AS/NZS 1892.5, *Personal equipment for work at height Part 5: Manufacturing requirements for lanyard assemblies and pole straps*
9. Standards Australia, AS 1674.1, Safety in welding and allied processes Part 1: Fire precautions
10. Industrial Rope Access Trade Association, IRATA International, https://irata.org
11. Standards Australia, AS 1674.1, *Safety in welding and allied processes Part 2: Electrical*



26. Welding and Cutting Under Water and Under Pressure

26.1 Introduction

Where welding and cutting operations are required underwater and under an increasing pressure of one atmosphere for each 10 metres of depth there are process difficulties and personnel risks that should be referred to competent professionals. Divers' risks are covered by AS/NZS 2299[1] and its parts. The presence of gases, heat, electricity, tool backpressures, disorientation, noise, light and bubbles has to be additionally considered. Diver/welders need to undertake a nationally accredited training curriculum to ensure that they are aware of problem solving and process difficulties related to depth.

26.2 Proven Equipment

Underwater welding and cutting should only be undertaken using electrodes designed specifically for the underwater environment. Proven equipment specific for the underwater welding and cutting environment is available; a manually operated double pole single throw current supply switch that interrupts the current flow to welding/cutting electrode must be part of any underwater activity. Alternating current (AC) should never be used for welding and cutting activities beneath the water surface. Only direct current (DC) power sources should be used for underwater welding and cutting as it provides a stable current flow. Electrode negative (straight polarity) is preferable, with the return lead positive as the current then flows away from the welder. All underwater activities must be attended by a top side dive team member in voice communication with the diver/welder.

At the wave zone, activity must be either completely in air, or if in water, suited to complete immersion. At shallow depths to 20m wave surging abounds and below this to about 50m diver/welders can continue to operate in bounce diving mode. At greater depths to 400m specialised commercial systems have been proven safe in saturation diving mode.

Welding may be done using manual wet electrodes to about 80m, but weld strength is subject to prevailing conditions and diver/welder skill. Electrode types are generally stainless steel to a depth of 10 metres, nickel based to 30metres and rutile type up to 100 metres.

Semi-automatic and automatic systems can use qualified procedures in gas filled hyperbaric enclosures when the composition and welding conditions are compensated for the effects of pressure. Conventional welding practice may be used in customised pressure-tight housings. Wet cutting by hand-held oxygen-arc methods with tubular rods, carbon or exothermic electrodes is usually very rough. A straight and smooth finish can be achieved by using a water jet with entrained abrasives.

Mechanical fastenings incorporating drilling, tapping, grinding or ram-set fixtures are practical. In particular friction welded studs installed using hand carried pneumatic tools are available and safe. Surface cleaning with water jet entrained abrasives, power brushes or very high-pressure water can be used for marine growth removal. Non-destructive examination is possible using very bright lights, photography, stereo image analysis, magnetic particle inspection, ultrasonic testing and gamma radiography. For work in depths of 50m and deeper, remote controlled vehicles with robotic arms and specialised tooling are used economically and this practice removes many of the diver hazards.



26.3 Prevention of Electric Shock

In underwater welding and cutting, the diver is immersed in a potentially dangerous situation, but this is mitigated by practicing and following established safety protocols using proven equipment. A properly outfitted underwater welder dressed in a fully insulated suit (ideally sealed in a rubber or neoprene dry suit, with either dry or wet gloves supplemented by surgical type gloves worn underneath as a further barrier against current flow) and pressurized helmet with air and communication supplied via an umbilical cord is at minimal risk of electric shock.

The electric shock danger for the underwater welder comes directly from the electrode. As indicated in Section 26.2, the welder and the topside person operating the manual double pole single throw switch activating the welding power supply must be in direct communication, and, the switch must never be energized unless specifically directed by the welder. Both the work lead and the work return leads should be interrupted by this switch. The welder must have the electrode inserted and pointed directly at the work before requesting the activation of the welding power. The welder must tell the top side operator to open the switch and that action be confirmed prior to changing electrodes. The return current clamp must be connected directly to the piece being cut or welded and visible to the welder during the weld – this ensures that the current path is direct through the work and away from the welder.

Welding cables must be inspected to ensure no bare cable is exposed and all insulation is in good condition, not worn and thin. When the power is supplied to the electrode, any leakage can flow as stray electric current through the water. Leakage in the cable insulation will allow stray welding current to flow back to the source. A stray current path is usually visible as a path of bubbles indicating the current path through the water. Stray welding current must be prevented as it is a source of electric shock.

Because of the numerous safety requirements described above, SCUBA equipment must never be used for underwater welding.

While the incidence of underwater welder electrocution is extremely low, it is only by following the strict industry rules and procedures that fatalities of this nature are prevented.

> **Note***: As at November 2026, the USA Defence Technical Information Center (DTIC) had only one recorded incident of an underwater welder dying while welding underwater.*

26.4 Personnel

All diving personnel engaged in this work must have qualified diving skills, current medical certification for diving, experience and training in their particular responsibilities and the safety precautions associated with:

a) Working underwater.

b) Changing depth and effects of pressure.

c) Disorientation control.

d) Communication in water and with surface personnel.

e) Technical procedures being employed.

The diver/welder must be fully trained in and qualified in the preparation and use of the equipment, and also have passed a procedure test to a nominated standard e.g. ISO 15614-9[2], ISO 15614-10[3], ISO 15618-1[4], ISO 15618-2[5], AWS D3.6M[6]. Training should be undertaken in a government or industry approved training establishment. This will ensure proper safety awareness and assist in weld quality assurance.

No work should be undertaken until the above conditions are completely met.

26.5 Procedures

In view of the specialised procedures required to be adopted in welding, cutting and related work under these conditions, it is recommended that:

a) A well-documented manual of underwater practices and support activities is known and referred to on site.

b) New procedures are trialled and qualified (e.g. to ISO 15614-9[2], ISO 15614-10[3] or AWS D6.3M[6]) under tank immersion or other safe situations.

c) Reference is made to the considerable amount of detailed information that is available in AS/NZS 2299[1] from the ADAS (Australian Diver Accreditation Scheme), from AWS D3.6M[6] and supplier's handbooks.

d) Welds made underwater can only be considered temporary, unless deemed otherwise by an authorising body such as Lloyds, ABS, and DNV who can approve permanent welds to be made underwater.

It is known that welds carried out in a wet environment are subject to quenching and hydrogen saturation within the weld and heat affected zone (HAZ) that can lead to

micro cracking in the HAZ. Welds made in a hyperbaric habitat are also subject to a hydrogen rich environment, with a higher amount of hydrogen being absorbed into the weld zone with increasing depth, thus producing the same inconsistencies as a wet weld.

Surface quality welds (Class A) can be produced with correct training, procedures and expert advice from specialists. The requirements for the classes of weld are defined in AWS D3.6M[6] covering classes A, B and O.

Class A	Comparable to the equivalent surface weld quality, meeting design stresses and applications.
Class B	Intended for less critical applications where lower ductility, moderate porosity and limited discontinuities may be allowed. Suitability for a particular application should be verified by "Fitness for Purpose" evaluation.
Class O	Class O welds should meet the requirements of a designated Code or Specification determined by the Customer and other additional requirements specified in AWS D3.6M.

26.6 References

1. Standards Australia, AS/NZS 2299 (series), *Occupational diving operations*
2. International Standards Organisation, ISO 15614 9, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 9: Underwater hyperbaric wet welding*
3. International Standards Organisation, ISO 15614-10, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 10: Hyperbaric dry welding*
4. International Standards Organisation, ISO 15618-1, *Qualification testing of welders for underwater welding — Part 1: Hyperbaric wet welding*
5. International Standards Organisation, ISO 15618- 2, *Qualification testing of welders for underwater welding — Part 2: Diver-welders and welding operators for hyperbaric dry welding*
6. American Welding Society, AWS D3.6M, *Underwater welding code*

27. Protection During Weldment Testing

27.1 Introduction

A number of weld tests are carried out during and on completion of welded fabrication. Some of these tests introduce hazards to health or safety that require persons nearby during testing to be informed of the dangers and appropriate precautions. Such tests commonly encountered include non-destructive and pressure testing.

27.2 Radiographic Testing

This non-destructive testing method is used frequently on major or critical weldments to assess the integrity and conformance of the welds. The common forms of this testing involve the use of X-ray sets or radioactive isotope units. The ionising radiations emitted are invisible and extremely harmful unless exposures are kept within well-recognised limits.

It is important for all welding personnel to appreciate that:

a) Health risks may arise with radiographic testing.

b) Precautions are essential to avoid accidental exposure.

c) Operators of radiographic equipment are required under statutory regulations to exercise strict control over persons directly assisting with the testing (including compulsory wearing of dosimeters) and to prevent other people working nearby from entering areas where radiation levels are excessive. All operators require a Licence, upon passing a radiation safety examination, issued by the State Authorities within whose jurisdiction they are working.

d) Where it is necessary to enter the exposure area, film badges and dosimeters are required to be worn to monitor the exposure. Film badges are required to be regularly forwarded to the relevant authority to provide verification that all exposures are within safe limits.

e) Warning signs (see Figure 27.1) and barriers must be erected when gamma ray testing is being carried out and no attempt is to be made to enter these restricted areas.

f) The person conducting a business or undertaking (PCBU) at the facility where radiography is to be performed has overall legal responsibility for safety. General guidelines to assist PCBU's in organising the work so that it is conducted safely and efficiently are available in Figure 27.2.

g) In complex process plants and factories, it is emphasised that in most cases the radiographer will need assistance in this regard. The PCBU must discuss the job with the radiographer and ensure that precautions are taken to eliminate the possibility of personnel inadvertently circumventing



Figure 27.1 Ionizing radiation warning sign

the barriers that the radiographer will erect, e.g. by proceeding along elevated platforms or by being concealed in equipment, ducts or other structures. It is advisable and good practice for management of the company, on whose premises the radiographic inspection is being undertaken, to appoint a responsible officer (who has operational control over the workforce). Their duty is to oversee the radiographic location during the inspection to ensure that the workers remain outside the designated radiation area (there is a tendency for the workers to ignore the radiation danger signs).

h) Radiographic equipment must not be tampered with. Serious injury can result from contact with gamma ray sources (see Figure 27.2).

i) Locking devices fitted to exposure containers must never be tampered with or removed by unauthorised personnel.

j) More detailed instructions may be found in AS 2243.4, and AS 2177.

27.3 Magnetic Particle Testing

There is the danger of electrical shock or burns and damage to the eyes or ears due to blowing particles.

Equipment used for this testing that may require electrical power cables, must be electrically safe (see Chapters 4 and 14).

Aerosol cans are commonly used for background paint and magnetic ink. Aerosols should be tightly controlled and protected from potential interaction with hot metal, arcs and sparks associated with hot work.

The carrier for magnetic particles is typically kerosene, which can irritate the skin and poses a fire and explosion hazard, particularly when used in close proximity to hot work.

27.4 Penetrant Testing

This method uses various chemicals, and fumes from solvents should be avoided. In confined spaces forced airflow must be provided to prevent concentration of solvent fumes labelled as noxious.

27.5 Pneumatic Testing

This test uses compressed air or other non-flammable gases to check both the integrity and leak tightness of welded containers of various types.

As the volume of the container and the pressure of the air in it increases, the stored energy becomes greater and if welds should be excessively weak or over stressed because of excessive pressure, this energy can result in a violent explosion. Accidents of this type are reported each year and cases are known where persons testing containers of approximately 2 cubic metres volume have been killed with air pressures as low as 60kPa.

For these reasons statutory authorities and regulations should be consulted prior to carrying out such tests. Welding personnel should therefore appreciate that:

a) Testing with compressed air or gas can be dangerous and that the danger increases as the volume and pressure increases.

b) Statutory regulations concerning this test must be complied with. Whenever pneumatic testing is required, precautions must be taken to avoid over-pressurising the container and to avoid the risk of rupture (see Clause 5.11 of AS 1210[3] and AS 4037[4]).

c) Flammable, toxic or explosive gases must not be used for this test.

27.6 Hydrostatic Testing

This test is the normal method of pressure testing pressure vessels, boilers and piping. It serves the same function as pneumatic pressure testing but uses water or other non-hazardous liquids in order to greatly reduce risks associated with rupture. Wherever possible, this method should be used in preference to pneumatic pressure testing.

Because test pressures frequently exceed 20,000kPa in quite large vessels, it is essential to ensure that:

a) The vessel is suitably supported.

b) All air in the vessel is replaced by water before testing.

c) Test pressures are not exceeded.

d) Nobody puts himself in line with gasketed joints.

Notes:

1. *Similar precautions apply for Acoustic Emission Testing as the vessel is under pressure.*
2. *Care is needed in draining of thin-walled vessels and tanks to avoid collapse by vacuum equipment since all traces of water must be removed.*

Guidance on the Management of Safety in Industrial Radiography

Introduction

The person conducting a business or undertaking (PCBU) where radiography is performed, has overall responsibility for safety. The radiographer has specific responsibilities for the safe use of his equipment. Guidance is given herein to assist the Australian welding and fabrication industry in:

a) ensuring that radiography can be conducted on site with minimum disruption to work, and

b) outlining the communications required for safe and efficient conduct of radiography.

The information given here is necessarily very general. It is strongly advised that details of the work are discussed with the radiography provider well in advance.

What is Radiography, and Why is Safety an Issue?

Radiography involves the use of a beam of radiation to create an image that shows the internal structure of an otherwise opaque object. The radiation can damage living tissue and precautions must be taken to ensure no-one is exposed to hazards by the process.

Job Organisation and Planning

The person conducting a business or undertaking must assign responsibility for the work to an individual in his or her employ who has sufficient knowledge of and authority within the worksite, and ensure the radiographer is aware of who is assigned and how he or she may be contacted while work is being performed.

The radiographer needs to know what components and what parts of each component are to be inspected by radiography, the material it is made of and its thickness, and what acceptance standard applies. In some instances, detailed discussion may be required so the radiographer has a clear idea of the intent of the inspection.

The radiographer will need to have sufficient access to both sides of the components.

Safety Precautions

An area around the work site – the 'radiation zone' – will need to be vacated of all personnel. Work should be planned for the day in such a way that this can occur with minimum disruption. The radiation zone may be several tens of metres across depending on the situation and the type and strength of the source of radiation, which can vary considerably. Signs and barriers usually need to be erected to ensure that people do not inadvertently enter the radiation zone.

Concrete blocks and other building materials offer very little shielding from the radiation, so the radiation zone extends beyond any wall, floor or ceiling that falls within it. Likewise, pressure vessels and ducts offer negligible protection to any occupant. The radiographer must be assured that any part of the radiation zone that cannot be reasonably monitored visually is not occupied while the radiation beam is active. It may be necessary for the owner to provide assistance to achieve this. Particular care must be taken if the radiation zone crosses a property alignment, and it may then be necessary to make suitable arrangements with the neighbours in advance. Where the radiation zone extends into public property it may be necessary to make arrangements with local authorities.

Each situation will be different, and in many instances, there may be a way around a particular problem. For example, the radiation beam can often be mostly directed away from a sensitive area, but this will depend on the geometry, size and mobility of the component and the nature of the inspection.

Figure 27.2 Guidance on the management of safety in industrial radiography

27.7 Structural Proof Testing

Many welded structures and machines are given an initial proof load test that checks the integrity of various components and welds. Failures resulting in serious accidents sometimes occur, and thus personnel associated with or near the test must be safely positioned, particularly during any burst test of pressure equipment or collapse during testing of structures.

27.8 Leak Testing

This test is commonly used to check for leaks in various containers and piping. While the stress levels developed during this test are lower than in pneumatic pressure testing, there can be an explosion risk where pressures and volumes are high, and pressure is not adequately controlled.

Hence the precautions listed in Section 27.5 should also be adopted but where flammable gases are used, leaks must not be checked with any flame.

27.9 Macro Cross-Section Examination

Macro testing of welded joints is often carried out by personnel in fabrication shops for confirmation on the weld shape, the extent of penetration and the soundness of the welded joint prior to sending test coupons to an accredited laboratory.

27.9.1 Safety Precautions

The preparation of etchants involves the handling of potentially dangerous substances. Consequently, etching solutions should only be prepared by or under the guidance of experienced people in a controlled environment and using the appropriate safety equipment. Persons using the etchants must likewise be aware of the correct method of storage, handling and use and the potential hazards of misuse.

Commonly used etchants for etching macro cross-sections are:

a) Nital – a solution of 1% to 10% nitric acid (HNO_3) mixed with alcohol. It is used for carbon steels. Most common etchant for Fe, carbon and alloys steels and cast iron - Immerse sample from seconds to minutes; also suitable for Mn-Fe, Mn-Ni, Mn-Cu, Mn-Co alloys.

b) Sodium Hydroxide (NaOH) – used for aluminium. Mix sodium hydroxide flakes or pellets in water and stir until dissolved. Immerse the specimen for 10 to 60 seconds.

c) Tucker's reagent – a solution of 45% HCl, 15% HF, 15% HNO_3, 25% H_2O (water). It is used for aluminium. Immerse the specimen for 10 to 60 seconds.

d) Marble's reagent – a solution of copper sulphate ($CuSO_4$) 10 g, hydrochloric acid (HCl) 50 ml, water (H_2O) 50 ml. It is used for etching Ni, Ni-Cu and Ni-Fe alloys and super-alloys. Add a few drops of H_2SO_4 to increase activity. Immerse the specimen for 10 to 60 seconds.

e) Chrome regia – a solution of 30% CrO_3, 50%, HCl, 20% H_2O. It is used for stainless steels.

Etchants containing hydrofluoric acid (chemical formula HF), occasionally used to etch aluminium, aluminium alloys and stainless steels, should be avoided due to the extreme hazards associated with their use. Reference should be made to the manufacturer's SDS sheet for hydrofluoric acid for further information.

27.10 References

1. Standards Australia, AS 2243.4, *Safety in laboratories, Part 4: Ionizing radiations*
2. Standards Australia, AS 2177, *Non-destructive testing — Radiography of welded butt joints in metal*
3. Standards Australia, AS 1210, *Pressure vessels*
4. Standards Australia, AS 4037, *Pressure equipment — Examination and testing*



28. Welding and Cutting in Machines and Special Locations

28.1 Introduction

In machines, general industrial plant and special locations, additional hazards may be encountered to those already discussed in previous Chapters i.e. in addition to electrical, explosion, fire, falls etc. These special hazards also need consideration (see also Chapter 20).

28.2 Lock-Out and Tag-out

In machines, conveyors, cranes, earthmoving and transport equipment there is also a hazard that the equipment will be inadvertently operated while the welder or helper is inside the machine. Cases are known where persons have been caught during repairs in kilns, conveyors, rolls etc.

In these circumstances, it is essential to ensure that the machine cannot be operated until all persons are out of danger. Energy sources including electric, hydraulic or pneumatic power control, fuel sources and "stored energy" must be satisfactorily isolated and locked so they cannot be inadvertently operated.

> **Note**: *Stored energy (also referred to as potential energy) includes the energy possessed by a component or machine as a result of its position or condition rather than its motion or other power sources e.g. accumulators, a raised or suspended component or weight, loaded (e.g. coiled) spring, charged battery etc.*

Additionally, a suitable system of checks should be used to indicate the presence of persons in or on machines where a person would not be readily noticed.

One successful system is the Lock-Out, Tag-Out System whereby each person entering a complex machine places a tag near the controls, locks out and isolates all energy sources with their personal lock, and therefore preventing the machine from being operated until all tags and locks are removed by the person placing them (see Chapter 3 and Section 28.5).

28.3 Special Locations

28.3.1 Introduction

Where welding or cutting is to be carried out in special or unusual conditions, it is essential that any possible hazards be identified so that all involved are aware and suitable precautions can be taken. Hence, it is necessary that the plant or site manager or other responsible person be informed of the proposed welding operation and an approval received before work is commenced.

28.3.2 Additive Manufacturing

Additive manufacturing is the manufacturing of a 3-dimensional object, usually specialist robotic welding, laser welding or surfacing, or more commonly via 3-D printing using plastic substrates. When working with robots or other automated welding processes, the hazards and precautions regarding welding activities and associated hazards continue to apply e.g. exposure to fume, ultra fine dusts, UV and IR arc radiation, noise, etc.

> **Note**: *Refer also to Weld Australia's Technical Guidance Note TGN SW02 – Laser Safety[1] and AS/NZS IEC 60824.14[2].*



For 3D printers, these devices use various polymers as their consumables and the printing process can involve surface temperatures of up to 350°C. Accordingly, the process can lead to the emission of lung irritants such as volatile organic compounds (VOCs) and ultrafine particulates. The emission rate and quantity of the emissions will depend on the materials used in the printing process, the energy input, and quantity of volatile compounds within the consumables used. Local exhaust or good general room ventilation may be required to manage the emissions[3].

28.3.3 Cobots

Cobots are collaborative robots designed to work in close proximity to and interact with people. Whilst robots are fully guarded to exclude direct interaction with people, cobots are capable of working directly and safely with people, automatically. Specialist advice on safety precautions and limitations of these machines should be sought directly from the manufacturer of the machine installed or under consideration for installation.

28.4 Working in Tanks, Pipelines, Pressure Vessels, Boilers and Other Containers

Here, in addition to the hazards covered in previous Chapters, it is essential that precautions be taken to prevent inadvertent opening of valves or similar openings or operation of conveyors. For this reason, such openings or controls should be isolated and locked to ensure that they cannot be opened or operated while personnel are in an unsafe location. Personnel should be physically fit to perform their duties in this equipment.

28.5 Isolation

a) Isolation planners, isolating persons and protected persons must all be trained and have current authorization for the specific areas of operation.

b) Isolating persons must understand and be able to demonstrate the 'verification step' for all isolations.

c) Isolating persons must understand and demonstrate controls for stored energy and associated isolation requirements e.g. hydraulics, pneumatics, suspended loads, electrical etc.

d) Protected persons must attach their personal red lock/danger tag to the isolator/group board before working on isolated plant or equipment. Contractors must be supervised by an authorized person when attaching their personal red lock/danger tag to isolator/group board before working on isolated plant or equipment. More detailed information on isolation planning, performing isolations, isolation equipment and isolation procedures is given in Chapter 3.

28.6 References

1. Weld Australia, Technical Guidance Note TGN- SW02, *Laser Safety*
2. Standards Australia, AS/NZS IEC 60825.14, *Safety of laser products Part 14: A user's guide*
3. Zschiesche W, *Advanced technologies and materials – New health hazards at workplaces?*, International Institute of Welding, Document VIII-2299-20



29. General Industry Protection

29.1 Introduction

Welding personnel will frequently be exposed to many additional hazards that arise in general industry but are not specifically related to welding. Examples of such hazards are:

a) Stepping on, striking against or being struck by objects (excluding falling objects).

b) Struck by falling objects.

c) Caught in or between objects.

d) Over-exertion, strenuous movements, etc.

Where appropriate, these situations have been referred to in previous Chapters of this Technical Note e.g. Chapter 25 *Welding and Cutting at Heights or Below Construction*.

This Chapter deals with more general considerations of industrial safety that have been demonstrated by experience to be major causes of industrial accidents. Additional information is available in Safe Work Australia's Code of Practice *Managing risks of plant in the workplace*.

29.2 Ergonomic Considerations

Ergonomics is the design of work so that the best match between human factors and the work environment is achieved. This comprehensive approach takes into consideration individual's capabilities and limitations and the nature of the task. Examples of situations in which ergonomic considerations are appropriate include:

a) Correct design of benches and jigs to avoid discomfort and fatigue.

b) Simple lifting devices to avoid musculoskeletal disorders, slipped disc, hernia, muscle straining, etc. caused by incorrect manhandling of heavy equipment.

c) Adequate lighting to avoid accidents, eyestrain and stress.

The main areas of concern to welding personnel are considered below in 29.3 to 29.8.

29.3 Thermal Discomfort

Working in extremely hot or cold conditions can lead to considerable discomfort and to "heat" or "cold" stress. This will depend on:

a) *Hot conditions*: see Chapter 23.

b) *Cold conditions*: In cold weather, where possible, shops and work sites should be provided with a facility to avoid excessive drafts. This can often be achieved by appropriate use of mobile screens or temporary partitions. Such screens also facilitate welding using gas shielded processes and provide some protection from rain.

Attention is drawn to the need for adequate work clothing to be worn in cold weather and in site welding. Special kneepads may be needed in some cases.

29.4 Lighting

29.4.1 General

Arc and gas welding usually provide sufficiently good local illumination of the workpiece. Adequate general lighting is also required to allow safe access and handling of equipment and consumables.

The quantity and distribution of light required for comfortable and efficient working depends essentially on the type of work being performed and the operator's vision. Where major variations in work type occur, a facility for obtaining additional local illumination may be required.

Detailed recommendations in respect of artificial lighting of buildings can be found in AS/NZS 1680[1] and its parts. Important general considerations include:

a) Avoidance of excessive glare either directly from the light source or by reflection.

b) Obtaining sufficient but not excessive contrast between the workpiece and background.

c) Colour and direction of light.

29.4.2 Colour

In welding environments selection of colour is important in avoidance of glare and obtaining a satisfactory general level of illumination. Colours should be pleasant (it is not necessary to choose dark colours – see Section 15.3), and preferably have a matt finish. Background features, such as piping (other than colour coded piping – see AS 1345), air conditioning ducting or structural supports, should be the same colour as the background unless they present a hazard. This will reduce the degree of distraction.

Colour coding systems for piping (see AS 1345[2]) should be adhered to in order to avoid hazards that could arise due to the nature of the contained liquid or gas.

29.5 Noise and Vibration

29.5.1 Noise

See Chapter 18.

29.5.2 Vibration

Welding under conditions of vibration may cause discomfort and, if severe, lead to difficulty in welding. Such vibration could occur when welding at heights in construction or maintenance. Control of vibration or discontinuing of work will be required where it is excessive.

29.6 Working Posture

Difficult or uncomfortable postures will lead to rapid fatigue and reduced concentration thereby increasing the risk of incidents or accidents. The work should be placed at a height that allows the operator to adopt a stable and comfortable position. Sustained, poor posture can be harmful. Work is best performed at waist level. Work performed above or below this level increases the effort required to do the task. This is particularly important where site conditions introduce additional hazards.

29.7 Hazardous Manual Tasks

When moving and using equipment, workpieces etc., care should be taken to *think first and plan the moves*:

a) Can the task be handled alone or is assistance needed?

b) Are gloves, safety footwear or other forms of personal protective equipment needed?

c) Where is it going?
   i) heights
   ii) how far
   iii) over uneven ground
   iv) bench space

d) Then use a sensible handling technique:
   i) get close to load with feet in a stable position
   ii) get a secure safe grip
   iii) don't twist body
   iv) don't handle from too high or too low
   v) don't continue if the object is too heavy or unstable

Organise work to eliminate unnecessary handling and effort; for example, transport cylinders on a trolley.

29.7.1 Correct Position for Lifting Tall Cylinders

Gas cylinders are usually tall and heavy, and awkward to lift and move. When lifting is required, the preferred lifting techniques include use of:

a) cylinder trolley fitted with large diameter pneumatically wheels;

b) team lift to share the load. A cylinder grabber may be used to assist in the lift;

c) tail-gate lifters, scissor lifts and forklifts to allow vertical transfer of cylinders from one elevation to another provided that the cylinders are suitable restrained from falling or moving.

Alternatively, cylinders may be edge-rolled short distances, preferably not more than 2 meters.

29.7.2 Rigging

Where larger workpieces and major items are to be positioned or manipulated for welding fabrication work or readied for transport, the work must be undertaken by a licensed Rigger.

29.8 Other Ergonomic Conditions

These include correct height of seats, workbenches, identification of controls, layout of work, clarity of instructions and notices, job design. All can make important contributions to safety and wellbeing of personnel. Further details can be found, for example, from State/Territory Departments dealing with occupational health and qualified Ergonomists/Human Factors professionals.

29.9 Housekeeping

This term refers generally to such factors as the layout and tidiness of the working environment, identification of hazards and walkways etc. and storage of equipment and materials. Close attention to housekeeping can result in a marked reduction in the possibility of accidents occurring and has a favourable psychological effect on personnel. Some of the important factors to be considered are noted below:

a) *Roadways*: Many accidents occur with moving vehicles on plants and sites. Unobstructed visibility and use of readily visible caution signs are important considerations.

b) *Aisles or Walkways*: These should be clearly identified, of sufficient width to enable employees to move without danger, and always remain unobstructed.

c) *Floor*: Both work and walking areas should be of non-slip construction and preferably be easily cleaned.

d) *Exits*: Sufficient exits should be available to allow rapid evacuation of personnel and they should be adequately marked by permanent signs and distinctive colours.

e) *Handrails*: Where required, these should be designed and constructed to the applicable application standard e.g. AS/NZS 1554.1[3].

f) *Floor Openings*: Openings require clear identification and the provision of guardrails to prevent falls.

g) *Storage*: Suitable storage facilities should be provided for materials and equipment.

h) *Cleanliness*: Attention should be paid to high standards of cleanliness and tidiness.

i) *Spills*: Spillage of oils or water should be promptly attended to.

j) *Scrap*: Scrap should be immediately placed in bins provided.

k) *Housekeeping*: Good housekeeping can also reduce secondary exposures to contaminants such as dusts and chemicals.



a) Incorrect Lifting
Bending of back over the load and faulty handling techniques can lead to:
- a ruptured or slipped disc in spine
- a strained muscle or fatigue
- a hernia
- an injury to the hand, foot or leg



b) Correct lifting
Requires less effort and is safer. Technique is:
- spread feet apart for balance; locate front foot beside load and point it in direction of travel; locate other foot behind centre of load
- bend knees (not beyond 90°)
- ensure correct grip
- maintain straight back
- lift with legs

Figure 29.1 Correct lifting technique

29.10 Plant and Equipment

Defective plant and equipment or inadequate protective devices lead to many industrial accidents. Some of the important factors to be considered are noted below:

a) *Power Supply*: See Chapters 4 and 14.

b) *Machine Guarding*: Statutory regulations apply to guarding of machines and these must be consulted and applied at all times. Machines and hand tools must not be used if protective guards are either defective or have been removed.

c) *Electrical Equipment*: Grinders, drills and any other power tools must be effectively earthed or insulated. Extension cords should not be used unless it is unavoidable to do so.

d) *Stored energy*: Plant and equipment that has been in used and may be deformed or damaged can give rise to the sudden release of energy in the form of spring back or other movement in the event that supporting welds are removed – see Sections 4.1.2 and 6.9.

Equipment should be periodically checked for cuts in insulation, loose plugs and connectors. Where work in extremely wet areas is involved, battery powered low voltage equipment is strongly recommended/required.

29.11 Psychological Factors

29.11.1 General

Performance and safety records of personnel are being increasingly related to the psychosocial (i.e. mental health and wellbeing) of the individual. WHS legislation requires that psychosocial hazards be identified and eliminated or if not reasonably practicable, minimised as far as reasonably practicable[4].

Similar to the process of managing workplace hazards described in Section 3.2 of this Technical Note, the risk management process can be applied to identify and manage psychosocial hazards and associated risks. This is a four-step circular process as shown in Figure 29.1 and involves the following process:

(a) Identify the psychosocial hazards (refer to 29.11.2);
(b) Assess the risks associated with the hazards identified, including workplace considerations (see 29.11.3) and human factors (see 29.11.3);
(c) Control the risks to eliminate the hazards if practicable or otherwise minimise the risks associated with exposure to the hazards; and,
(d) Review of the control measures, including ensuring their effectiveness over time.

This process is an ongoing process supported by consultation with all workers affected by the identified hazards.

29.11.2 Psychosocial Hazards

Psychosocial hazards are defined as hazards that may cause psychological harm, whether or not it may also cause physical harm. These hazards may arise from or relate to:

(a) the design or management of work; or
(b) a work environment; or
(c) plant at a workplace; or
(d) workplace interactions or behaviours.

29.11.3 Workplace Considerations

In determining the control measures required to be implemented to eliminate or minimise the psycho-social risks health and safety, WHS legislation requires that all relevant matters be considered. These include:

(a) the duration, frequency and severity of the exposure of all personnel to the psychosocial hazards; and
(b) how the psychosocial hazards may interact or combine; and
(c) the design of work, including job demands and tasks; and



Figure 29.2 Management of psychosocial hazards[4]



(d) the systems of work, including how work is managed, organised and supported; and

(e) the design and layout, and environmental conditions, of the workplace, including the provision of:
  i) safe means of entering and exiting the workplace; and
  ii) facilities for the welfare of workers; and

(f) the design and layout, and environmental conditions, of workers' accommodation; and

(g) the plant, substances and structures at the workplace; and

(h) workplace interactions or behaviours; and

(i) the information, training, instruction and supervision provided to workers.

29.11.4 Human factors

Workplace related human factors that warrant attention include the following:

a) Management attitudes can to a large extent determine the attitudes of all personnel. Attempts should be made to:
  i) Develop a team spirit and exchange views.
  ii) Provide sufficient information to enable employees to understand overall objectives and their particular role.
  iii) Develop a health and safety program.

b) Supervisor attitudes should be based on achieving very good worker relationships.

c) Where exceptionally long shifts are being worked there is a need for assessment of the work patterns for the welders and allied trades to avoid increased risks caused by operator fatigue and inadequate supervision.

d) Monotonous work can quickly lead to lack of care or incentive. Where possible, job planning should provide for job rotation or other suitable means of relieving boredom.

e) Individual limitations should be accounted for by paying attention to mental and physical abilities, aptitudes, training and experience when determining job placements.

f) Grouping of individuals where required should be aimed at maximising the compatibility of teams.

g) Receiving and recognising constructive ideas from all employees should be encouraged, e.g. through adoption of suggestion schemes that promote continuous improvement.

h) Latest developments relating to occupational stress, bullying and risk taking.

29.12 Natural Hazard Elements

The safety of health of personnel exposure to natural elements must be assured against the special hazards.

a) *Rain*: Slips, unstable equipment, electric shock, impair weld quality and heat treatment
[**Control**: Time or delay work or provide rain protection or work inside].

b) *Wind*: (as above for rain)

c) *Sun*: Heat stress, problem handling hot materials, sun burn, skin cancer (see Chapter 23).
[**Control**: avoid work in the sun, shade the workplace]

d) *Lightning*: Protection against lightning is required on buildings or structures or out in open spaces during the construction stage appropriate to local conditions in respect of the frequency and severity of electrical storms. Relevant information is given in AS 1768. The main precaution is to exit places at high risk of lightning strikes.

> **Note***: Numerous weather "apps" are readily available for download and installation to smart phones and tablets devices.*

e) *Water*: Work in swamps, river crossings or trenches or underground may introduce hazards as for rain and also drowning.
[**Control**: Time or delay work or provide suitable protection]

f) *Grass or Bush Fires*: Fire and burns from ignition by welding and hot work
[**Control**: Clear all combustible materials]

g) *Wildlife*: Snakes, spiders, insects, crocodiles
[**Control**: Due diligence with regards to the local environment and warning signs (e.g. crocodiles)]

h) Allergies

29.13 Personal Gear

Wearers of hearing aids, cochlear implants, pacemakers, other electronic equipment, jewellery (e.g. rings, watches, body piercing etc.) should check with manufacturers, doctors or others to ensure safety when likely to be exposed to high magnetic fields (e.g. magnetic particle inspection or high current welding) and high frequency power sources (that can heat metal objects).
Piercings and body jewellery may also lead to increased chance of injury.

29.14 First Aid

a) Statutory regulations specify minimum requirements for provision of First Aid and medical facilities that *must* be adhered to.

b) First aid equipment and instruction must be readily available on or near site work.

c) At least one person should have an appreciation of essential first aid[5].

d) The address and telephone number of the nearest available medical service, hospital and ambulance service should be widely displayed.

29.15 Materials Handling

Failure to make adequate provision for materials handling and storage can lead to increased risks of accidents. Some considerations that need to be made include:

a) The need for provision of designated storage areas with appropriate storage racks, lifting facilities and the like.

b) Provision of designated access to and from storage area.

c) The use of mobile equipment (e.g. forklifts) and potential for pedestrian interaction.

d) Design of storage areas to ensure ease of handling and secure location of materials.

e) Safe disposal of waste.

29.16 Personal Issues

Management and personnel should be aware of and take reasonable action to ensure risk arising from personal hazards below during welding operations, travel to and from work and at other times are acceptably low:

a) *Drugs and alcohol*: can greatly increase risks in workplaces (avoid or suitably control). Some workplaces have a zero tolerance for drugs and alcohol which is tested using screening techniques.

b) *Smoking*: especially important if excessively exposed to welding fume or other contaminants.

c) *Stress*: from all sources particularly by time and personal matters (Control: Try to reduce).

d) *Medication*: (e.g. sedation, diabetic), medical devices (e.g. pacemakers, hearing aids etc) and during rehabilitation: In these cases, medical advice should be followed.

e) *Illegal actions*: Workers must comply with all legislation and regulations.

29.17 Safe use of Compressed Air

Compressed air is a good source of energy, but it has to be handled very carefully in a work environment. Some of the things that need to be borne in mind are:

a) Safety while testing tanks, containers etc;

b) Cleaning using compressed air (injury to the eyes by flying particles, fire hazards etc.);

c) Misuse of compressed air (e.g. body orifices, cuts, open wounds);

d) Hose whipping;

e) Safe use of air tools (use hose coupling safety clips and hose safety whip checks);

f) Accidents while using compressed air for discharging fuels;

g) Explosive rupture of air receivers of poorly maintained compressor equipment.

29.18 References

1. Standards Australia, AS/NZS 1680 (series), *Interior and workplace lighting*
2. Standards Australia, AS 1345, *Identification of the contents of pipes, conduits and ducts*
3. Standards Australia, AS/NZS 1554.1, *Structural steel welding, Part 1: Welding of steel structures*
4. Safe Work Australia, Model Code of Practice, *Managing psychosocial hazards at work*
5. Authorised Manual of the St John Ambulance Association in Australia, *Occupational First Aid*



30. WHS Case Studies

30.1 Welding and Musculoskeletal Disease

Welders run a higher risk than average of acquiring pain in the musculoskeletal system. A generally high prevalence of complaints of this nature is a common finding as in other types of manual work. In a discussion of the specific risks associated with welding, each joint system in the human body must be considered separately.

With respect to low back pain, the prevalence of complaints is high, but it has not been shown that welding work entails a higher risk than other types of say, metal work.

Neck pain seems to be slightly more prevalent in welders than in comparable groups. Biomechanical studies imply that the type of visors that are manoeuvred through neck movements may play a role here. There is a need, however, for more thorough studies in this area before reaching a definite judgement.

There is epidemiological evidence that welding work plays an etiological role in the development of shoulder pain due to tendinitis in the rotator cuff. This observation has also been substantiated through clinical and experimental studies.

With respect to knee complaints, the high prevalence found in shipyard welders seems to be due to problems associated with mechanical pressure in kneeling work in general.

The relative risk for various hand problems in welders found in epidemiological studies warrants a closer look with respect to possible aetiology. To some extent, the complaints may logically be associated with exposure to hand-held vibrating tools or welding with semi-automatic equipment, due to the weight of the welding gun and cable. The high prevalence of Dupuytren's disease, however, and symptoms such as numbness and general weakness in the hand should be investigated clinically and experimentally to establish their possible relations to welding work.

A critical look at the scientific evidence available with respect to musculoskeletal complaints and disorders in welders gives rise to the following conclusions:

a) Musculoskeletal symptoms are prevalent in welders;

b) Welding work entails an increased risk for shoulder pain due to inflammatory reactions in the rotator cuff;

c) Further studies should be carried out with respect to hand and neck problems.

30.2 Designing GMA Welding Guns with Welder Comfort in Mind

A range of manufacturers has been improving the ergonomic design of welding guns, to increase welders' comfort, reduce fatigue and lower the risk of cumulative trauma disorders.

Welding guns are hand tools, but they add heat and must be held in stiff positions for longer periods of time, more so than most other hand tools. Welding guns should be fitted to the job and the welder. Many cumulative trauma disorders can be attributed to poor tool design and poor training. Factors contributing to cumulative trauma disorders in welding include:

a) Handle design

b) Weight

c) Cable strain relief

d) Trigger and trigger location

e) Welder training

30.3 Hand Tools

In the use of hand tools, one important consideration is the static loading of the shoulder, forearm, hand and



finger muscles. Static muscle loading varies with the weight of the tool and the orientation in which it is hold. Static muscle loading varies with the rotational torque required to manoeuvre the weld gun.

30.4 Ergonomic Welding Chair

Ergonomic welding chairs and stools with a movable saddle depending on the welding position, are readily available to assist the welder to position themselves comfortably during welding to minimise strain and fatigue.

Welding may take place in a variety of postures, ranging from welding downhand in an optimal working zone to welding overhead, kneeling or squatting. Irrespective of posture, however, the high precision demanded by the task requires postural stabilisation, particularly of the hand and the arm. This means that the stabilising muscles of the shoulder are active to a high degree for as long as the welding task continues.

Low-level physical injury can be avoided by doing warm-up exercises and flexing / stretching exercises prior to the activity. When working in ergonomically challenging positions it is important to take regular breaks and repeat stretching exercises.

High quality of workmanship and high productivity are dependent on optimum ergonomic conditions for the welder. Allowances must also be made for any necessary PPE requirements for the process used and materials being welded.

Appendix A: Further Reading

Bibliography

Additional information may be obtained from the documents listed in this section.

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Work Health and Safety Authorities

Work health and safety authorities throughout Australia publish Codes of Practice and other documents to assist industry comply with National and State legislation and regulations.

These publications include the Australian Code for the transport of dangerous goods by road and rail, National Transport Commission, Edition 7.9 2024.

Refer also to internet web sites operated and maintained by the Statutory Authorities listed in Appendix B.

International Symbols

A number of standardised pictograms are used to provide information and warnings on packaging of goods and permanently fixed to certain equipment throughout the world. Examples can be found in:

- ISO 7001 graphical symbols – public information symbols
- IEC 60417 graphical symbols for use on equipment (this is also available as an online database comprising all graphical symbols published in IEC 60417)
- EU Regulation on the Classification, Labelling and packaging of substances and Mixtures
- UN Globally Harmonised System of Classification and labelling of chemicals (GHS)
- United States Department of Transportation (DOT)



Appendix B: Statutory Authorities

List of occupational health authorities, industrial departments and occupational health, safety and welfare legislation associated with the safety and health issues referred to in this Technical Note. **Note**: Entries were correct at November 2026.

Australian Government
SafeWork Australia
Post: GPO Box 641, CANBERRA ACT 2601
Phone:1300 551 832
Email: info@swa.gov.au
www.safeworkaustralia.gov.au

Comcare
Post: GPO Box 9905, CANBERRA, ACT 2601
Phone: 1300 366 979
Email: generalenquiries@comcare.gov.au
https://www.comcare.gov.au

New South Wales
SafeWork NSW
92-100 Donnison Street
GOSFORD NSW 2250
Phone: 13 10 50
Email: contact@safework.nsw.gov.au
www.safework.nsw.gov.au

Victoria
WorkSafe Victoria
1 Mallop Street
GEELONG VIC 3220
Phone: 1800 136 089
Email: info@worksafe.vic.gov.au
https://www.worksafe.vic.gov.au/

Northern Territory
NT SafeWork
Post: GPO Box 1722, DARWIN NT 0801
Phone: 1800 019 115
Email: ntworksafe@nt.gov.au
www.worksafe.nt.gov.au

ACT
WorkSafe ACT
Phone: 13 22 81
Post: PO Box 158, CANBERRA CITY ACT 2601
Email: worksafe@act.gov.au
Training enquiries: worksafetraining@act.gov.au

Queensland
WorkSafe Queensland
280 Adelaide Street
BRISBANE QLD 4000
Post: GPO Box 69, BRISBANE QLD 4001
Phone: 1300 362 128
Fax: (07) 3006 6400
https://www.worksafe.qld.gov.au/

South Australia
SafeWork SA
33 Richmond Road
KESWICK SA 5035
Phone: 1300 365 255
https://www.safework.sa.gov.au/

Western Australia
WorkSafe Western Australia
Post: Locked Bag 14, CLOISTERS SQUARE WA 6850
Phone: 1300 307 877
Email: wscallcentre@lgirs.wa.gov.au
https://www.worksafe.wa.gov.au/contact-us

Department of Local Government, Industry Regulation and Safety
Post: Locked Bag 100, EAST PERTH WA 6892
Phone: 1300 136 237
Email: safety@lgirs.wa.gov.au
https://www.worksafe.wa.gov.au/contact-us

Tasmania
WorkSafe Tasmania
Post: PO Box 56, ROSNY PARK TAS 7018
Phone: (03) 6166 4600
Email: wstinfo@justice.tas.gov.au
https://worksafe.tas.gov.au/

New Zealand
WorkSafe NZ
Level 6, 86 Customshouse Quay
WELLINGTON 6011 NEW ZEALAND
Post: PO Box 165, WELLINGTON 6140 NEW ZEALAND
Telephone: 0800 030 040 (NZ only) or +64 4 897 7699
https://worksafe.govt.nz/

Appendix C: 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. In addition, they evaluated ultraviolet light from arc welding and classified it as Carcinogenic to Humans (Group 1).

Their assessments were subsequently published in IARC's Monograph 118 in July 2018.

The International Institute of Welding (IIW) through their Commission VIII experts, are evaluating the findings published by IARC and a position statement is being prepared.

C2 Weld Fume

Following discussions with Commission VIII, Weld Australia advises that current fume management recommendations remain valid and recommends that the guidelines published within this Technical Note and Weld Australia's *Fume minimisation guidelines* be followed.

C2.1 Recommendations

In compliance with National and State WHS Regulations, conduct a risk assessment 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.). The following actions should be considered in the risk assessment:

1. Where practicable, remove the welder from the source of the fume by mechanising or automating the welding process.
2. In conformance with Weld Australia's *Fume minimisation guidelines*, arrange the work piece so that the welder's head is not in the plume. Note that:
   (i) Unless welding in the horizontal (PC or 2G), overhead (PD, PE, 4F, 4G) or vertical (PF, PG, 3F, 3G) 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) Whilst all welding processes generate fume, the plume may not be visible to the welder, or with some processes, the observer.
3. Relying on a light cross-draught in the vicinity of the welder's face to ensure that the fume is either drawn or blown away from the welder's breathing zone can be unreliable. Whilst mechanically assisted ventilation (e.g. a fan) can be utilised, cross draughts sufficient to disperse fume may cause weld quality issues. Other fume management equipment such as fume extractors (e.g. fixed, downdraft or portable) may be required.
4. Utilise personal protective equipment such as respirator masks and air fed helmets if alternative methods of fume control are not reasonably practicable.

Care should be taken to ensure that other workers are not exposed to the fume by allowing it to accumulate in areas away from the welding or welding related process.

Specialist advice may also be sought from an occupational hygienist e.g. www.aioh.org.au, particularly in the preparation and implementation of the risk assessment, and the verification of the application of the controls.



C3 Ultraviolet Radiation

The IARC assessment of data relating to welder's exposure to ultraviolet radiation has confirmed an increased risk of skin cancers and ocular (eye) cancers. The classification of ultraviolet light from arc welding as *Carcinogenic to Humans* (Group 1) is consistent with previous evaluations of ultraviolet radiation as a human carcinogen published in Monograph 100D in 2012.

C3.1 Recommendations

In addition to and in support of any control measures recommended by the Australian workplace safety regulators, Weld Australia recommends members ensure welders avoid all direct exposure to ultraviolet radiation from arc welding processes. Recommended control options include:

1. Wearing of approved protective clothing specifically designed for welding, and, covering all exposed areas of the skin with clothing that incorporates a high UPF rating.
2. Use of suitable darkened eye filters (or auto darkening face shields) e.g. conforming with AS/NZS 1338.1.
3. Regular application of sunscreen with a high SPF factor in conformance with the manufacturer's instructions.

Appendix D: Example Safe Work Method Statement (SWMS)

SWMS No.: 018	Work Activity Description: Oxy Cutting
All foreseeable OHS and Environmental Hazards and Risks associated with the works must be assessed and allocated controls in this SWMS the Project Risk assessment is to be consulted in the compilation/review of this SWMS. All persons involved in the works must have been consulted in the development and/or modification or revision of this safe work method statement. This SWMS to be reviewed as required when a change in activity, system, design, variation, plant, legislative or company requirement is apparent or minimum every 3 months. All high risk activities are to be reviewed minimum monthly utilising Observation.	

Project:		**Project No:**		**Approved Date:**		**Planned Commencement Date:**	
Senior Employee Representative:		**Business Address:**				**ABN:**	
Personnel Consulted on Development of SWMS:				**To be Reviewed By:**	Supervisor HSE Department		
Personnel Responsible for Monitoring this Activity:				**Legislation, Australian Standards and Codes of Practice Consulted:**	OH&S act Vic 2004 OH&S Regs Vic 2007 WHS 2011 Welding Processes COP 2018		
Risk Assessment reviewed: YES	**This is a High Risk Construction Activity: YES**			**Laing O'Rourke Primary Standards Consulted:**	SR02 SWMS SR03 JSA prestart PS08 PPE SR 11 Training and inductions PS44 certificates and competency PS37 manual handling PS39 permits to work PS40 plant and equipment isolation PS34 Hot works		

Plant and Equipment Required for this Activity: Oxy, acetylene, cutting torch, igniter, gas bottle trolley. Welding PPE.	
Plant and Equipment Inspections Required: inspect gas hoses, flash back arrestors annual inspection, regulators	
Materials Used: Oxy, Acetylene	**MSDS Required: YES, Oxy, Acetylene**
Personnel Qualifications Required for this Activity: Qualified Tradesman	
Specific Training Required for this Activity: Site Induction	

Hierarchy of Control: *Highest level of Control* **- Elimination** → **Substitution** → **Engineering** → **Administration** → **PPE -** *Lowest Level of Control*

NOTE: The above 'Hierarchy of Controls' must be considered and applied as part of the risk assessment process. Where ELIMINATION cannot be reasonably applied then, SUBSTITUTION, ENGINEERING, ADMINISTRATION and PPE can be considered as preferred controls in descending order.

ACCEPTANCE	POSITION[1]	SIGNATURE	DATE
We hereby accept the controls as detailed in this SWMS and confirm / controls will be implemented and complied with.	**1. SUBCONTRACTOR / WORK SUPERVISOR Name:**		
Accepted by LORAC Representatives	**2. Factory manager Name:**		
	3. Supervisor Name:		
	4. HSE Advisor Name:		

Notes: [1] All relevant signatures must be obtained prior to the commencement of work. Obtain signatures in the order indicated

Review No.	1	2	3	4	5	6	7	8	9
Name and Initials									
Date									

Probability: **5** = Almost Certain **4** = Probable **3** = Moderate **2** = Unlikely **1** = Rare	**Consequence:** **5** = Multiple/Singular Fatality **4** = Nonfatal but permanent injury **3** = Injured no return to work (LTI) **2** = Injured return to work restricted duties(MTI) **1** = Injured immediate return to work (FAI)

1- 6 Acceptable **7 - 12 Acceptable with strict Control Measures or Short Duration** **13 - 25 UNACCEPTABLE**

PROCEDURE (Break the job down into steps)	**POTENTIAL SAFETY AND ENVIRONMENTAL HAZARDS** (What can go wrong)	**Initial Risk Rating**			**Control Measures**	**Residual Risk Rating**			**PERSON RESPONSIBLE** (to ensure management method is applied)
		P X	**C**	**T**		**P X**	**C =**	**T**	
Step 1 – All personal in area to be made aware of work to take place	Lack of communication causing injury	**3**	**4**	**12**	Communicate to all personal in area of work taking place. Ensure correct use of PPE.	**2**	**4**	**8**	Tradesman
Step 2 – Identify and set up Work Area	Unauthorised start-up of equipment.	**3**	**4**	**12**	Barricade work area to identify area and prevent unauthorised entry	**2**	**4**	**8**	Tradesman
	Unauthorised entry to work area.	**3**	**4**	**12**	Barricade work area to identify area and prevent unauthorised entry	**2**	**4**	**8**	Tradesman
Step 3 – Check equipment/ tools are in good working condition and correct for task being performed	Cuts, punctures, strains.	**3**	**3**	**9**	Replace any damaged/worn tools.	**2**	**3**	**6**	Tradesman
	Burns	**4**	**4**	**16**	Check equipment condition and replace faulty/ damaged items. Ensure correct use of PPE as per company policies	**2**	**4**	**8**	Tradesman
	Explosion	**4**	**5**	**20**	Check equipment condition and replace faulty/ damaged items. Equipment to have no oil/grease applied during assembly.	**2**	**5**	**10**	Tradesman
Step 4 – Isolate equipment	Unexpected start-up of equipment	**3**	**4**	**12**	LOTO as per company policy's	**1**	**4**	**4**	Tradesman
Step 3 – Oxy Cutting	Fumes causing comfort issues and or long term illness	**4**	**4**	**16**	Ensure you are working in a well-ventilated area.	**2**	**4**	**8**	Tradesman
	Object being worked on can explode or create a fire resulting in fatalities and or burns	**4**	**5**	**20**	Operator is to ensure that oxy cutting activity is not performed on objects or plant in which a flammable substance has been manufactured, used, handled or stored unless it is completely free of the substance Operator is to ensure they have a fire extinguisher within their in the vicinity of their work area in case of a fire breakout	**2**	**5**	**10**	Tradesman

Probability: **5** = Almost Certain **4** = Probable **3** = Moderate **2** = Unlikely **1** = Rare					**Consequence:** **5** = Multiple/Singular Fatality **4** = Nonfatal but permanent injury **3** = Injured no return to work (LTI) **2** = Injured return to work restricted duties(MTI) **1** = Injured immediate return to work (FAI)				
1- 6 Acceptable **7 - 12 Acceptable with strict Control Measures or Short Duration** **13 - 25 UNACCEPTABLE**									
PROCEDURE (Break the job down into steps)	**POTENTIAL SAFETY AND ENVIRONMENTAL HAZARDS** (What can go wrong)	**Initial Risk Rating**			**Control Measures**	**Residual Risk Rating**			**PERSON RESPONSIBLE** (to ensure management method is applied)
		P X	**C**	**T**		**P X**	**C =**	**T**	
	Exposure to non-iodizing radia-tion with hot solids	**4**	**4**	**16**	Workers are to ensure they are wearing oxy cutting goggles or glare rated medium/high impact face shield and clear safety glasses.	**2**	**4**	**8**	Tradesman
	Pieces of slag can come away from work pieces and can make contact with workers and or leads and hoses	**4**	**4**	**16**	Workers are to ensure they are in a position to operate whereby molten slag will not drop on to them. Workers will also ensure that their leads are out of the way and there is no chance that it can be touched by falling slag. Ensure correct use of PPE as per company policies	**2**	**4**	**8**	Tradesman
	Coming into contact with extremely hot work surfaces	**4**	**3**	**12**	Cover or shield likely affected areas. Control heat migration by cooling surrounding area. If possible, remove item to a safer place.	**2**	**3**	**6**	Tradesman
Step 10 – Clean area/ pack up	Slips, trips, falls	**3**	**4**	**12**	Use correct PPE and following good housekeeping procedures as per company polices.	**1**	**4**	**4**	Tradesman
Step 13 – Emergency Plan	Delayed medical assistance	**3**	**4**	**12**	In the event of an emergency call factory manager/supervision. Call trained level 3 first aiders. Call 000.	**1**	**4**	**4**	Tradesman

We, the undersigned, confirm that we were consulted in the development of this Safe Work Method Statement nominated above and have been explained its contents. We also confirm that we are qualified to carry out the works identified above, a copy of to evidence our required qualifications have been provided to LORAC and to undertake this activity are current. We also clearly understand that the controls in this SWMS must be applied as documented; otherwise work is to cease immediately.

NAME	QUALIFICATIONS REQUIRED and issued to LORAC FOR THIS ACTIVITY	SIGNATURE	DATE	TIME	EMPLOYER

Any revision or modification to the SMWS is required to follow the same process as detailed above and be signed off by all participants.



Appendix E: Typical Form for a Hot-Work Permit

HOT-WORK PERMIT		
Contact: _____ (Responsible Officer) **Phone:** _____		
If you answer No to any of the following questions and can't address the issue yourself, you must stop and seek advice from your Supervisor. This Hot Work Permit is required for any welding, brazing, thermal or oxy cutting, friction cutting, heating and other fire or spark producing operation in any area not designated as a Hot Work Area.		
1. Specific location of the hot work		
2. Hot work covered by the permit		
3. Equipment to be used *(e.g. oxy-acetylene cutting equipment, arc-welding equipment, grinders). Ensure equipment is well maintained.*		
4. Is a Safe Work Procedure (SWP) and/or Pre-job Risk Assessment available and has it been communicated to the work party? *The Responsible Officer shall ensure that risk assessment has been carried out and communicated to the work party.*	☐ Yes	☐ No
5. Have hot-work hazards been identified and controls put in place to eliminate the risks associated with the hazards (see AS 1674.1)? *The Responsible Officer shall ensure that appropriate controls have been put in place to eliminate the risks associated with the hazards.*	☐ Yes	☐ No
6. Fire fighting equipment – to be laid out at the worksite *(List the type, size, quantity and location of firefighting equipment allocated to the site as a result of risk assessment).*		
7. Is the equipment approved for use at the site for the work you are doing?	☐ Yes	☐ No
8. Are flashback arrestors fitted to both ends of the hoses on oxy-fuel gas equipment?	☐ Yes	☐ No
9. Arc Welding Is there a HRD fitted to welding power sources that have an open circuit voltage exceeding extra low voltage (see AS 1674.2)?	☐ Yes	☐ No
a. Have the ambient temperature and humidity been measured at the work place?	☐ Yes	☐ No
b. Changes in ambient temperature and humidity whilst arc welding are monitored? *Temperature and humidity changes must be monitored throughout the hot work.* NOTE: Ambient temperatures >25°C and/or humidity ≥ 70% can cause a rapid build up of sweat in the welder's clothing, gloves and PPE.	☐ Yes	☐ No
c. Is it raining or is rain predicted? *If rain is likely, welding must cease unless the welder remains dry and protected.*	☐ Yes	☐ No

HOT-WORK PERMIT		
Contact: _____ (Responsible Officer) **Phone:** _____		
d. Are processes in place to ensure the welder's clothing, gloves and PPE remains dry and in good condition? *Clothing, gloves and PPE that dampens or is damaged must be replaced.*	☐ Yes	☐ No
e. Has the welding environment been assessed (see AS 1674.2)? Category _____ *Assume welding environment category is Category C unless proved otherwise.*	☐ Yes	☐ No
f. Have safety precautions for the welding environment been implemented?	☐ Yes	☐ No
10. Is the required PPE for the hot work available and in good order?	☐ Yes	☐ No
11. How long will the area be monitored by the firewatcher after the hot work is completed? *This will depend on the nature of the work, combustible materials, and other matters identified in the risk assessment.*	_____ Hours	
12. Are SDS Sheets available for the welding equipment and materials being worked on, and possible products of the hot-work process?	☐ Yes	☐ No
13. In the event of an emergency, is the procedure available and understood?	☐ Yes	☐ No
14. Competent Personnel *Competent personnel only shall be used for hot work*		
a. Is a firewatcher(s) required? *Firewatchers shall be stationed in the area near the hot work and shall follow the procedure specified in AS 1674.1*	☐ Yes	☐ No
b. If required, has a firewatcher been organised?	☐ Yes	☐ No
c. Is the work party trained in the correct and safe use of the hot-work equipment?	☐ Yes	☐ No
d. Is the work party trained in the use of the fire protection equipment?	☐ Yes	☐ No
e. Will the hot work affect a designated confined space?	☐ Yes	☐ No
f. Are confined space trained personnel required? *If Yes: Use Confined Space Permit*	☐ Yes	☐ No
15. ISOLATION AND PREPARATION OF THE WORK AREA Determine whether the following items have been isolated, removed, or checks made: NOTE: All questions are to be answered and initialled by the issuing responsible officer. 'N/A' means 'not applicable'.		
a. Have drains, pits and depressions been checked, isolated and sealed?	☐ Yes	☐ No
b. Have combustible materials been removed from the work area or made safe? *All combustible materials should be removed from within* **15 m** *(around, above and below) of the hot work.*	☐ Yes	☐ No
c. Where it is not possible to remove combustible materials, has the area been controlled? Has the area been cleaned?	☐ Yes	☐ No
d. Have tanks, valves, vents and pipelines been blanked off or effectively isolated?	☐ Yes	☐ No
e. Is ventilation adequate? *Consider the possibility of changing conditions and ensure that airflow is adequate*	☐ Yes	☐ No



HOT-WORK PERMIT		
Contact: _____ (Responsible Officer) **Phone:** _____		
f. Are spark and flash screens in place?	☐ Yes	☐ No
g. Have leaks from valve and pump glands, flanges and the like been controlled?	☐ Yes	☐ No
h. Have pressure relief valves been vented to safe areas?	☐ Yes	☐ No
i. Has contaminated ground been covered?	☐ Yes	☐ No
j. Is the fire equipment adequate, checked and laid out ready for use?	☐ Yes	☐ No
k. Is the fire protection equipment within range (10m) of the proposed work	☐ Yes	☐ No
l. Is the fire pump or fire brigade on standby?	☐ Yes	☐ No
m. Is the wind direction satisfactory for hot work to be done?	☐ Yes	☐ No
n. Has product movement been stopped in the area of hot work?	☐ Yes	☐ No
o. Has the site of the hot work been isolated and roped off?	☐ Yes	☐ No
p. Have all mechanical/electrical/hydraulic energies been isolated and tagged?	☐ Yes	☐ No
q. Have all unnecessary power cables and gas hoses been removed from the immediate work area?	☐ Yes	☐ No
r. Do Automatic Fire Systems need to be isolated? *The Responsible Officer must be notified if the system is to be isolated.*	☐ Yes	☐ No
16. ATMOSPHERE Atmospheric testing may be required at the work site and to monitor atmospheres within closed spaces affected by hot work		
a. Is atmospheric testing required?	☐ Yes	☐ No
b. Is continual monitoring required?	☐ Yes	☐ No
c. Equipment make and model *(Ensure the test equipment is capable of determining the gases that may be present)*		
d. Serial No.		
e. Date of last equipment check *(Gas testing equipment should be challenge tested on calibrated gas mixtures on a regular basis)*		
f. Time of test (*If continual monitoring is required a separate table should be used to record results of tests)*		
g. Results of tests *(If continual monitoring is required a separate table should be used to record results of tests)*		
h. Percentage of L.E.L. (*Ensure the concentration of any flammable gas and flammable vapour is less than 5% of its lower explosive limit (L.E.L.))*		

HOT-WORK PERMIT

Contact: _____ (Responsible Officer) **Phone:** _____

i. Is hot-work safe to proceed (see AS 1674.1)?	☐ Yes	☐ No

17. SPECIFIC CONDITIONS AND PRECAUTIONS

a. The following conditions and precautions were observed

b. This permit is valid from _____ am/pm on ___/___/___ to _____ am/pm on ___/___/___

c. Name of contractor performing the work

d. Order or contract no.

e. Name and signature of firewatcher (where required):

_____ (Print Name) _____ (Signature)

f. Permit received by:
I have read and understood this permit and agree to carry out the work observing all the conditions of this permit.

_____ (Print Name) _____ (Signature)

g. Person in charge of location
I have read and understood this permit and agree to carry out the work observing all the conditions of this permit.

_____ (Print Name) _____ (Signature)

h. Responsible Officer:
The work area described above is, in my opinion, in a safe condition for the work described to be done, provided the precautions listed are fully observed

_____ (Print Name) _____ (Signature)

i. Return permit:
I accept the work as defined in section 2 and 3 of this permit has been completed and I cancel this permit
This permit was cancelled by:

_____ (Print Name) _____ (Signature)

This permit was returned to: At: am/pm on ___/___/___

_____ (Print Name) _____ (Signature)

Responsible Officer:
The worksite has been inspected by me at the expiry/cancellation of this hot-work permit not less than 30 minutes after the cessation of hot work and declared safe for normal operations to resume.

_____ (Print Name) _____ (Signature)

THIS HOT-WORK PERMIT SHOULD BE PROMINENTLY DISPLAYED ON THE WORKSITE



Appendix F: Typical Form for a Confined Space Entry Permit

CONFINED SPACE ENTRY PERMIT		
If you answer No to any of the following questions and can't address the issue yourself, you must stop and seek advice from your Supervisor. A Confined Space Entry Permit is required for entry into a confined space as defined in WHS regulations and AS/NZS 2865. This permit may be used for hot work in confined spaces for any welding, thermal or oxy cutting, friction cutting, heating and other fire or spark producing operations in a confined space not designated as a Hot Work Area.		
1. Specific location of the hot work		
2. Hot work covered by the permit		
3. Equipment to be used *(e.g. oxy-acetylene cutting equipment, arc-welding equipment, grinders). Ensure equipment is well maintained.*		
4. Is a Safe Work Procedure (SWP) and/or Pre-job Risk Assessment available and has it been communicated to the work party? *The Responsible Officer (R.O.) shall ensure that risk assessment has been carried out and communicated to the work party.*	☐ Yes	☐ No
5. Have hot-work hazards been identified and controls put in place to eliminate the risks associated with the hazards? *The R.O. shall ensure that appropriate controls have been put in place to eliminate the risks associated with the hazards.*	☐ Yes	☐ No
6. Fire fighting equipment – to be laid out at the worksite *(List the type, size, quantity and location of firefighting equipment allocated to the site as a result of risk assessment).*		
7. Is the equipment approved for use at the site for the work you are doing?	☐ Yes	☐ No
8. Are flashback arrestors fitted to both ends of the hoses on oxy-fuel gas equipment?	☐ Yes	☐ No
9. Arc Welding Is there a HRD/VRD fitted to welding power sources that have an open circuit voltage exceeding extra low voltage?	☐ Yes	☐ No
a. Have the ambient temperature and humidity been measured at the work place?	☐ Yes	☐ No
b. Changes in ambient temperature and humidity whilst arc welding are monitored? *Temperature and humidity changes must be monitored throughout the hot work.* NOTE: Ambient temperatures >25°C and/or humidity ≥ 70% can cause a rapid build up of sweat in the welder's clothing, gloves and PPE.	☐ Yes	☐ No
c. Is it raining or is rain predicted? *If rain is likely, welding must cease unless the welder remains dry and protected.*	☐ Yes	☐ No
d. Are processes in place to ensure the welder's clothing, gloves and PPE remains dry and in good condition? *Clothing, gloves and PPE that dampens or is damaged must be replaced.*	☐ Yes	☐ No

CONFINED SPACE ENTRY PERMIT		
e. Has the welding environment been assessed? *See AS1674.2. Welding environment category shall be deemed Category C unless proved otherwise.*	☐ Yes	☐ No
f. Is the welder insulated from the workpiece? *The welder shall be insulated from the workpiece using dry, non-flammable insulated mats to prevent contact with the workpiece whilst welding.*	☐ Yes	☐ No
10. Is the required PPE for the hot work in a confined space available and in good order? *Also consider the need for respiratory protection, personal atmospheric monitoring equipment etc.*	☐ Yes	☐ No
11. How long will the area be monitored by the firewatcher after the hot work is completed? *This will depend on the nature of the work, combustible materials, and other matters identified in the risk assessment.*	_____ Hours	
12. Are SDS Sheets available for the welding consumables, cleaners, antispatter etc and materials being worked on, and possible products of the hot-work process?	☐ Yes	☐ No
13. In the event of an emergency, is the procedure available and understood?	☐ Yes	☐ No
14. Competent Personnel *Competent personnel only shall be used for hot work in a confined space*		
a. Is a firewatcher required? *Firewatchers shall be stationed in the area near the hot work and shall follow the procedure specified in AS 1674.1 Clause 3.6*	☐ Yes	☐ No
b. If required, has a firewatcher been organised?	☐ Yes	☐ No
c. Is the work party trained in the correct and safe use of the hot-work equipment?	☐ Yes	☐ No
d. Is the work party trained in the use of the fire protection equipment?	☐ Yes	☐ No
e. Will the hot work affect a designated confined space?	☐ Yes	☐ No
f. Is the work party trained in the correct and safe confined space procedures?	☐ Yes	☐ No
g. Has a trained observer/stand-by person been organised? *Refer to WHS Regulations, AS 1674.2 and AS/NZS 2865*	☐ Yes	☐ No
15. ISOLATION AND PREPARATION OF THE WORK AREA Determine whether the following items have been isolated, removed, or checks made: NOTE: All questions are to be answered and initialled by the issuing responsible officer. 'N/A' means 'not applicable'.		
a. Have drains, pits and depressions been checked, isolated and sealed?	☐ Yes	☐ No
b. Have combustible materials been removed from the work area or made safe? *All combustible materials should be removed from within* **15 m** *(around, above and below) of the hot work.*	☐ Yes	☐ No
c. Where it is not possible to remove combustible materials, has the area been controlled? Has the area been cleaned?	☐ Yes	☐ No
d. Have tanks, valves, vents and pipelines been blanked off or effectively isolated?	☐ Yes	☐ No
e. Is ventilation in use and adequate? *Consider the possibility of changing conditions and ensure that airflow is adequate*	☐ Yes	☐ No



CONFINED SPACE ENTRY PERMIT		
f. Are spark and flash screens in place?	☐ Yes	☐ No
g. Have leaks from valve and pump glands, flanges and the like been controlled?	☐ Yes	☐ No
h. Have pressure relief valves been vented to safe areas?	☐ Yes	☐ No
i. Has contaminated ground been covered?	☐ Yes	☐ No
j. Is the fire equipment adequate, checked and laid out ready for use?	☐ Yes	☐ No
k. Is the fire protection equipment within range (10m) of the proposed work	☐ Yes	☐ No
l. Is the fire pump or fire brigade on standby?	☐ Yes	☐ No
m. Is the wind direction satisfactory for hot work to be done?	☐ Yes	☐ No
n. Has product movement been stopped in the area of hot work?	☐ Yes	☐ No
o. Has the site of the hot work been isolated and roped off?	☐ Yes	☐ No
p. Have all mechanical/electrical/hydraulic energies been isolated and tagged?	☐ Yes	☐ No
q. Have all unnecessary power cables and gas hoses been removed from the immediate work area?	☐ Yes	☐ No
r. Do Automatic Fire Systems need to be isolated? *The R.O. must be notified if the system is to be isolated.*	☐ Yes	☐ No
16. ATMOSPHERE Atmospheric testing may be required at the work site and to monitor atmospheres within closed spaces affected by hot work		
a. Is atmospheric testing required?	☐ Yes	☐ No
b. Is continual monitoring required?	☐ Yes	☐ No
c. Equipment make and model *(Ensure the test equipment is capable of determining the gases that may be present)*		
d. Serial No.		
e. Date of last equipment check *(Gas testing equipment should be challenge tested on calibrated gas mixtures on a regular basis)*		
f. Time of test (*If continual monitoring is required a separate table should be used to record results of tests)*		
g. Results of tests *(If continual monitoring is required a separate table should be used to record results of tests)* Oxygen _____% Other gases _____ (less than_____) Other gases _____ (less than_____) Other gases _____ (less than_____) Other airborne contaminants_____		
h. Percentage of L.E.L. (*Ensure the concentration of any flammable gas and flammable vapour is less than 5% of its lower explosive limit (L.E.L.))*		

CONFINED SPACE ENTRY PERMIT		
j. Is hot-work safe to proceed in the confined space?	☐ Yes	☐ No
i. Is hot-work safe to proceed?	☐ Yes	☐ No
17. SPECIFIC CONDITIONS AND PRECAUTIONS		
a. Conditions for entry are as follows (specify requirements, if needed):		
With supplied air respirator?	☐ Yes	☐ No
Without supplied air respirator?	☐ Yes	☐ No
b. The following conditions and precautions were observed and in use. *(Consider the need for fume control, intrinsically safe equipment, communication equipment etc.)*		
c. Emergency response procedures in place?	☐ Yes	☐ No
d. Emergency equipment available?	☐ Yes	☐ No
e. This permit is valid from _____ am/pm on ___/___/___ to _____ am/pm on ___/___/___		
f. Name of contractor performing the work		
g. Order or contract no.		
h. Name and signature of firewatcher (where required): _____ (Print Name) _____ (Signature)		
i. Name and signature of observer/stand-by person (where required): _____ (Print Name) _____ (Signature)		

j. Permit received by:
I have been advised of and understand the risk control measures and precautions to be observed with the entry and tasks in the confined space, and, agree to carry out the work observing all the conditions of this permit.

Entry			Exit		
Name	**Date**	**Time**	**Name**	**Date**	**Time**

CONFINED SPACE ENTRY PERMIT

k. Person in charge of location

I have read and understood this permit and agree to carry out the work observing all the conditions of this permit.

_____ _____

(Print Name) (Signature)

l. Responsible Officer (R.O.)

The risk control measures and precautions appropriate for the safe entry and execution of the tasks in the confined space have been implemented and the persons required to enter the confined space have been advised of and understand the requirements of this written authority. The work area described above is, in my opinion, in a safe condition for the work described to be done, provided the precautions listed are fully observed.

_____ _____

(Print Name) (Signature)

m. Return permit:

I accept the work as defined in section 2 and 3 of this permit has been completed and I cancel this permit

This permit was cancelled by:

_____ _____

(Print Name) (Signature)

This permit was returned to: At: am/pm on ___/___/___

_____ _____

(Print Name) (Signature)

The worksite has been inspected by me at the expiry/cancellation of this confined space permit and declare that:

(i) All personnel and equipment has been accounted for; and,

(ii) All equipment has been checked and restored correctly; and,

(iii) It is safe for normal operations to resume.

_____ _____

(Print Name) (Signature)

THIS CONFINED SPACE PERMIT SHOULD BE PROMINENTLY DISPLAYED ON THE WORKSITE



Notes



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. Four appendices give details on the mechanism, material factors, 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 found 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 flaws 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 (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 important 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 - Cost Effective Quality Management for Welding

Provides guidelines on the application of the AS/NZS ISO 9000 series of Quality Standards within the welding and fabrication industries. Guidance on the writing, development and control of Welding Procedures is also given.

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 by trainees 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.



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