WTIA Technical Note No. 22

Welding Electrical Safety

The SMART TechNet Project has been supported by Federal and State Governments and Australian industry

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EXPERT TECHNOLOGY TOOLS for the Welding Industry

What are they?

An Expert Technology Tool (ETT) is a medium for diffusion and take-up of technological information based on global research and development (R&D) and experience to improve industry performance.

It can be formatted as a hard copy, software (fixed, interactive or modifiable), audiovisual (videos and sound tapes) or physical samples. It can be complemented by face-to-face interaction, on-site and remote assistance, training modules and auditing programs.

The diagram overleaf and the information below show how the WTIA has introduced a group of ETTs to help companies improve their performance.

ETTs and the SME – how can they help my Total Welding Management System?

A Total Welding Management System (TWMS) is a major ETT with supporting ETTs created specifically to assist Australian industry, particularly those Small to Medium Enterprises (SMEs) that do not have the time or finance to develop an in-house system. These companies, however, are still bound by legal requirements for compliance in many areas such as OHS&R, either due to government regulation or to contract requirements. The TWMS developed by the WTIA can be tailor-made by SMEs to suit any size and scope of operation, and implemented in full or in part as required.

What is Total Welding Management

Total Welding Management comprises all of the elements shown in the left-hand column of the table shown overleaf. Each of these elements needs to be addressed within any company, large or small, undertaking welding, which wishes to operate efficiently and be competitive in the Australian and overseas markets.

The Total Welding Management System Manual (itself an Expert Technology Tool) created by the WTIA with the assistance of industry and organisations represented within a Technology Expert Group, overviews each of these elements in the left-hand column. It details how each element relates to effective welding management, refers to supporting welding-related ETTs, or, where the subject matter is out of the range of expertise of the authors, refers the user to external sources such as accounting or legal expertise.

Knowledge Resource Bank

The other columns on the diagram overleaf list the Knowledge Resource Bank and show examples of supporting ETTs which may, or may not, be produced directly by the WTIA. The aim, however, is to assist companies to access this knowledge and to recognise the role that knowledge plays in a Total Welding Management System. These supporting ETTs may take any form, such as a Management System e.g. Occupational Health, Safety and Rehabilitation (OHS&R), a publication e.g. WTIA Technical Note, a video or a Standard through to software, a one-page guidance note or welding procedure.

Clearly, ETTs such as WTIA Technical Notes, various Standards, software, videos etc are readily available to industry.

The group of ETTs shown overleaf relate to a general welding fabricator/contractor. The ETT group can be tailor-made to suit any specific company or industry sector.

A company-specific Knowledge Resource Bank can be made by the company omitting or replacing any other ETT or Standard.

Total Welding Management for Industry Sectors

Total Welding Management Systems and the associated Knowledge Resource Banks are being developed for specific industry sectors, tailored to address the particular issues of that industry and to facilitate access to relevant resources. A company-specific Total Welding Management System can be made by the company adding, omitting or replacing any element shown in the left hand column, or ETT or Standard shown in the other columns. This approach links in with industry needs already identified by existing WTIA SMART Industry Groups in the Pipeline, Petrochemical and Power Generation sectors. Members of these groups have already highlighted the common problem of industry knowledge loss through downsizing, outsourcing and privatisation and are looking for ways to address this problem.

The concept of industry-specific Total Welding Management Systems and Knowledge Resource Banks will be extended based on the results of industry needs analyses being currently conducted. The resources within the Bank will be expanded with the help of Technology Expert Groups including WTIA Technical Panels. Information needs will be identified for the specific industry sectors, existing resources located either within Australia or overseas if otherwise unavailable, and if necessary, new resources will be created to satisfy these needs.

How to Access ETTs

Management System ETTs, whether they are the Total Welding Management Manual (which includes the Quality Manual), OHS&R Managers Handbook, Procedures, Work Instructions, Forms and Records or Environmental Improvement System, can be accessed and implemented in a variety of ways. They can be:

- Purchased as a publication for use by industry. They may augment existing manuals, targeting the welding operation of the company, or they may be implemented from scratch by competent personnel employed by the company;
- Accessed as course notes when attending a public workshop explaining the ETT;
- Accessed as course notes when attending an in-house workshop explaining the ETT;
- Purchased within a package which includes training and on-site implementation assistance from qualified WTIA personnel;
- Accessed during face-to-face consultation;
- Downloaded from the WTIA website www.wtia.com.au

ETTs created by the WTIA are listed on page 37 of this Technical Note. Call the WTIA Welding Hotline on 1800 620 820 for further information.

TOTAL WELDING MANAGEMENT SYSTEM supported by KNOWLEDGE RESOURCE BANK

TOTAL WELDING MANAGEMENT SYSTEM MANUAL
ETT: MS01
(Including Welding Quality Management System)

→ ETTs: MANAGEMENT SYSTEMS | ETTs: OTHER RESOURCES | ETTs: STANDARDS → **KNOWLEDGE RESOURCE BANK**
i.e. resources for the Total Welding Management System (Notes 1 and 2)

ELEMENTS:	ETTs: MANAGEMENT SYSTEMS	ETTs: OTHER RESOURCES	ETTs: STANDARDS
1. Introduction			
2. References			
3. Management System		TN19 Cost Effective Quality Management	AS/NZS ISO 9001 AS/NZS ISO 3834
4. Management Responsibilities (incl. Risk Management)		TN19 Cost Effective Quality Management	AS 4360
5. Document Control			
6. Production Planning			
7. Contracts			
8. Design		TN6 Control of Lamellar Tearing TN8 Economic Design of Weldments TN10 Fracture Mechanics TN12 Minimising Corrosion TN13 Stainless Steels for Corrosive Environments TN14 Design & Construction Steel Bins	AS 4100 AS 1210 BS 7910
9. Purchasing (incl. Sub-Contracting)			
10. Production and Service Operations		TN1 Weldability of Steels TN2 Successful Welding of Aluminium TN4 Hardfacing for the Control of Wear TN5 Flame Cutting of Steels TN9 Welding Rates in Arc Welding TN11 Commentary on AS/NZS 1554 TN15 Welding & Fabrication Q&T Steels TN16 Welding Stainless Steels TN17 Automation in Arc Welding TN18 Welding of Castings TN21 Submerged Arc Welding Videos – Welding Parts A & B PG02 Welding of Stainless Steel	AS/NZS 1554 AS 1988
11. Identification and Traceability		TN19 Cost Effective Quality Management	
12. Welding Coordination			ISO 14731
13. Production Personnel			
14. Production Equipment			
15. Production Procedures		TN1 The Weldability of Steel TN9 Welding Rates in Arc Welding TN19 Cost Effective Quality Management	
16. Welding Consumables		TN3 Care & Conditioning of Arc Welding Consumables	
17. Heat Treatment			AS 4458
18. Inspection and Testing		PG01 Weld Defects	AS 2812
19. Inspection, Measuring and Test Equipment			
20. Non-Conforming Product			
21. Corrective Action		TN20 Repair of Steel Pipelines	AS 2885
22. Storage, Packing and Delivery			
23. Company Records		TN19 Cost Effective Quality Management	
24. Auditing			
25. Human Resources			
26. Facilities			
27. Marketing			
28. Finance			
29. OHS&R	MS02 OHS&R – Managers Handbook MS03 OHS&R – Procedures MS04 OHS&R – Work Instructions MS05 OHS&R – Forms & Records	TN7 Health & Safety in Welding TN22 Welding Electrical Safety Fume Minimisation Guidelines Video – Fume Assessment	AS 4804 AS 1674.2
30. Environment	MS06 Environmental Improvement MS	TN23 Environmental Improvement Guidelines for Welding	AS/NZS 14001
31. Information Technology			
32. Innovation, Research and Development			
33. Security			
34. Legal			

Note 1: Examples of ETTS listed are not all-embracing and other ETTs within the global information supply can be added. ETTs can be formatted in a range of media.
Note 2: Dates and titles for the ETTs listed can be obtained from WTIA or SAI.

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This Technical Note:

This Technical Note is an Expert Technology Tool developed as part of the very successful SMART TechNet Project, supported by industry and Federal and State Governments. It was developed in response to a recent series of electrical safety incidents in the welding and fabrication industries. It is designed to provide practical guidance and a summary of the latest information available from a wide range of research and experience, with the goal of helping to prevent such incidents. It was prepared by WTIA under direction of WTIA Technical Panel 9 *Occupational Health and Safety and Environment*.

Acknowlegments

WTIA wishes to also acknowledge the contribution of all its members, members of WTIA Technical Panels and Committees, WTIA SMART Groups and all those in industry who have contributed in various ways to the development of this Expert Technology Tool including Mr Chris Smallbone and Mr Stan Ambrose (OAM) of WTIA for the initial concept and critical review.

Particular acknowledgment is given to the input from members of the Technology Expert Group formed from industry, government and other organisations. Members of the Technology Expert Group include:

Mr Bruce Cannon – BHP Steel – Flat Products

Mr Bob Cunningham – BHP Steel – Flat Products

Mr Ian Dick – Retired

Mr John Gate – SafetyPro Services (Gate-Leven Pty Ltd)

Mr Kevin Huckstepp – Welding Industries of Australia

Mr John Taylor – Qualmet Services Pty Ltd

Mr John Waudby – NSW Dept of Mineral Resources, Mine Safety and Environment

Mr Neil Wickham – Lightning Welding and Electrical

The Technical Note is a revision of the 2002 first edition. It will be revised from time to time and comments aimed at improving it will be welcomed.

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INTRODUCTION

Although electric arc welding can be performed perfectly safely, there are circumstances when there is a substantial risk of electric shock. Precautions against this risk include use of properly maintained 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 it 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.

This document reviews each of the following elements:

- Equipment
- The Human body
- The Workplace
- Australian Standards

Arc welding is a versatile, every-day engineering practice widely adopted in manufacturing, mining and general industry.

Under favourable conditions the risks associated with electric arc welding can be readily controlled by adoption of sound principles and are normally regarded as acceptable. Under less favourable conditions, circumstances can occur that considerably increase risk to the extent where serious injuries and fatalities may occur. In recognition that there is a variance of hazards, this document addresses safeguarding a person against electric shock. Methods of working in hot, damp or humid environments are also described. All advice given in this Technical Note applies equally to personnel other than welders who may be engaged in welding operations and therefore may be exposed to the same electrical hazards.

This Technical Note can be considered a commentary on AS 1674.2-2003 *Safety in welding and allied processes – Electrical*.

ELECTRIC ARC WELDING AND GOUGING EQUIPMENT

2.1 Introduction

This chapter refers to measures which should be adopted for safety in the use of processes which use an electric arc between an electrode and work piece or between electrodes to develop heat for welding, cutting or gouging. These processes require particular safety consideration in respect of the possible hazards (Table 2.1) which are electrical, radiation, burns, fume and noise.

2.2 Welding Power Source

2.2.1 Types of Welding Power Sources or Machines

A wide range of direct current (d.c.) and alternating current (a.c.) forms of electricity are utilised, including:

a) Low frequency a.c., including mains frequency (50/60 Hz).

b) High frequency (HF) a.c. (exceeding 10kHz).

Table 2.1 Safety Considerations in Arc Welding, Arc Cutting and Arc Gouging

Process		Arc Exposure	Hazards (Note 1)				
Title	Abbreviation		Electric Shock	Radiation (Note 2)	Burns (Note 3)	Fume (Note 4)	Noise
Manual Metal Arc Welding	MMAW	OPEN	X	X	X	X	(Note 9)
Gas Tungsten Arc Welding	GTAW or TIG Welding	OPEN	X	X	X	X (Note 5)	(Note 9)
Gas Metal Arc Welding	GMAW or MIG or CO2 Welding	OPEN	X	X	X	Note 5	(Notes 9 & 10)
Flux Cored Arc Welding							
– with Gas Shield	FCAW	OPEN	X	X	X	X (Note 5)	– (Note 9)
– without Gas Shield		OPEN	X	X	X	X	– (Note 9)
Submerged Arc Welding	SAW	ENCLOSED	X	– (Note 6)	X	– (Note 7)	–
Electroslag Welding	ESW -CG	EFFECTIVELY ENCLOSED	X	X (Note 6)	X	X (Notes 7 & 8)	–
Electrogas Welding	EGW	PARTIALLY ENCLOSED	X	X	X	X (Note 8)	X
Plasma Arc Welding & Cutting	PAW, PTAW or PAC	OPEN	X	X	X	X	X
Plasma Arc Cutting							
– Water Shrouded		ENCLOSED	X	–	–	–	X
– Submerged		ENCLOSED	X	–	–	–	–
Arc Air Gouging-		OPEN	X	X	X	X	X

Notes:

1. X indicates hazard
2. Ultraviolet, visible and infra-red radiation
3. Includes hot objects and particles
4. Due to consumables, materials and coatings
5. Shielding gas also introduces risk of asphyxiation
6. Slight risk of accidental exposure. Limited protection advisable.
7. Fume level is low and welder is remote from arc.
8. Welder is also remote from fume
9. Noise levels relatively low – main source is motor driven equipment.
10. Pulsed MIG and some dip transfer modes might require hearing protection.

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c) d.c. (some types of rectifiers impose a mains frequency wave form on the d.c.).
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:

a) Machines driven by electric motors, petrol or diesel engines.
   (i) Generators that provide d.c..
   (ii) Alternators that provide a.c. or, with rectifiers, d.c.
b) Transformers which reduce mains voltage to that required for welding:
   (i) Transformers that provide a.c.
   (ii) Transformer/rectifiers that provide d.c.
c) Solid State power supplies (including pulsed welding units):
   (i) Solid State d.c. units.
   (ii) Solid State a.c. units.
   (iii) Inverter units, a.c. and d.c.
      – Square wave low frequency a.c.
      – HF a.c. including HF ignition or re-ignition devices added on to d.c. or low frequency a.c. supplies.

Many welding machines, especially engine-driven units, also provide single and/or three phase auxiliary power outlets.

2.2.2 Compliance

In Australia, welding machines must comply with AS 1966 *Electric arc welding power sources*. Certain classes of portable welding machines are required to conform to AS/NZS 3195:2002 *Approval and test specification – Portable machines for electric arc welding and allied processes* or equivalent standards.

Such machines are required to have a clearly visible name-plate which legibly and indelibly provides information relevant to the operating conditions of the machine. Name-plates provide essential information and should not be interfered with in any manner.

When selecting equipment, consideration must be given to their working environment rating (IP).

2.2.3 Open Circuit Voltage

Welding machines generally have an open circuit voltage in the range of 35 to 113 V. The open circuit voltage (ie voltage between welding terminals ready for welding but carrying no current) presents the greater hazard. OCV is accordingly restricted by AS/NZS 3195 for two classifications:

a) For use in environments with increased risk of electric shock. The open circuit voltages at all possible settings must not exceed:
   (i) d.c. 113 V peak; or
   (ii) a.c. 68 V peak and 48 V rms
b) For use in environments without increased hazard of electric shock. The open circuit voltages at all possible settings shall not exceed:
   (i) d.c. 113 V peak; or
   (ii) a.c. 113 V peak and 80 V rms

Although voltage is thus limited, electrocution is still possible and precautions to prevent electric shock should be adopted.

2.2.4 High Frequency Equipment

High frequency is often used to facilitate arc starting in GTAW (TIG), for example. The source of high-frequency (HF) current and the HF circuit shall be constructed to prevent a voltage in excess of that in Section 2.2.3 and at the supply frequency being applied to the welding current in the event of insulation or equipment failure. It shall not be possible for the voltage of the HF circuit to exceed 3500 V or the HF current to in the output circuit to exceed 50 mA.

The circuit also must be such that HF current will not create a danger for the welder, e.g. inside confined spaces with metal walls. Additional precautions should be taken to prevent interference by electromagnetic fields created by HF currents with other equipment. (See equipment operating instructions for specific measures).

2.2.5 Service Conditions

Welding machines that comply with AS 1966 are capable of delivering their rated current and operating satisfactorily:

a) At ambient air temperature up to 40^{0}C.
b) In atmospheres where gases, dust and radiation normally produced by the welding arc are present.

Machines 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.

Where machines are required to be located out of doors, suitable protection must be provided to protect it from the environment. Special protection is required for machines exposed to corrosive fumes, steam, shock loading or severe weather.

Many industrial situations contain hose down areas as defined in AS/NZS 3000:2000 *Electrical installations (known as the Australian / New Zealand Wiring Rules)*. Unless the welding machine has the correct IP rating it should not be used in hose down areas.

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

Standards Australia is in the process of replacing AS 1966 parts 1, 2 and 3 with a new standard based upon CEI/IEC 60974-1, which is the basis of many world standards. Welding machines to these standards are marked with a degree of protection on their compliance plate. Machines for use outdoors are rated with a degree of protection IP23. Machines with a degree of protection IP21 are only suitable for use indoors. If the degree of protection is not stated on the machine, the manufacturer should be consulted. If the machine 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.

2.2.6 Machine Loading

Care should be taken to ensure that:

a) The electric current rating of the selected machine is adequate to handle the welding job.

b) The machine is not operated above the manufacturer's current rating at the respective rated duty cycle (Reference AS 1966).

Caution must be exercised when using low duty cycle or low current rated machines for processes which readily allow the duty cycle or rating to be exceeded.

2.2.7 Installation, Operation and Maintenance

Machines not provided with a connecting plug must be directly connected to the electricity supply by a competent person in accordance with AS/NZS 3000. Flexible, trailing cables must be used for machines that are moved around.

Figure 2.1 indicates a typical method for connection of plant to the electrical supply and to work.

Do NOT connect work/return terminal to electrical systems earth or to machine case. Any connection between the output terminals and the machine 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.

Where machines are installed adjacent to each other (Figure 2.2) or where welders are working in close proximity to each other, special care is required to avoid the risk of shock due to the combined voltage of the adjacent machines (See Chapter 4). Open circuit voltage between electrode holders should be checked to ensure this does not exceed 113V for d.c. machines and 113V peak, 80 V r.m.s. for a.c. machines, unless positive screens or barriers prevent physical contact between either welders or workpieces.

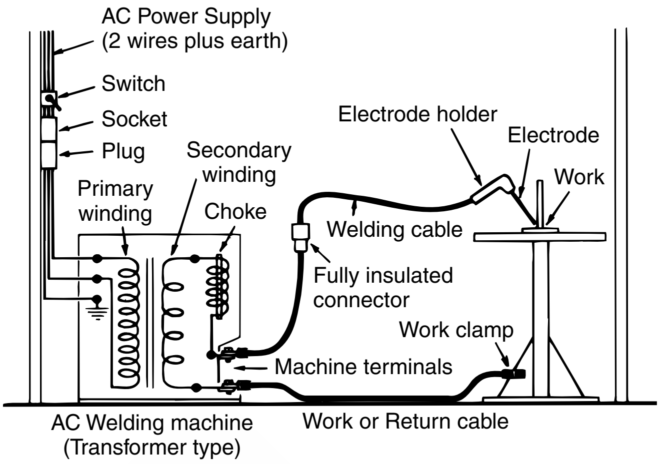


Figure 2.1 Typical Electrical Connections for Arc Welding Machines

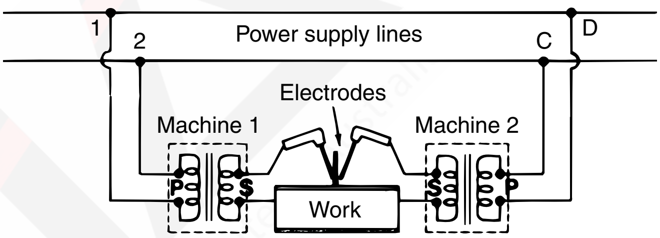


Figure 2.2 Safe Connection of Adjacent Welding Machines for Simultaneous Operation

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, ie voltage between the electrodes will be 2 x OC voltage.
2. Supply connections 1 and 2 are either active and neutral respectively of a single-phase supply, or two wires of a three-phase supply, depending on the voltage for which the machines are designed.

Table 2.2 Capacity of Copper Welding Cables (Compiled from AS/NZS 1995:1995)

Nominal Cross-sectional Area Of Conductor mm²	Approximate Overall Diameter mm	Current Rating (Amperes) at Maximum Duty Cycle (%) (Note 1)			
		100	60	30	25
8	8.6	80	100	145	160
10	9.5	90	120	165	180
16	10.8	125	160	225	245
25	12.9	165	210	300	330
35	13.6	205	265	375	410
50	16.1	260	335	475	520
70	18.0	325	415	590	645
95	20.9	390	505	715	780
120	22.9	455	585	830	910
150	24.9	535	690	975	1070
185	28.3	600	775	1095	1200
240	30.9	715	920	1305	1430

Note 1: 100% duty cycle based on cycle time of 1 hour. All other duty cycles based on cycle time of 5 minutes.

Correct handling and use of welding machines together with regular maintenance and inspection are essential to ensure safe operation.

2.2.8 Inspections of Power Sources and Accessories

A pre-start check should be carried out by the operator before powering up the welding equipment and commencing welding operations. Refer Appendix C.

Routine inspection and testing should be carried out by a competent person to ensure the electrical safety of the equipment and accessories. Refer AS 1674.2 - 2003 Section 5 for minimum frequencies and items to be checked during routine inspections. It is a requirement of AS 1674.2 - 2003 that the owners of the welding machine keep suitable records of periodic tests and a system of tagging including the date of the most recent inspection

2.2.9 Maintenance

Maintenance of equipment should only be carried out by a competent person.

2.3 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. Therefore, particular care should be exercised to ensure equipment is installed and maintained in a safe condition and in accordance with the manufacturer's recommendations. Special care should be taken to prevent contact with high voltages and ensure suitable earthing.

2.4 Welding Cables

2.4.1 General

The welding and work return cables must be of sufficient capacity for the welding current (Table 2.2) and the insulation must be sound.

Cables should conform to AS/NZS 1995:1995 *Welding Cables*. They should not be replaced or repaired except by a competent person (see 2.4.2). Cable lengths should be as short as possible to avoid increased risk of cable damage and voltage drop. All cables should be kept clear of other personnel, walkways and areas where they can be damaged.

Frayed cable or damaged insulation can cause fire or injury. Damaged cables should be repaired or replaced.

2.4.1.1 Long Cables

As cable length increases there is a progressive voltage drop that must be considered. Refer AS 1674.2 – 2003 Clauses 4.2.2. and 4.2.3. The maximum cable length can be calculated using the welding machine OCV, the cable resistance in Ohms/km and the welding current.

Example 1. Calculation of maximum cable length for a given size and current capacity.

Consider the case where a welding current of 110 Amps is required. Consider the welding power source OCV to be 70 Volts and the 16 mm^2 cable has a resistance of 1.16 Ohms /km (Refer AS/NZS1995:1995 Table1).

Firstly calculate maximum allowable voltage drop to comply with the maximum allowable of 10% (Refer AS 1674.2 Clauses 4.2.2 and 4.2.3 – 2003).

Voltage drop (V) = Open Circuit Voltage x 10/100
= 70 Volts/10
= 7 Volts

Next calculate allowable total resistance.

Allowable resistance (Ohms) = Voltage drop/Maximum current
= 7 Volts/100 Amps
= 0.07 Ohms

Then calculate maximum length of cable.

Cable length (m) = Resistance (Ohms)/ Cable resistance (Ohms/km) x 1000
= 0.07 Ohms/1.16 Ohms/km x 1000
= 60.3 metres

The result is valid for the OCV, cable size and current level used in the calculation.

Example 2. Calculation of cable size for a given length and current capacity.

Consider the case where a welding current of 110 Amps is required. Consider the welding power source OCV to be 70 Volts and the total cable length required is 100 m.

Firstly calculate maximum allowable voltage drop to comply with the maximum allowable of 10% (Refer AS 1674.2-2003 Clauses 4.2.2 and 4.2.3).

Voltage drop (V) = Open Circuit Voltage * 10/100
= 70 Volts/10
= 7 Volts

Next calculate allowable total resistance.

Allowable resistance (Ohms) = Voltage drop/Maximum current
= 7 volts/100 Amps
= 0.07 Ohms

Now calculate the maximum cable resistance in Ohms/km.

Cable resistance (Ohms/km) = Allowable resistance (Ohms)/Cable length x 1000
= 0.07 Ohms / 100 x 1000
= 0.7 (Ohms /km)

A suitable cable would be 25 mm^2 which has a resistance of 0.758 Ohms /km (Refer AS/NZS 1995 Table 1)

The result is valid for the OCV, cable length and current level used in the calculation.

The above exercises illustrate that cable selection is based on consideration of a number of variables. To satisfy all rules there are calculations and comparisons with published tables required. In the event that a cable size satisfied the rules in AS 1674.2 Clauses 2.2.2 and 4.2.3 then the requirements of AS/NZS 1995 Table 1 and duty cycle must be considered.

There is also the requirement in AS 1674.2-2003 that "*Welding leads longer than 9 m should not be used, unless the voltage drop of the current used does not exceed the values of Clause 4.2.3*". There was no supporting argument for this requirement found in that Standard or any of the other documents reviewed. It is therefore considered that this requirement is in keeping with the general requirement that cables be kept as short as practicable. Keeping cables short minimises voltage loss, minimises risk of cable damage, avoids the temptation to loop cables to deal with excess length and minimises the risk of injury to personnel during handling.

In order to support higher welding currents or extend significant distances between welding power sources and the work, the cable cross section may need to be quite large. This will mean that the handling of cables will be more difficult due to their increased mass and this consideration may limit the practical length of cable.

2.4.2 Cable Connections

Where connections to welding leads or joining of leads 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.

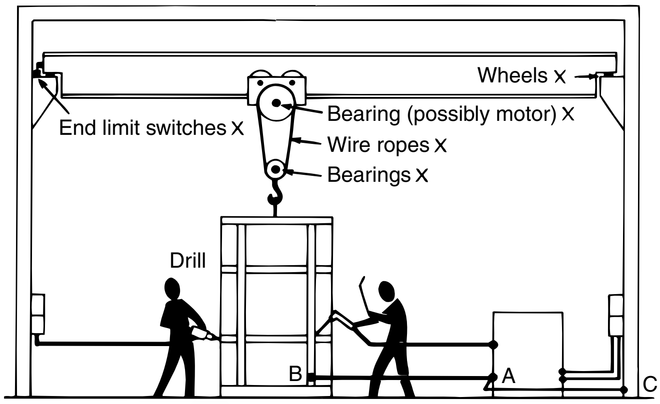
When connecting to terminal posts, the use of undersized bolts or oversized washers makes an unsafe connection that is prone to work loose and overheat. Always use the correct size brass bolts, nuts and washers.

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. Each joint or connection shall have a resistance of not more than the equivalent resistance of 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 return clamps shall be carried out by a competent person. A competent person is defined in AS/NZS 3760: 2001 *In-service safety inspection and testing of electrical equipment* as *"A person, who the person in charge of the premises ensures has acquired through training, qualification, experience or a combination of these, the knowledge and skill enabling that person to perform the task required correctly."*

Output lead connections shall have clean contact surfaces, and shall be properly tightened and adequately protected against inadvertent contact.



(a) Defective Work Returns Causing Damage and Injury

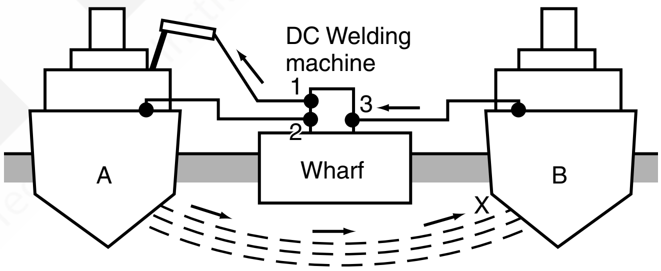
If work return lead AB or its connections are defective, high current may leak through incorrect alternate connection AC, causing damage to:

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 Returns 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 2.3 Work Return Leads – Incorrect Connection Points

Connection of flexible output leads to the welding power source or to extend cables may be carried out by the welder.

The power source shall be switched off or otherwise isolated from the power supply before the connection or disconnection of the output leads to the output terminals.

2.4.3 Work Return

Work return cables or conductors should not be referred to as "earth" and the active output circuit must remain insulated from earth.

Often work returns (and their connections) used in welding are inadequate. The main requirements are to provide a sound and safe electric current return path with low resistance connections and the following should be avoided:

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a) Faulty work return connections. These can cause electrical shock or fire due to overheating.
b) Always connect close to the work or work table and never connect work return cables to structural systems, piping in plant or the like. 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 impressed electrical currents. Corrosion can occur to hulls of ships during maintenance welding (see Figure 2.3a and 2.3b) and a similar situation will occur in any situation where an electrolyte is involved in the welding circuit, such as wet floors.
c) The current-carrying capacity of the work return cables shall be not less than that of the electrode cables.
d) Work return connections should always be secure with firm contact providing a good electrical connection.

2.5 Electrode Holders

2.5.1 Type

Electrode holder should conform to AS 2826 – 1985 *Manual metal-arc welding electrode holders* which concerns the following three types:

Type A *All-insulated holder.* Under conditions of use all conductive parts are completely covered by non-hygroscopic insulating material.

Type B *Insulated holder*. Under conditions of use no live part of the holder, when placed in any position on a flat surface, can touch the surface.

Type C *Holder with insulated handle which does not fulfil the requirements of Type A or B.*

Types A and B are preferred.

Effective heat insulation or cooling of the holder handle, eg provision of air ducts can considerably reduce welder discomfort.

2.5.2 Class

AS 2826 lists five classes of electrode holder and prescribes the welding current and duty cycles for which holders may be used. (Refer to Table 2.3). These conditions should be adhered to in order to reduce overheating and accidents. Holders should be suitably marked to identify class and type eg. marked as AS 2826 No. 300/60.

Table 2.3 Rating of Electrode Holders (AS 2826 – 1985)

Classification			Electrode diameter and cable size	
Designation	Rated Current A	Duty Cycle Percent	Minimum range of diameters of electrode core wire capable of being held mm	Nominal cross-sectional area of copper cable capable of being connected† mm^2
Class 130/25*	130	25	1.6 to 3.2	16
Class 220/30*	200	30	1.6 to 6.3	25
Class 300/30*	300	30	2.0 to 6.3	35
Class 300/60	300	60	2.0 to 8.0	50
Class 400/60	400	60	3.2 to 8.0	70

* The ratings for Class 130/25, 200/30 and 300/30 electrode holders are designed to satisfy the conditions for use with limited input and light industrial power sources (see AS 1966, Part 1 and 2)

† The nominal size of copper cable does not preclude provision of facilities for connections to other sizes of cables. The nominal cable sizes need to correspond to the ratings of the respective holder.

2.5.3 Gripping Action

Screw action types are preferred to spring action types as they provide more uniform contact with the electrode and less overheating of the holder.

2.5.4 Cable Anchorage and Connection

The cable to the holder should be lightweight and flexible to avoid operator fatigue. Although the anchorage of the cable to electrode holder is required to fulfil test requirements on manufacture to AS 2826, 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 electric shock.

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

2.5.5 Routine Inspection

This should include checks for:

a) Loosened metallic screws in the holder.
b) Burnt or cracked insulation which exposes electrical conductors.
c) Overheating and damage at cable connections.

2.5.6 Use

Holders can be damaged by throwing or dropping. Care should therefore be exercised in handling this equipment. Welding electrodes should always be removed from holders after use.

The use of faulty or damaged electrode holders is the most common cause of electric shock.

2.6 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) *Current rating and duty* cycle specified by the manufacturer should be adhered to. Note: Argon and argon mixtures will have a major effect in derating a torch designed for carbon dioxide shielding.
b) *Maintenance* procedures specified by the manufacturer should be observed and no modifications or alterations attempted.
c) Heat shields or cooling devices provided must be maintained and always used to prevent discomfort, burning of skin or deterioration of the equipment.

2.7 Insulating Materials

An electrical insulator can be defined as a material which has such low conductivity that the flow of electricity through it is negligible. They are used to separate electrical conductors from other items, including humans. Primary insulation is defined as insulation in direct contact with the electrical conductors. Secondary insulators are not in direct contact and serve as backup insulation in cases of failure of primary insulators.

The following are examples of primary insulation in welding equipment.

- Leads – insulation on electrode conductor and work or return conductor.
- Terminations
- Connections
- Electrode holders

The following are examples of secondary insulation used in the welding trade:

- Leather gauntlet gloves with cotton or felt lining
- Unlined leather gauntlet gloves
- Cotton or drill overall material
- Cotton gloves intended to be used as liners
- Pigskin riggers gloves, both lined and unlined
- Fireproof capes
- Leather welding aprons and spats
- Safety boots
- Rubber mats and duck boards

Bear the following in mind when using secondary insulation materials:

- Secondary insulation materials **when dry** are adequate to prevent most electric shocks from the secondary side of welding power sources.
- The integrity of the material is important since only a small perforation can expose the operator to electric shock
- As moisture levels rise the resistance of all porous materials will fall, removing any secondary insulation effect.
- Secondary insulation materials cannot be relied on in wet, damp or humid conditions.
- Electrocutions occur at currents of less than 1/1000th of welding currents. A single strand of a frayed cable will deliver enough current for an electrocution.

Personnel are exposed to a risk of electric shock whenever they are in the vicinity of a welding machine that is powered up. AS 1674.2-2003 requires that:

- Output terminals on the welding power source shall be enclosed, covered or otherwise protected, to prevent inadvertent contact.
- Covers shall be of a robust design, with adequate mechanical properties, and effectively maintained.
- Welding leads shall be insulated and the insulation shall be in good repair.

Degradation of insulation can occur rapidly in industrial environments and frequent inspections and rigorous maintenance is required to ensure electrical safety.

2.8 Voltage Reduction Devices (VRDs)

Welding open circuit voltages (OCV) can prove lethal. Voltage Reducing Devices (VRDs) are safety enhancements that greatly reduce the risk of exposure of welding personnel to potentially hazardous voltages produced by a welding power source. A voltage-reducing device or system should automatically reduce the no-load or open circuit voltage (OCV), to a no-load voltage of:

- 35 V for d.c. and
- 35 V peak, 25 V rms for a.c.

or less when the resistance of the output circuit exceeds 200 Ohms. Response time for switching to reduced voltage shall be 0.3 seconds for a.c. circuits and 0.5 seconds for d.c. circuits. The function of a VRD is to reduce the OCV to a safer, lower level when welding ceases. VRDs have the following features:

- When no welding is taking place and the output circuit resistance is high, the voltage is limited. Most commercial VRDs reduce the OCV to around 12 V.
- When the electrode is brought in contact with the work, lowering circuit resistance below about 200 Ohms, the full secondary circuit voltage is applied and allows an arc to establish.
- 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.
- It is also important to understand the response time of a VRD and ensure that this is minimal.
- Some VRDs have an intentional delay of some seconds before they reduce the OCV. This is more than enough time for a welder to be electrocuted.
- When purchasing a VRD, select one designed to fail in a safe manner. Failure must not result in unsafe conditions due to lack of protection.
- VRDs are the best option for achieving the low OCV requirement of a wet hazardous environment when using a drooping characteristic power source (a.c. or d.c.). They are recommended for other locations, although some reduction in the ease of striking has been experienced.

2.8.1 Internal VRD Power Sources

- These are power sources with a VRD fitted internally.
- This is an additional safety feature because it prevents inadvertent or deliberate bypassing of the VRD.
- A number of manufacturers offer equipment with inbuilt VRDs providing improvements in operator appeal and reduced cost.

Further information is given in Appendix B, Guidance Notes on VRDs for Manual Metal Arc Welding and Arc Gouging Power Sources.

2.9 Power Switching

Welding machines supplied by mains power (240 V a.c. or 415 V a.c.) have an input (primary) circuit. Switching the higher voltage, lower current primary circuit or the lower voltage, higher current secondary circuit may be used to interrupt the power supply.

2.9.1 Switch-controlled welding power sources

- Standard on FCAW & GMAW (MIG) equipment.
- Available on some MMAW (Stick) equipment
- Secondary active only when operator closes switch on the handpiece.
- Dramatically reduces the window of opportunity for exposure to OCV.
- Requires an additional control lead back to the welding power source.

2.9.1.1 Switch-Controlled MMAW Power Sources:

- MMAW welding machines with a switch on the electrode holder. The "switch" may be a remote control or any other means that enables control of a switch mounted within the welding power source.
- The welder operates the "switch" to power up the welding machine when a welding arc is required.
- There is no voltage on the secondary circuit unless the "switch" is operated.
- There is still some risk as the welder may accidentally operate the switch, e.g. while changing electrodes.

AS1674.2-2003 requires that a "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."

Some devices have an automatic latching feature that keeps the circuit closed until the welding current is interrupted. Latching devices should immediately disengage when the welding arc is broken.

2.9.2 In Line Switches

- Provide positive isolation
- Not a fail safe device
- Relies entirely on observer/assistant, and may be ineffective particularly if the welder is already in trouble
- Not effective if welder tries to operate without an assistant.
- Requires a conscious act by the welding operator or his assistant every time it is used to open the circuit e.g when changing electrodes.
- Requires an assistant's constant attention.
- In an alternative in-line switch design, operation is activated by a trigger switch in the electrode holder.

The Effect of Electric Current on the Human Body

3.1 Introduction

In an electric circuit the current is determined by the voltage and the electrical resistance. The higher the voltage, the higher the current and the higher the resistance, the lower the current. These properties expressed in terms of Ohm's law, form the basis of this chapter; the human body being the major component of the electrical circuit.

The Standard AS/NZS 60479.1:2002 *Effects of current on human beings and livestock – General aspects,* describes the effect of electric current on the human body. Of prime importance in the severity of an electric shock are the magnitude of the voltage applied, the type of current (alternating or direct), and the resistance of the body and any insulation. The risk of electrocution is dependent on a number of factors, including the current path, the applied 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. The resistance of the human body typically varies from 650 to over 6500 Ohms. Other resistances in the electric arc-welding circuit, such as insulation and protective clothing are required to reduce the risk and severity of electric shock. The open circuit voltage provides the most risk of an electric shock. Electric shock is less likely to occur while the arc is operating as the resistance of an arc is relatively low. With drooping characteristic machines (as used for MMAW and GTAW) the open circuit voltage (40 to 100 volts) is considerably higher than the arc voltage (19 to 35 volts). Electrical currents as low as 30 milli Amps a.c. or 100 milli Amps d.c. can provide a fatal electric shock. The open circuit voltage of a welding machine can kill in adverse circumstances. Electric shock can lead to ventricular fibrillation, which is a form of heart failure and can lead to death within a few minutes. Prompt resuscitation may save the victim. Other possible effects of electric shock are tissue burns, nerve damage and in severe cases complete respiratory failure.

3.2 Severity of Shock

The severity outcome of an electric shock depends on the following interrelated factors:

- Applied voltage
- Impedance or resistance of body
- Type of current – a.c., d.c., d.c. pulsed, d.c. smoothed
- The magnitude of the current flowing through the body
- The path of the current through the body
- The duration of the shock
- The reaction to shock by the victim
- Individual susceptibility.

3.3 Applied Voltage

Voltage is the driving force for the current to flow. Thus, in general, the higher the voltage, the greater the magnitude of current flowing through an electrical circuit.

When a human being is part of the electric circuit, a higher current will normally cause more damage, subject to a series of other factors, discussed elsewhere in this document.

3.4 Current

Electric current is defined as a movement of electric charges. The magnitude of current (I) flowing through the body depends on the applied voltage (V) and the electrical resistance or impedance (R), in Ohms, of the person. The higher the voltage, the greater the current that will flow. Conversely for a given voltage the higher the resistance, the lower will be the flow of current.

These quantities are related in terms of Ohm's law i.e :

$$R = V / I$$

Where R = Resistance, measured in Ohms (Ω)
V = Voltage, measured in volts (V)
I = Current, measured in amperes (A)

In alternating circuits, capacitive and inductive components cause a shift in phase. To account for the phase shift, the term impedance has been defined as a measure of how much the circuit opposes the flow of alternating currents. For the purpose of this discussion, however, the term resistance will be used for both direct, alternating and pulsed electrical circuits.

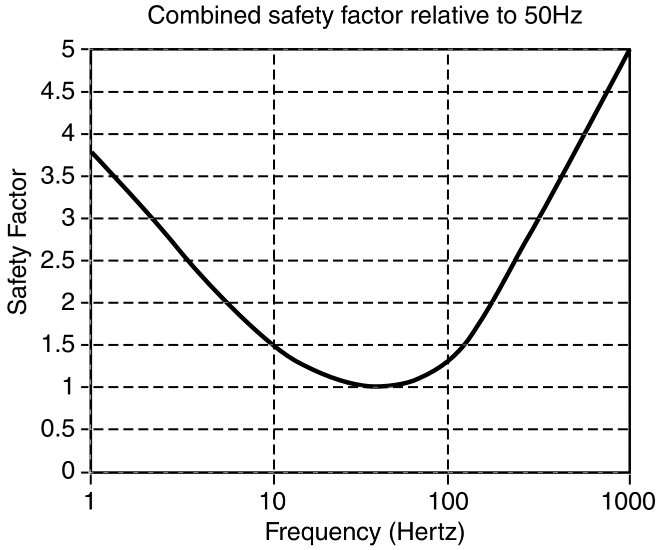

Figure 3.1 Effect of a.c. Frequency

3.4.1 Types of Current

We find different current types in welding applications. The types usually found are listed in decreasing risk level:

Low Frequency a.c. (a.c. 50 Hz-causes fibrillation of the heart)	**Highest Risk**
High frequency (HF) a.c.	↓
d.c. with ripple (usually 50 Hz)	↓
d.c. pulsed (Pulsed at 25 – 500 Hz)	↓
d.c. smoothed	**Lowest Risk**

3.4.2 Alternating Current (a.c.)

Alternating current can be defined as a flow of electric charge which changes direction at a regular rate. The rate of direction change (frequency) is measured in hertz (Hz). Thus, one cycle per second is defined as one hertz.

Compared to direct current, alternating current increases the injurious effect in 3 ways:

- Current flow will rise due to capacitive effects, mainly associated with the touch resistance.
- a.c. causes involuntary muscle contractions, which have the effect of tightening the persons grip onto the conductor, prolonging the exposure time and reducing the contact resistance, often with dire consequences. This typically occurs from 10 mA. See Table 3.3.
- The most serious effect is due to the interaction of the current waveform with the neural and muscular electrical signals of the heart. (The heart muscles are electrically activated via nerves connected to it).

The combined effect of these factors is that alternating current in the frequency range of 15-100 Hz is more dangerous than direct current by a factor of up to 5.

At higher frequencies, the risk decreases, due to the tendency of current to flow more superficially, causing less internal damage. (See figure 3.1). At around 50 Hz there is an optimum impedence match.

3.4.3 Direct Current

Even though deaths have occurred due to d.c. electrocutions, accidents with d.c. welding equipment are much less frequent than for a.c. This is largely due to the fact that:

- With d.c., the "let-go of parts gripped" is more voluntary.
- For shock durations longer than the period of the cardiac cycle the threshold of ventricular fibrillation is considerably higher than for prolonged alternating current.
- To produce the same damaging effects to the body the magnitude of direct current can be up to two to four times greater than for a.c.

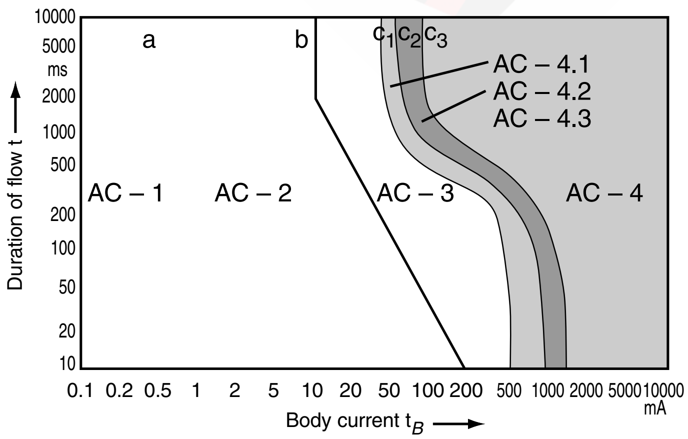

Figure 3.2 Time/current zones of effects of alternating current 15 Hz to 100 Hz (for explanations, see table 3.1)

Note:
As regards ventricular fibrilation, this figures relates to the effects of current which flows in the path left hand to both feet. for other current paths, see 3.6 and table 5. The threshold values for durations of current flow below 0.2's apply only to current flowing during the vulnerable period of the cardiac cycle.

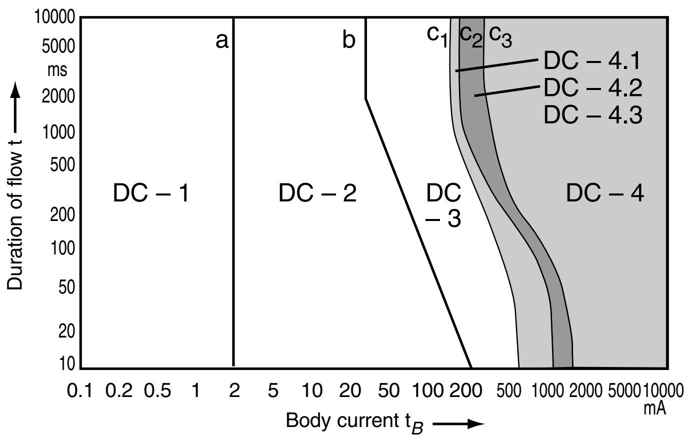

Figure 3.3 Time/current zones of effects of direct current (for explanations, see table 3.2)

Note:
As regards ventricular fibrilation, this figure relates to the effects of current which flows in the path left hand to both feet and for upward current. The threshold values for durations of current flow below 0.2's apply only to current flowing during the vulnerable period of the cardiac cycle.

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Table 3.1 Time/current zones for a.c. 15 Hz to 100 Hz

Zone Designation	Zone Limits	Physiological effects
AC-1	Up to 0.5 mA Line a	Usually no reaction
AC-2	0.5 mA up to line b	Usually no harmful physiological effects
AC-3	Line b Up to Curve c	Usually no organic damage to be expected. Likelihood of cramplike muscular contractions and difficulty in breathing for durations of current-flow longer than 2 s. Reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
AC-4	Above Curve c	Increasing with current magnitude and time, dangerous pathophysiological effects such as cardiac arrest, breathing arrest and severe burns may occur in addition to the effects of zone AC-3.
AC-4.1	c - c	Probability of ventricular fibrillation increasing up to about 5%
AC-4.2	c - c	Probability of ventricular fibrillation up to about 50%
AC-4.3	Beyond curve c	Probability of ventricular fibrillation above 50%
* For durations of current flow below 10 ms, the limit for the body current for line b remains constant at a value of 200 mA		

Table 3.2 Time/current zones for d.c.

Zone Designation	Zone Limits	Physiological effects
DC-1	Up to 2 mA Line a	Usually no reaction Slight pricking pain when switching on and off
DC-2	2 mA up to line b	Usually no harmful physiological effects
DC-3	Line b Up to Curve c	Usually no organic damage to be expected. Increasing with current magnitude and time, reversible distances of formation and conduction of impulses in the heart may occur
DC-4	Above Curve c	Increasing with current magnitude and time, dangerous pathophysiological effects. For example, severe burns are to be expected in addition to the effects of zone DC-3
DC-4.1	c - c	Probability of ventricular fibrillation increasing up to about 5%
DC-4.2	c - c	Probability of ventricular fibrillation up to about 50%
DC-4.3	Beyond curve c	Probability of ventricular fibrillation above 50%
* For durations of current flow below 10 ms, the limit for the body current for line b remains constant at a value of 200 mAa		

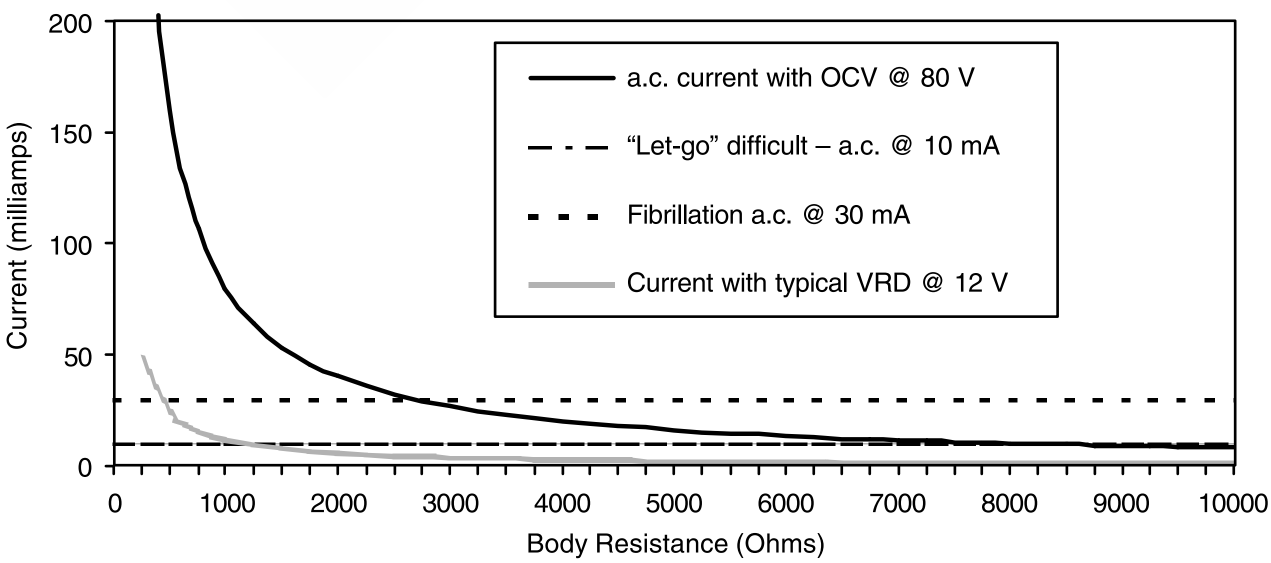

Figure 3.4 Effect On Current Of Varying Body Resistance At Constant Voltages

3.4.4 The Effect of Current Level

Table 3.3 Effect of d.c. and a.c. current levels on the human body

Effect	d.c.	a.c. (50 Hz)
Threshold of Perception	2 mA	0.5 mA rms
Threshold of "let go"	300 mA (Below 300 mA: painful, cramp-like muscular contractions)	10 mA rms
Threshold of ventricular fibrillation	30 mA (For longitudinal rising current, shorter than 0.2 sec) 60 mA (For longitudinal falling current, shorter than 0.2 sec)	30 mA rms

The above table gives average current levels for the various effects. Values may vary considerably, depending on circumstances and individual susceptibility. This table illustrates the greater risk with a.c. when current levels approach 10 mA and the welder may be unable to let go.

3.5 Exposure Time

The longer a person is subjected to an electrical current, the more damage is caused. The effect is graphically illustrated in figures 3.1 and 3.2 based on AS/NZS 60479.1:2002.

Electric shock current level is dependent on OCV and total body resistance. When total body resistance is low we are more vulnerable to electric shock.

3.6 Electric Impedance of the Human Body

For the purpose of this discussion, the electric impedance of the human body is considered to be resistive only. There is also a small capacitive component in total body impedance. This is related to touch surfaces and the inter-surfaces between different body tissue types. The capacitive component will have a small influence on the energy absorbed (ie the severity of shock). This effect is, however, ignored in this document.

A variety of body impedance values are defined such as:

- **Internal impedance:**
  The impedance between two electrodes touching two points on the body, after removing the skin.
- **Impedance of the skin:**
  Impedance between an electrode on the skin, and the body tissues underneath.
- **Total human body impedance**
  Vectorial sum of the internal and skin impedances.

There are a number of transient body impedance values eg. at the onset of an electrical current, an initial total body impedance applies. Also, after some time of electric current flow, body tissues, including the skin, start breaking down, changing impedance values.

Human body impedance values are not constant but affected by (but not limited to) the following:

- Moisture/sweat
- Contact area

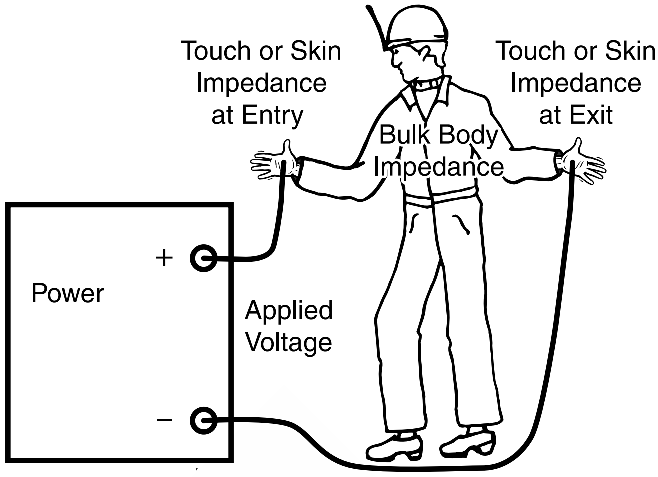

Figure 3.5 Human Body Impedance

- Stress
- Contact force
- Applied voltage
- Stage of current flow (Onset, Intermediate, After changes in body tissues took place).
- Individual physiological make-up.

Due to the variance in impedance, statistical values are often used as shown in Table 3.4, extracted from AS/NZS 60479.1:2002.

Table 3.4 Total Body Impedance Z_T for current path hand to hand a.c. 50/60 Hz for large surface area of contact and dry conditions

Touch voltage (V)	Values for the total body impedance (Ohms) that are not exceeded for the following percentages of the population.		
	5%	50%	95%
25	1750	3250	6100
50	1450	2625	4375
75	1250	2200	3500
100	1200	1875	3200
125	1125	1625	2875
220	1000	1350	2125
700	750	1100	1550
1000	700	1050	1500
Asymptotic value	650	750	850

For general calculation purposes, a value of 500 Ohms is often used, chosen below the 650 Ohms asymptotic value in Table 3.4.

Total dry body impedances, according to the table, typically vary from 650 to 6000 Ohms. According to AS/NZS 60479.1:2002, "At voltages up to approximately 50V, values measured with contact areas wetted with fresh water, are 10% to 25% lower than in dry conditions and conductive solutions decrease the inpedence considerably down to half of values measured in dry conditions. In one case study, a person receiving a fatal shock had an estimated total body impedance of only 200 Ohms. (See case studies in this document). This once more illustrates the variance in impedance values.

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The Workplace

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

Note: These precautions apply to all electrical equipment i.e. Power sources, machines, feeders, supply cables, welding leads, holders and guns.

4.1.1 Management

a) All operations must be carried out in a safe manner and in a safe workplace. Particular requirements in respect of electrical shock, wet conditions, fire and explosion (especially below the work), radiation, etc. should also be considered.

b) All welders should be instructed in and provided with, or have access to, printed instructions, concerning safe operations with the equipment being used. Special measures are required for non-English speaking personnel.

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.

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, eg at heights or within vessels, should be understood and adhered to. (see Reference 2).

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

g) Fumes generated is dependent upon processes and materials and requires a fume control plan. (See Reference 2).

4.1.2 Installation and Handling of Equipment Connected to Electrical Supply

a) Ensure equipment has the required current capacity, environmental (IP) rating and is in good working order. Tag out any defective power sources, electrode holders or leads and have them repaired or scrapped.

b) Connect to main supply safely in accordance with AS/NZS 3000. Only a competent person shall install such equipment.

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

d) Ensure correct earthing of machines and feeders.

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

f) Locate welding cables safely to avoid damage.

g) Ensure work return is safely connected. (See section 2.4.3)

4.1.3 Installation and Handling of Engine Driven Equipment

a) Some engine driven equipment with power outlets require earth staking or bonding to an earth grid prior to operation.

b) Position Engine Driven Equipment so that persons are not exposed to exhaust gases.

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 connection per manufacturer's recommendations.

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

4.1.4 Maintenance and Inspection by Maintenance Personnel

a) Adopt routine periodic inspection and repair and keep records where necessary.

b) For engine driven equipment, also carry out routine inspection and maintenance.

c) Adopt routine checks of oil level and moisture content in oil cooled transformers.

d) Clean equipment by periodic blowing out with e.g. reduced pressure compressed air with safety nozzles. Do not use other gases for this purpose. Increased frequency of cleaning is required where metallic dust may be present.

4.1.5 Maintenance and Inspection by Welders and Operators

Do daily:

a) Check for defective electrode holders and guns, insulation damage, overheating or suspected defects.
b) Ensure all connections at the welding machine, in-line cable connections, wire feeders, electrode holders and welding guns are tight and contact areas are clean (see Appendix C).
c) Check welding leads for damage and correct size. Position cables such that they are less likely to get damaged.
d) Report and clean up all fuel leaks and spillages in engine driven equipment.
e) Ensure exhaust gases create no problem.
f) If a Voltage Reduction Device is fitted, check that this is operating according to the equipment manufacturer's specifications (see Appendix B for further details).

4.2 Electricity Supply to the Welding Machine and Ancillary Equipment

The voltage on the input or primary side of the welding machine is dangerous. The welder must not tamper with the electricity supply except for switching, plugging or unplugging the machine. Only a competent person should perform repairs and maintenance to the electrical components of a welding circuit and machine. If a number of a.c. MMAW machines are to be connected to the same workpiece, ensure a licenced electrician is requested to connect all machines to the same phase pair and with the same direction (see Chapter 2). This will ensure there is no voltage between adjacent electrode holders. Care must be taken to position supply cords to welding plant and ancillary equipment where there is no risk of damage. Electrocution has occurred when a power supply cord rested on an overheated terminal of a power source. The power supply cord insulation melted allowing full mains voltage to contact the work terminal.

4.3 Risk of Shock and Choice of Welding Process

The risk of electrocution from the output or secondary side of the welding machine is dependent on the welding process. In most cases, a process using direct current is considerably safer than one using alternating current, because the threshold voltage for ventricular fibrillation is approximately 2 to 4 times greater with d.c. than a.c. Another effect is that a.c. causes muscle contraction, causing the hand to grip onto the source of the electric shock rather than release it.

4.3.1 Resistance Welding

Little Hazard. Voltages are 4 to 12 volts a.c. and d.c..

4.3.2 Manual Metal Arc Welding (MMAW), Arc Gouging

Most electrocutions have occurred with the MMAW process. The Open Circuit Voltage (OCV) is usually 40 to 113 volts d.c. or 40 to 80 volts rms a.c. with these machines. The main risk occurs when changing electrodes, because the electrode holder is live.

4.3.3 Gas Tungsten Arc Welding (GTAW)

GTAW has similar open circuit voltages to MMAW, both a.c. and d.c. The power should be turned off while changing tungsten electrodes. Strike the arc 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 high frequency equipment are high (2000 to 3000 volts), currents are relatively low. This is because the body's resistance to these high frequencies is high and current tracks 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 heart pacemakers.

The use of GTAW by the scratch start method when there is no trigger switch to close the output circuit exposes the welder to the risk of shock due to contact with a live electrode or gun parts at OCV.

4.3.4 Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)

These processes have a low risk of electrocution because open circuit voltages are low, only d.c. is used, and the power is switched at the torch.

4.3.5 Submerged Arc (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 to turn off the power source while changing the electrode wire or assembling or disassembling the equipment.

4.3.6 Plasma Welding and Cutting

The voltage necessary to create a plasma is of the order of 100 to 700 volts. The risk of electrocution is high only

Table 4.1 Typical Open Circuit Voltage for Various Processes

Electric Welding Process	Relative Hazard	Open Circuit Voltages	Power Type
Resistance	Negligible	4-12	a.c. & d.c.
MMAW	High	50-113*	a.c. & d.c.
GTAW	High	50-113*	a.c. & d.c.
GMAW	Low	15-60	d.c.
FCAW	Low	20-60	d.c.
Submerged Arc	Low	25-113	a.c. & d.c.
Electroslag	Low	30-113	a.c. & d.c.
Underwater	Very High	50-80	a.c. & d.c.
Air Carbon Arc	High	50-80	a.c. & d.c.
Plasma Arc cutting	High	100-700	d.c.
Electron Beam	Medium #	30,000-200,000	d.c.
Laser	Medium #	1,000-40,000	d.c.
Arc Metal Spray	High	40-113	d.c.

Protected by Interlocks * Maximum for a.c. = 80 volts

if the equipment is disassembled with the power on, or if it is damaged. It is important to follow safe practices (See Reference 2) and the manufacturer's instructions.

4.4 Avoiding the Risk of Electrocution in Manual Welding

Work practices which must be followed to prevent a welder being exposed to the electrical hazard of the secondary circuit involve a combination of three strategies: avoid contact with the electrode, avoiding contact with the work piece, and limiting the open circuit voltage.

4.4.1 Preventing Contact with the Electrode

The most fundamental safety requirement is for the welder to always avoid bare skin contact with the electrode or live parts of the electrode holder or gun. The electrode has to be regarded as an electrical conductor. During manual metal arc welding, dry welding gloves **MUST** be used for handling the electrode holder, when inserting a new electrode or to steady its tip during welding. Bare hands, damp or defective gloves shall not be used. The electrode holder for manual metal arc welding should preferably be of the Australian Standard AS 2826 Class A standard.

4.4.2 Preventing Contact with the Workpiece

It is good practice to prevent hand contact with the electrode, however, there have been incidents of electrocution where there has been accidental contact between the electrode and the face, neck or arm pit. Some other precaution is necessary; ideally insulation from the workpiece. All parts of the workpiece have to be regarded as electrically live, therefore live areas can surround the welder. Use 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 that provides good coverage insulates the welder from the workpiece, provided it is dry. One weakness of relying on clothing for insulation is that overalls, leather jackets and denim jeans are often fastened with zips and/or brass studs. All parts of the body should be covered. Dry overalls or shirt and trousers, insulated boots and welding gloves are a minimum requirement. Leather jackets, leggings or knee pads 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 Section 4.5 should be applied. Preferably workpieces should be clamped together. If assistants have to hold parts for welding, they must wear dry welding gloves.

4.4.3 Limiting the Open Circuit Voltage

Work with the lowest OCV practicable by choosing the welding process from Table 4.1. Note that d.c. is generally less hazardous than a.c.

4.4.4 General: Safe Working Practices

a) Ensure the welding machine 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 2.2. for the welding and return leads. Avoid using bare metal straps as a work return. Never use gas or water pipes as part of the welding circuit. Connect the return as close as possible to the welding. Ensure the welding machine return is connected only to one workpiece.

c) Connect all leads (including the hot box if it is powered by the welding machine output) before turning on the power source. (A hot box is a heated electrode container).

d) Keep welding leads as short as possible. Only coil them using a pattern to minimise inductance (see below). Tangles of leads can overheat. Keep connection points (work return clamp, machine terminals, etc) clear of flammable materials, particularly insulated electrical leads, compressed air, oxygen and flammable gas hoses.

e) 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.

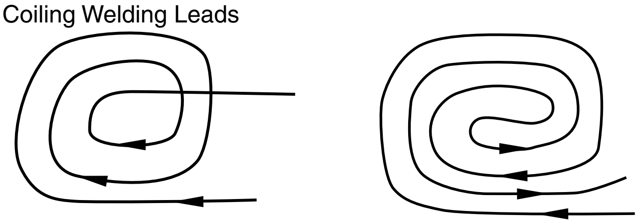
f) Do not drag live welding leads to the work. Ensure the electrode holder has no electrode in it before turning on the welding machine.

g) Ensure the welder is properly insulated from the workpiece. Use heat resisting mats, wooden duckboards or other means as insulation from the job and flooring. Wear at least two layers of dry clothing including dry leather jackets and rubber soled safety boots.

h) Use 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. Do not hold electrodes under the arm pit while changing them. Do not wrap the electrode lead around yourself.

i) Keep the welder and the work area dry. Do not use leaking water-cooled equipment. Dry up any condensation. Keep clothing and gloves dry from perspiration. Do not work in rain or standing water. Do not cool the electrode holder with water.

Coiling Welding Leads



WRONG –
Current flows in one direction
High inductance

RIGHT –
Current flows in both directions
Low inductance

Figure 4.1 Recommended practice for coiling welding leads

j) Work in a tidy manner. Where there is more than one welder, know which leads belong to each machine. Discard hot stub ends, offcuts, wire snips into a suitable receptacle, not on the floor.

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

l) Only use welding equipment for its intended purpose. Misuse can lead to severe burns, electrocution, arc flash and damage to equipment.

m) All incidents of electric shock, even minor ones, must be reported using the hazard reporting procedures. Steps must be taken to find the cause and prevent a recurrence.

4.5 Assessing the Risk of Electric Shock

4.5.1 Normal Environment

A normal environment is one where there is a low risk of becoming part of the welding circuit. This is equivalent to AS 1674.2 Category A environments. The risk of simultaneously touching the workpiece and the electrode is low. It is typically where the welder is working at a bench, welding small components, such as test pieces. The welder must be standing, lying or sitting on non-conducting material. When changing electrodes, the welder is not touching either the bench or the workpiece. The bench is often part of the circuit and is live, and covering parts of it with a leather coat or blanket where the welder may touch it is essential. In this situation, only the general precautions apply. (Refer Table 4.2.)

4.5.2 Hazardous Environment

This environment is where the welder is required to work while in contact with the workpiece or conducting materials connected to the workpiece. This is equivalent to AS 1674.2 Category B environments. It includes large steel building structures, storage tanks, conductive confined spaces, and onboard ships. The ambient temperature is less than 32°C and the area is dry. In this case, the welder only has to touch the electrode accidentally to get a shock. 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. 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 laying on the workpiece it may become hazardous. The hazard can be minimised by laying on leather-covered cushions, wooden duckboards, or similar insulation. It is not sound practice to rely on normal work clothing for insulation, because it is easily holed or moistened with sweat, and may have metal button or zip closures.

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 2865:2001 *Safe working in a confined space*. A confined space without an electrically conducting boundary is not electrically hazardous. A room with electrically conducted 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 it is a confined space then the precautions specified in AS/NZS 2865 are mandatory, to prevent asphyxiation, entanglement with machinery, entrapment or engulfment. Refer Table 4.2.

Table 4.2 Critical Open Circuit Voltages

Environment	Maximum OCV direct current	Maximum OCV alternating current
Non electrically Hazardous	113 volts	113 volts peak or 80 volts rms
Electrically Hazardous (dry)	113 volts	68 volts peak or 48 volts rms
Electrically Hazardous (wet)	35 volts	35 volts peak or 25 volts rms

Examples of such environments include

- underwater;
- in the splash zone close to the water's edge;
- while standing in water;
- in rain;
- welding in a hot or humid area when it is impossible to avoid accumulation of perspiration or condensation;
- in confined spaces.

If MMAW and allied processes have to be performed in these hazardous environments, a voltage reducing device (VRD) is recommended. This device is designed to reduce the open circuit voltage to less than 25 volts if the circuit resistance exceeds 200 ohms. A lower capital cost solution is to use a contactor switch which is operated by the welder or observer. Such a switch should be arranged so that the welding current is cut off except when striking the arc and welding. An observer is necessary to operate the contactor switch in confined spaces.

If the workspace is electrically hazardous, the following additional precautions apply:

- If possible, the area must be made non-hazardous by using insulation, in which case it can be treated as a normal environment.
- 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.
- 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,

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particularly how to disconnect the power and obtain help. They should probably carry a radio or mobile telephone to be able to call for assistance.

- There must be some means of breaking the circuit close to the observer. This should be either a twist lock in the electrode lead or the return lead clamp that can be removed.
- A person trained in resuscitation must be available at the work site.
- The maximum permitted open circuit voltage of the power source is 113 V d.c. or 48 V a.c.. Power sources which comply to this requirement are often marked with an S in a square box on the compliance plate, and sometimes on the front panel. d.c. only welding machines will all comply with the requirements, but most a.c.welding machines will not.

4.5.3 Environment with a high risk of electrocution

Where an electrically hazardous or normal environment is also hot, humid, damp or wet there is a high risk of electrocution. This is equivalent to AS 1674.2 Category C environments. This occurs if the temperature exceeds 32°C, so that the welder's clothing, particularly gloves become dampened in perspiration. It also occurs if welding is performed in rain, partially submerged, in damp mines, where waves can splash the welder or underwater. Typical areas where an extreme hazard may exist are mines, cofferdams, floating platforms, damp earth particularly trenches, tropical or inland work sites, inside vessels exposed to hot sun. If high preheat has to be used a hazardous environment may become extremely hazardous. Refer Table 4.2.

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:

- 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 frequently changed cotton liners avoids gloves becoming saturated with perspiration. It may be possible to avoid this situation altogether.
- 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.
- Equipment maintenance must not be undertaken in this environment.
- The maximum permitted voltage when an arc is not present is 25V a.c. or 35V d.c.

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 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, it should meet the following requirements:

a) the voltage of the control circuit or remote control device should not exceed 35 V d.c. or 25 V rms a.c.; and

b) the switching system should:

  (i) return the output circuit of the welding machine 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) 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).

An alternative solution for MMAW is to use a voltage reduction device (VRD), but this may not be an option with arc air gouging because of the intermittent nature of the arc in that process.

GMAW and FCAW machines comply with the restriction on maximum OCV because they are switched and they operate with low OCV d.c. There is no benefit in fitting VRDs to these machines.

Important Note: Many a.c. welding machines should not be used in a hazardous environment or an environment with a high risk of electrocution. The use of d.c. welding machines in place of a.c. significantly reduces this risk.

4.5.4 Confined Spaces

Confined spaces may be classified as Category B or Category C environment. Classification of all confined spaces as Category C is recommended. Initial assessment might indicate that Category B conditions are present in the confined space but this usually requires very closely controlled conditions and there may be a significant risk that, as work progresses, a Category B environment could degrade to a Category C environment.

AS 1674.2 - 2003 requires that provision is made, in close proximity to the observer, to allow the welding circuit to be quickly broken in the event of an accident. Four alternatives are documented.

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- An in-line switch in the secondary circuit is the most reliable method.
- A switch on the primary power to the welding power source is satisfactory for a mains-fed power source. Rotary type power sources (engine drives) usually have no provision for quick isolation by a switch.
- The use of a line connector (twist lock) can be difficult or time consuming to undo in an emergency.
- Removal of the work return clamp may be inappropriate unless it can be assured that no electrical contact will take place between the removed work clamp and the work. This method requires the observer to make contact with the electrical circuit on a component that is usually uninsulated. This may put the observer at risk of an electric shock.

4.6 Multiple Welding Machines

Dangerous voltages may occur between electrode holders if two or more welding machines are connected to the same workpiece. This can happen with d.c. machines if one machine is connected DCEN and the other DCEP. In this case a voltage of twice the open circuit voltage (up to 226 volts) may occur between the two electrode holders. This situation can also occur if two a.c.machines are connected to different phases of the mains, or with their connections opposed. In these cases the voltage between the two electrodes is 1.73 or 2 times (respectively) that of the individual machines (up to 160 volts). Therefore, to reduce the probability of electric shock:

- Ensure that the terminal on each machine marked “Electrode” is connected to the electrode and not the workpiece, and vice versa;
- Test the voltage between adjacent electrode holders;
- Do not locate two electrode leads close to one another unless there is no voltage between the holders;
- Ensure multiple a.c. machines are installed by a competent person and connected in phase.

4.7 Rescue of Victims

All persons associated with welding operations need to be familiar with rescue procedures. 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:* Determine if the victim is in contact with the conductor. If so, direct contact 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 himself.

c) *Rescuer Insulation:* Immediately disconnect the electrode holder by its twist lock, or knock off the return clamp. 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 he is 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 surroundings 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 ungently. All persons sustaining an electric shock should be medically examined before return to work.

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 person.

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REFERENCES

Australian Standards

Standards Australia has produced a series of standards relating to welding electrical safety. Some of these are referred to in this document.

AS 1674 – Safety in welding and allied processes

AS 1674.2-2003 Safety in welding and allied processes – Electrical

Specifies safety requirements for arc welding and allied processes, to prevent electric shock and minimise associated hazards, describes practices and safeguards that should be adopted by welders (including requirements for cable connections for alternating and direct current power sources, and requirements for any ancillary equipment) and gives examples of ways that shocks have been received and actions that may be taken in the event of a welder receiving an electric shock.

AS 1966 – Electric arc welding power sources

AS 1966.1 – 1985 – Transformer type

Part 1 specifies the requirements for the design, performance and rating of arc welding power sources of the transformer type. It covers transformer type power sources having an alternating current or direct current (rectified) output. Both single-operator and multi-operator machines are covered and calculations of equivalent loadings for multi-operator machines are included. Various routine and type tests are contained in the appendices.

AS 1966.2 – 1985 – Rotary type

Part 2 specifies the requirements for the design, performance and rating of arc welding power sources of the rotary type. It covers rotary type power sources having alternating current and/or direct current generator output. Both single operator and multi-operator machines are covered and calculations of equivalent loadings for multi-operator machines are included. Various routine and type tests are contained in the appendices.

AS 1966.3 – 1990 – Plasma arc cutting and welding types

Part 3 specifies the requirements for the design, performance and rating of arc welding power sources of the plasma type. It covers power sources for plasma arc cutting and welding and the electrical supply associated torches. It applies to plasma arc power sources having an output of the drooping characteristic type (substantially constant current) and specifies limits for open circuit voltages.

AS/NZS 1995:1995 Welding cables

Specifies construction, tests, current rating and duty cycle of welding cables using copper conductors and covered with R-CSP-90 or R-CPE-90 elastomer, or V-90 PVC compound.

AS 2826-1985 Manual metal-arc welding electrode holders

Applies to electrode holders designed for use with welding power sources complying with AS 1966, Parts 1 and 2. The electrode holders are divided into three major types depending on the insulation level, and further divided into five classes depending on the current rating and duty cycle. Construction performance requirements and test methods are also included.

AS/NZS 2865:2001 Safe working in a confined space

Provides requirements and guidance in eliminating or minimising the need to enter confined spaces and in avoiding hazards which may be encountered where entry to a confined space is unavoidable. Contains Sections dealing with risk identification and assessment, monitoring prior to entry, education and training as well as emergency response. Appendices provide additional guidance for cleaning and the precautions needed when undertaking hot work. A sample risk assessment form and written authority to enter are provided, as is a typical check list.

AS/NZS 3000:2000 – Electrical installations (Known as the Australian/New Zealand Wiring Rules)

Provides requirements for the selection and installation of electrical equipment, design and testing of electrical installations, especially with regard to the essential requirements for safety of persons and livestock from physical injury, fire or electric shock. Many of the prescriptive work practices contained in previous editions of AS 3000 have been removed and this Standard incorporates internationally accepted practices.

AS/NZS 3100:2002 – Approval and test specification – General requirements for electrical equipment.

Specifies essential safety requirements for approval and test purposes. It is a parent specification for a series of approval and test specifications.

AS/NZS 3195:2002 – Approval and test specification – Portable machines for electric arc welding and allied processes.

Specifies essential safety requirements for approval and test purposes. In Australia this Standard is to be read in conjunction with AS/NZS 3100.

AS/NZS 60479.1:2002 – Effects of current on human beings and livestock – General aspects

Provides basic guidance on the general aspects of the effects of electrical currents on persons and livestock for the establishment of electrical safety requirements. This Standard has been reproduced from and is technically identical with IEC 60479-1:1994.

AS/NZS 3760:2001 – In-service safety inspection and testing of electrical equipment

Specifies the procedures and criteria for the in-service safety inspection and testing of electrical equipment which is designed for connection by flexible cord. It also applies to cord extension sets, portable outlet devices, portable residual current devices and portable isolation transformers. Appendices include detailed test methods. It does not cover type approval tests for the design and construction of the equipment, nor does it include any procedural rules for the safe use of equipment.

References

1. Welding Handbook: Volume 1: Welding Technology: Eighth edition1989: American Welding Society.

2. Technical Note TN 7-98 Health and Safety in Welding: 1998: Welding Technology Institute of Australia.

3. Australian/New Zealand Standards detailed in Chapter 5.

4. Australasian Welding Journal, Volume 40, Fourth Quarter 1997. Published by WTIA

5. An Investigation into the causes and prevention of Electrocution Suffered as a result of operation of Welding Equipment. Ian R Dick. Thesis for Master's Degree at University of Adelaide. February 1998

Case Studies in Welding Electrical Accidents

Case studies A1 to A5 are from WTIA Records

Case studies A.6 to A.13 are from AS 1674 Part 2 – 2003 (Reprinted with the permission of Standards Australia International)

A.1 Electric Shock Incident in Pipe Trench

An excavation was made to gain access to a 150 mm diameter underground water pipe which was leaking.

A 100 mm pipe, also in the excavation, was approximately 400 mm from the 150 mm pipe. A small pump was used to remove seepage water from the excavation.

The welder held the MIG welding gun onto the 150 mm pipe and while inspecting a completed part of the weld, he inadvertently activated the welding gun trigger. The feeding wire (electrically live) touched his face, while, at the same time, his face was touching the 100 mm pipe. He received a severe, but fortunately non-fatal electric shock.

The electric circuit was completed via the wet soil, to the 150 mm pipe, which had the return lead back to the welding power source.

A.2 Electric Shock Incident on Structure

A welder and assistant were at a height on a structure, ready to weld a part to it (MMA). The assistant, wearing wet riggers gloves held the part in position with his left

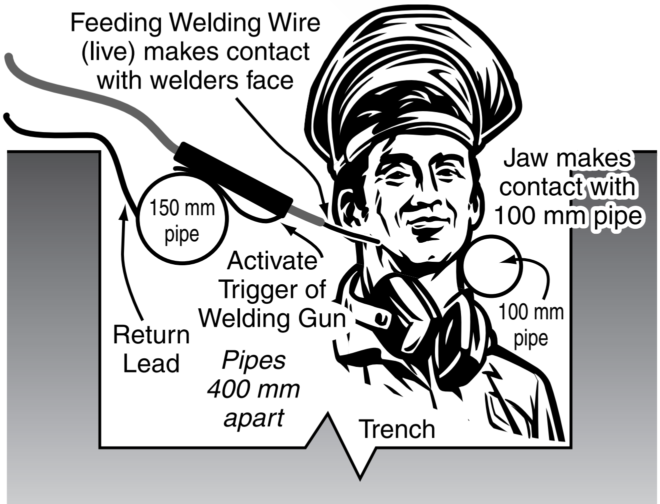

Figure A.1 Electric Shock Incident in Pipe Trench.

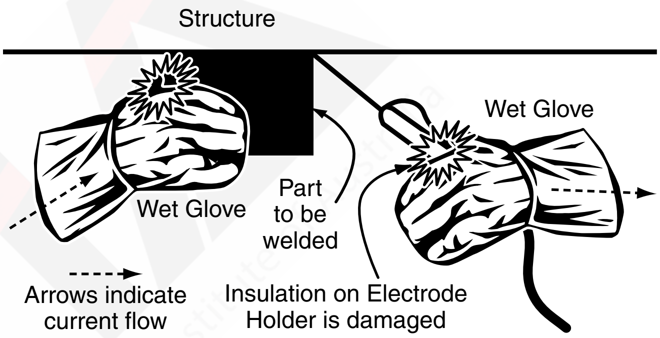

Figure A.2 Shock Incident on Structure

hand, while starting to tack weld with his right hand, holding the electrode holder. He received a severe electric shock, which fortunately, was not fatal. Inspection, after the accident, revealed a damaged electrode holder.

The electric current flowed from the electrode holder, via the damaged insulation, through the wet right hand glove, to his body, to the wet left hand glove and back into the structure. Part of the current may also have flowed through his feet, and into the structure.

Working at the height, posed the additional threat of injury due to falling, should he have jerked away from the source of shock.

A.3 Fatal Electric Accident in Underground Mine

A boilermaker, working alone, was welding (MMA) to a steel door and frame work in an underground mine. It was hot and humid and his clothes were damp from sweat. While changing electrodes, he received a fatal electric shock. An investigation revealed that he was not wearing gloves. Also, the electrode holder was damaged.

Electric current causing the fatal shock, flowed through one or both of the following paths:

a) From the electrode holder, through the defective insulation, into the bare right hand, through the body to earth via the feet or other body part touching the earth.

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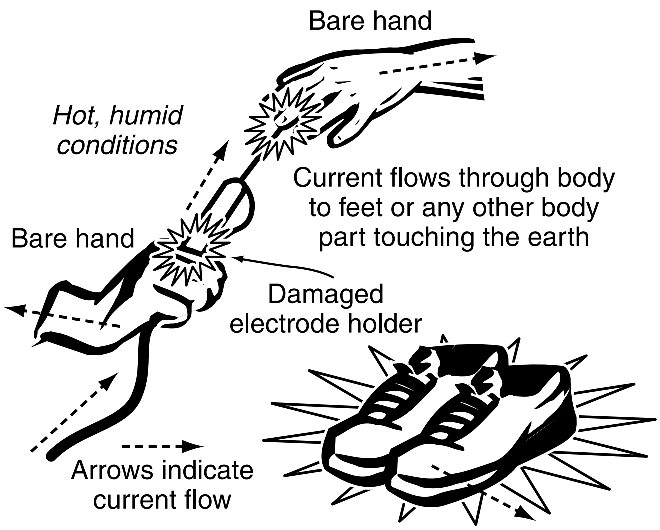

Figure A.3 Fatal Electric Accident in Underground Mine

b) From the electrode holder, through the electrode, into the bare left hand, through the body, to earth via the feet or other body part touching the earth.

A.4 Overflowing Concentrate Hopper in Mine Processing Plant

A welder was working on a metal ladder fixed against the outside of a copper concentrate hopper. The hopper was known to overflow and product could splash out. The welder was a subcontractor to the mine.

At the time of the incident his body was in contact with the ladder. He was wearing a harness attached to the ladder and there was an observer on the ground. The welder was holding a plate bracket in his left hand and he was wearing welding gloves.

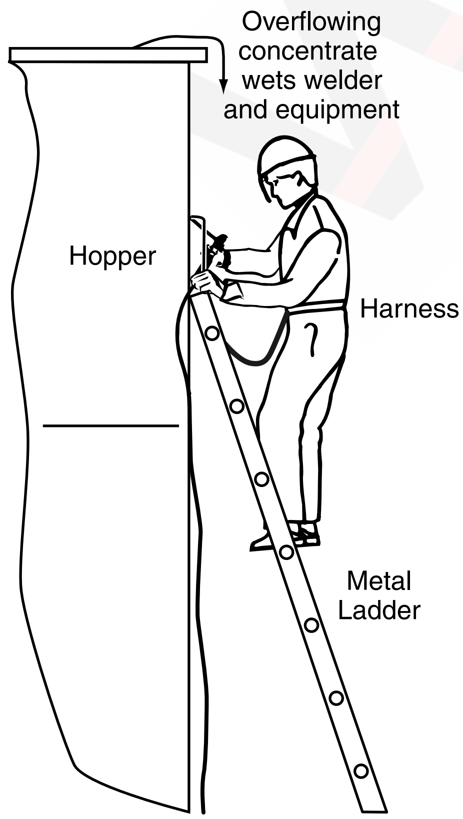

Figure A.4 Overflowing Concentrate Hopper

The hopper overflowed onto the welder and equipment. He experienced a severe shock, released the electrode holder and fell. His fall was arrested by the harness. He managed to climb down the ladder and asked the observer to turn off the welding machine.

The welder was taken to hospital and blood tests confirmed the severity of the shock. After a period of thirty hours, the blood chemistry was returning to normal and the welder was released.

The current path was from the left hand to the left arm. The welding machine was a light, portable d.c. inverter type. There was a VRD and a secondary circuit safety switch on site but it was kept in the engineer's office.

In this case study, the observer's response times were probably too slow to have made a secondary safety switch effective. A VRD would have limited the exposure time and may have prevented the welder getting a shock in the first place. (An electric shock duration of less than one second can be fatal at elevated current levels).

A.5 Humid Environment in Coal Washery

A welder was welding on a vibrating screen mechanism beam in a coal washery. He was lying on his back on the screen deck and was wearing cotton lined leather gloves. The deck he was lying on was electrically insulated from the work return cable.

The welder placed the electrode holder with an electrode stub in it on the screen deck. This raised the voltage of the surface the welder was lying on to the OCV of the welding circuit.

The welder was changing his body position when he felt a severe shock through his body and arm. He tried to move but had difficulty. After a period of time the welder managed to release himself from the circuit. The fact that the welder had difficulty letting go indicates the current level was probably 10 mA or more. This level of current is dangerously close to a level likely to cause ventricular fibrillation.

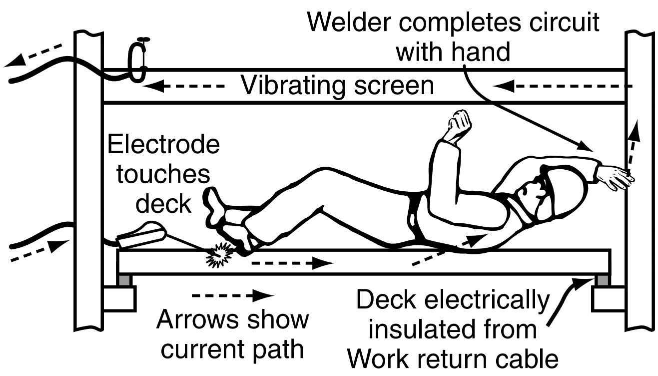

Figure A5. Incident in Coal Washing Plant

The welding machine was a single phase a.c. MMAW type. Marks indicated that the current path was from his back to the left forearm. There was no output safety switch or VRD in the circuit. The welder was working without an observer. It was a hot afternoon, the environment was humid and the welder's clothes were damp.

When the welder was found, he had climbed out of the screen. He was unable to communicate with his supervisor.

The welder was taken to a doctor for an examination and returned to work two days later.

A.6 Boiler Welding (1) (Fatal Accident)

A welder was leaning against the boiler wall while fitting a new electrode (See figure A.6). While being fitted, the electrode slipped, and touched the welder's neck. After the accident, current marks were found on his neck, back, and on the soles of his feet. The current flow would consequently have been as shown—from his neck through his torso to his back and feet. Through working in the closed room the welders working clothes had become soaked with perspiration thus establishing a very good electric connection to the boiler wall. The total resistance was estimated as being approximately 250 Ohms at the moment of the accident, and with 65 V no-load voltage at the transformer, the current would have been approximately 260 mA. Currents of this magnitude can only be endured for up to half a second but as the influence would seem to have been of longer duration, the welder died.

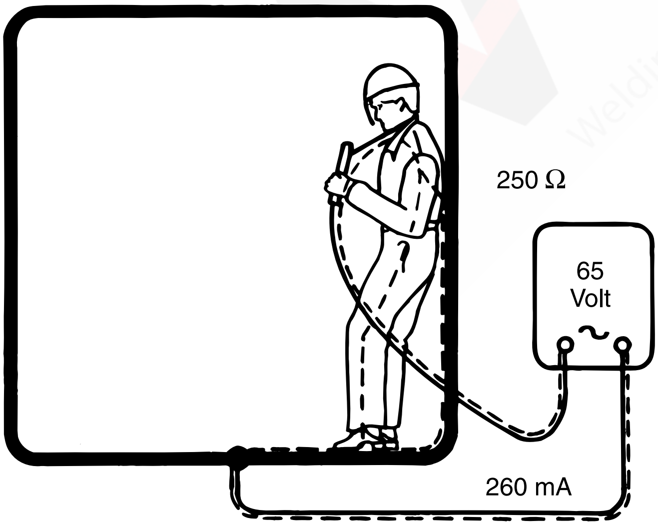

Figure A.6 Electrode Touching Welder's Neck Allowing Current To Pass Through The Torso To The Back And Feet.

A.7 Boiler Welding (2) (Fatal Accident)

(a) While leaning back on the boiler wall, the welder put the electrode holder under his arm. His perspiring back and armpit, in connection with an uninsulated welding handle, caused the current to flow from his armpit to his back. Because of the small resistance at the contact points and the short current path, the resistance was estimated at some 250 Ohms at the moment of the accident. At a no-load voltage of 70 V to 80 V, the current would have been approximately 300 mA, and this proved fatal.

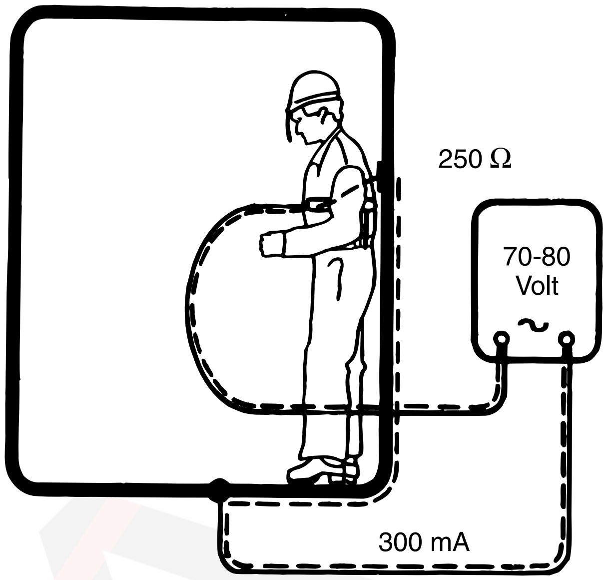

Figure A.7 Electrode Under Welder's Arm Causing Current Flow From Armpit To Back.

A.8 Boiler Welding (3) (Fatal accident)

This accident was caused by a faulty cable. The welder leaned his perspiring back onto the boiler wall. As he touched the faulty cable, he received a cramp and pressed the cable against his chest. Thus a chest-to-back electric contact was established. The resistance was estimated to have been approximately 200 Ohms and, at a voltage of 70 V, the current was approximately 350 mA at the moment of the accident and this proved fatal.

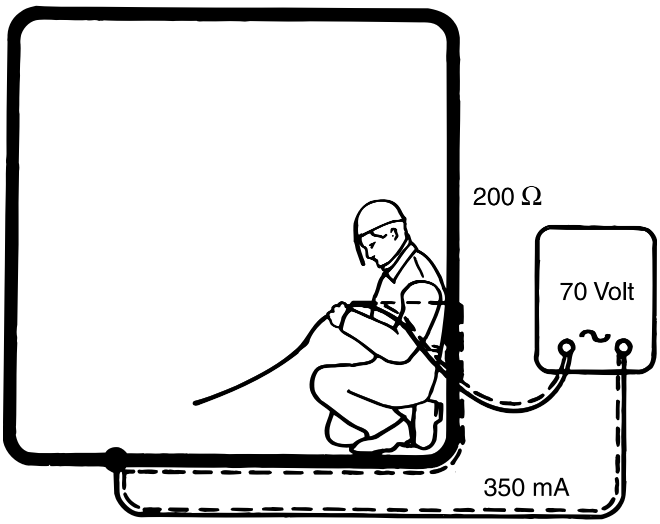

Figure A.8 Faulty Cable Causing Current Flow From Chest To Back.

A.9 Working Inside A Ship (Fatal Accident)

A welder was working in a vent shaft of a ship being built. He was kneeling at the bottom of the vent shaft where pools of water formed after rain. While he was fitting a new electrode, the electrode slipped and he hit himself near one eye. After the accident, current marks were found on the welder's knees and in the eye region. Since his knees presented a comparatively small area, a comparatively large pressure (approximately 85 percent of the body weight) had been pressed down against the moist metal base. The contact resistance was low, and the total resistance was estimated at approximately 600 Ohms at the moment of the accident.

At a no-load voltage at the welding transformer of 75 V, the current was calculated at approximately 125 mA at the moment of the accident. (A current of 125 mA is dangerous to life if it flows for 0.8 seconds or more).

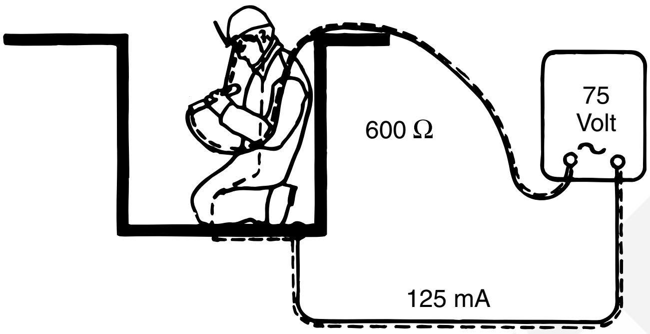

Figure A.9 Electrode Makes Contact With Face Causing Current Flow Through Torso To Knees.

A.10 Ship Repairs (Fatal Accident)

A welder was lying on a raft and carrying out repair work on the outside of a ship's hull. To assist the welder, and to ensure that no accident would occur, an assistant had been placed on a ladder close to the welder. The welder was finishing the work when a large wave flooded the raft and the welder. The startled welder dropped the electrode and holder onto his chest thus causing an electric contact to be established through his body and the salt water. The welder fell into the water but was soon pulled out on to the raft by his assistant who administered artificial respiration immediately. However, the welder could not be saved. The resistance in the circuit was estimated at approximately 700 Ohms and, at a no-load voltage of 70 V, the current was approximately 100 mA, sufficient in this case to prove fatal.

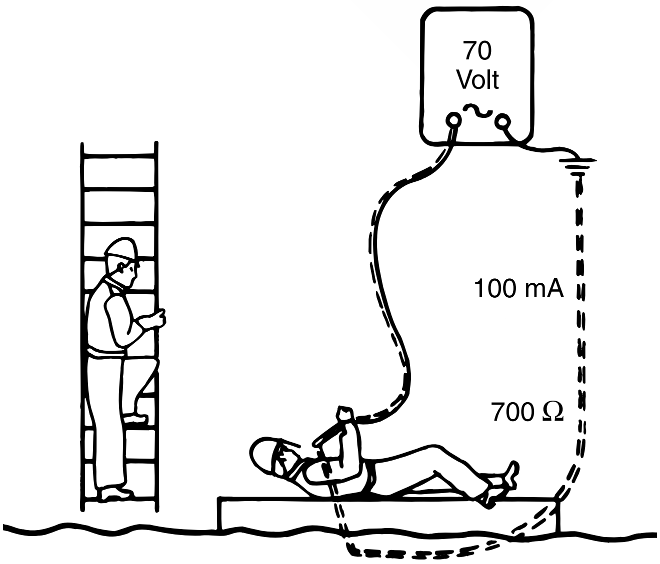

Figure A.10 Welder on raft flooded by wave.

A.11 Welding Outdoors (Fatal Accident)

The welder and his assistant were both standing on a base electrically connected to the welding transformer work return lead. It was raining. The assistant handed a metal object to the welder, and, at the moment the welder touched it, both received an 'electric shock'. Through analysis of the current marks it was found that the current had passed through the assistant's footwear, the assistant's body, the metal object, the welder's body to the electrode where the insulation was poor. Due to the many contact resistances and the comparatively long current path, the total resistance was estimated at 1900 Ohms. Since the transformer no-load voltage was 67 V, the current would have been approximately 35 mA. Currents of this magnitude are usually regarded as being harmless. In this case the assistant got off with a shock, whereas the welder died. This shows that two people may react differently to the same current influence and that consideration should be given to the varying body build and health condition of different people. The welder may have had a non-recognised heart condition which proved decisive to the course of the accident when exposed to a current.

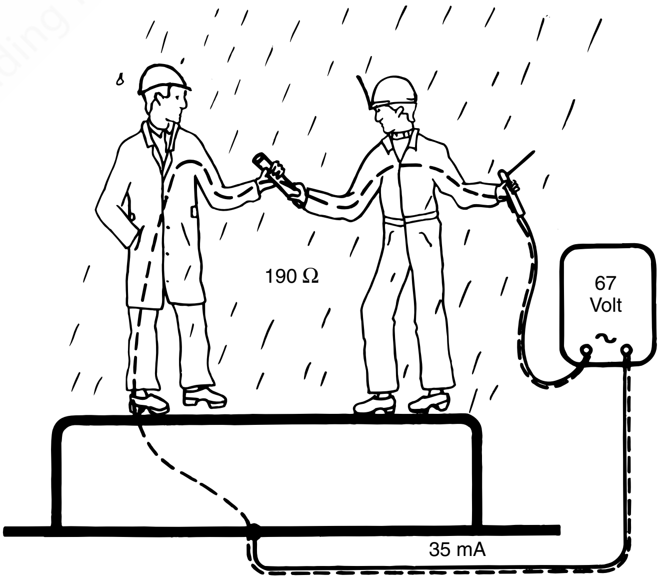

Figure A.11 Welder Holding Electrodes Is Handed Metal Object By Assistant Causing Current Flow Through Them Both.

A.12 Pulling a Cable (Fatal Accident)

A welder was pulling a cable up to the welding point by putting it over his shoulder. Due to a faulty cable insulation and poor footwear insulation, the welder

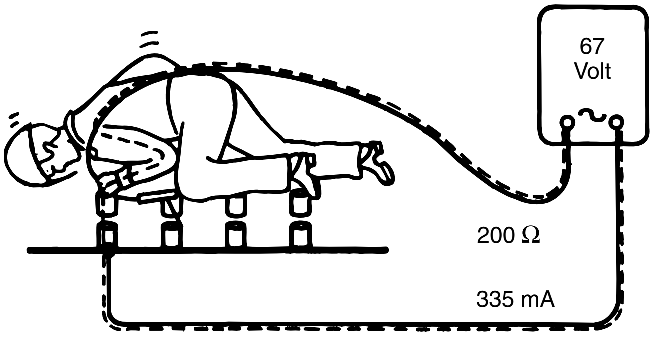

Figure A.12 Welder Pulls Faulty Cable Over Shoulder and Receives Fatal Shock.

received an electric shock causing him to fall. Thus contact was established from his head and chest to the cable on his shoulder as shown in figure A.12. The resistance was estimated at approximately 200 Ohms at the moment of the accident and, at 67 V no-load voltage, the current would have been approximately 335 mA and this proved fatal.

A.13 Electrical Accident Involving Mains voltage (Fatal Accident)

The power supply cord was resting on an overheated terminal of a power source. The PVC insulation of the power supply cord melted, allowing the active conductor of the cord to contact the work terminal, thus energising the output circuit and the work at mains voltage.

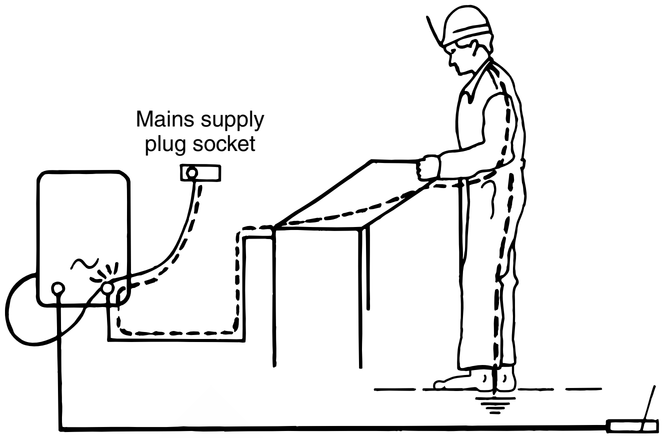

Figure A.13 Mains Supply Electrocutes Welder Through Hot Terminal On Power Source Melting Insulation.

The welder, who was barefooted, touched the work with his hand, and a circuit was completed through his body to earth.

At a voltage to earth of approximately 240 V, the current which flowed through his body proved fatal.

Appendix B

Guidance Notes on Voltage Reduction Devices for Manual Metal Arc Welding and Arc Gouging Power Sources

General description

Voltage Reducing Devices (VRDs) are safety enhancements that greatly reduce the risk of exposure of welding personnel to potentially hazardous voltages produced by a welding power source. A voltage-reducing device or system should automatically reduce the no-load or open circuit voltage (OCV), to a no-load voltage of:

- 35 V for d.c. and
- 35 V peak, 25 V rms for a.c.

or less when the resistance of the output circuit exceeds 200 Ohms.

VRD Types

Integrated VRDs

A number of welding machine manufacturers offer equipment with an inbuilt voltage reduction function. User acceptance of this type of VRD is high. This type of voltage reduction unit is the lowest cost option for new equipment.

Retro-fitted VRDs

There are three types of VRD commonly used.

Type 1 – Externally fitted to secondary circuit

This type of VRD is connected in series with the output of the secondary circuit on a welding machine and has four connections as follows:

1. Electrode lead from the welding machine to the VRD.
2. Work return lead from the welding machine to the VRD.
3. Electrode lead from the VRD to the welding hand-piece.
4. Work return lead from the VRD to the work clamp.

The leads connecting the output terminals of the welding machine secondary circuit to the VRD (1 & 2 above) are at unreduced open circuit voltage or welding voltage during operation of the equipment. The leads connecting to the welding hand-piece and the work clamp are at a reduced voltage of 35 V for d.c. and 35 V peak, 25 V rms for a.c. or less when the circuit resistance is greater than or equal to 200 Ohms. When the resistance drops below 200 Ohms, the voltage rises to the unreduced output voltage of the equipment.

This type of VRD is suitable for all a.c. and d.c. welding machines for MMAW and can be attached to whichever welding machine is to be used. These VRDs are usually housed in a rugged metal enclosure and weigh a few kilograms.

Type 2 – Internally fitted to secondary circuit

This type of VRD is identical in operation to the externally fitted VRD except that the VRD and all connections are located within the enclosure of the welding machine. There are added safety benefits in this arrangement because connection of wiring to the VRD is permanent.

This type of VRD is commonly used for engine drives and larger welding machines where there is enough internal space to fit the device. One disadvantage of this type is that the VRD is a permanent part of that particular machine and cannot be transferred if the power source fails.

Type 3 – Fitted to primary circuit

Type 3a

This type of VRD is suitable for the inverter type welding machines and consists of a small package of electronics connected into the voltage control electronics. It is fitted within the enclosure of the welding machine as a permanent installation and does not impact on the portability of the inverter welders.

Type 3b

This type of VRD is suitable for the a.c. to a.c. transformer type welders and electronically controls the voltage applied to the primary circuit winding which in turn reduces the output voltage. The package of electronics for these inverters is smaller than Types I and 2, and in some instances may be fitted internally. Alternatively the package may be attached to the outside of the welding machine enclosure.

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Type 1 and Type 2 VRDs are substantially larger and heavier than Type 3 VRDs.

Type 2, Type 3a and Type 3b VRDs are permanently wired into the welding machine.

Response Times

Response times for “turn on” (full voltage) and “turn off” (reduced voltage) operations of a VRD affect the operator appeal and more importantly, the degree of hazard reduction afforded to the welder by a VRD. Turn off time is of particular significance because this directly influences the time a welder could be exposed to the unreduced no-load voltage after the welding arc is broken as the electrode is lifted from the weld pool. Turn on time or arc strike time is also very important for ease of use of the welding machine when a VRD has been fitted.

Arc strike time

Arc strike time should be as fast as practical. Typical values are 20 milliseconds or less.

Turn off time

This is the time taken for the VRD to reduce the voltage to the low voltage state after the circuit resistance reaches or exceeds 200 Ohms. Maximum turn off time should be less than 300 milliseconds. Some VRDs have an adjustable turn off time delay, which may be adjusted up to 5 seconds. Turn off times greater than 300 milliseconds could lead to potentially fatal exposures to electric current under conditions of minimal welder body resistance.

Some VRDs have an adjustable turn off time delay, which may be adjusted up to 5 seconds. When a longer turn off time is used, welders must be made aware of the period of vulnerability to exposure to hazardous voltage before the VRD “turns off”. With slower response times, there is always a possibility of accidental contact with live parts of the circuit with potentially hazardous exposures to higher voltages before the VRD reverts to the low voltage state.

Operational parameters

Operational or strike resistance

A VRD should switch to the low voltage state (35 V for d.c. and 35 V peak, 25 V rms for a.c. or less) when the circuit resistance reaches or exceeds 200 Ohms. Conversely the VRD should turn on (switch to a high voltage state) when the circuit resistance is less than a specified value, which is usually significantly less than the turn off resistance.

Duty cycle

VRDs of Type 1 and Type 2 carry full welding current through the secondary circuit and have duty cycles determined by the current carrying capacity of the current switching components. Switches used are mechanical contactor types or solid state switching types. Selection of a VRD should be based on the expected service performance.

Thermal Overload

Type 1 or Type 2 VRDs should have thermal overload circuit protection.

Status Indicators

VRDs should have status indicator lights that clearly indicate high voltage or low voltage status.

Test circuits

Some VRDs are supplied with an internal test circuit that applies a low resistance across the output from the welding machine. The status indicator lights should change to red, indicating high voltage when the test button is depressed and return to green, indicating low voltage when the test button is released.

Fail to Safe

It is desirable that VRDs be designed to be “Fail-to-Safe”. VRDs are electronic or electromechanical devices and components used in their construction may fail. This could lead to a potentially unsafe situation where the VRD ceases to perform the function of reducing the unregulated open circuit voltage of the welding power source without indicating such failure to the user.

At the time of writing this note, there were no units known to be on the Australian market that were designated by manufacturers as “Fail-to-Safe”.

Testing of VRDs

Daily Check

A daily check should be made by the user of a VRD that indicator lights operate in accordance with equipment manufacturer’s specifications during a welding cycle.

Compliance

Compliance of the sensing circuit of a VRD should be tested regularly. Compliance of the sensing circuit is checked by connecting an insulated load resistor of suitable power rating across the output terminals of the welding machine, or if using a Type 1 VRD, across the output terminals of the VRD. The resistance value should be variable, from 50 Ohms to, say 220 Ohms. Voltage measurements shall be taken while resistance is being increased from 50 Ohms. The VRD should switch the unreduced no-load voltage to a voltage of 35 V for d.c. and 35 V peak, 25 V rms for a.c. or less when the resistance value is more than or equal to 200 Ohms.

Malfunctioning VRDs

If there is any indication of a malfunction of a VRD, the unit should be immediately withdrawn from service and the fault investigated by a competent service agent.

Personal Protective Equipment and Safe Working Practices

Always use personal protective equipment including rubber-soled boots, dry gloves, complete coverage with no bare skin on arms and legs and dry clothing.

Always use safe working practices. Avoid contact with workpiece, avoid contact with electrode, ensure safe placement of leads, use additional insulation such as rubber mats or duckboards, power off before changing electrodes.

Ensure all welding equipment, especially electrode holders, leads and connections are fully insulated, well maintained and frequently inspected for damage.

Never work alone and don't fall into the trap "It's only a small job, no need for all that gear"

WTIA Guidance Note 7: Recommended Welding Machine Daily Inspection and Pre-Start Check List

ITEM	DESCRIPTION OF INSPECTIONS TO BE CARRIED OUT	STANDARD
Power supply	Disconnect and isolate the power supply to the welding machine prior to performing these pre-start checks.	
Mains Supply Socket & Switch	Inspect for any obvious damage and defects to switch or socket. Ensure the correct size plug is fitted for the welding machine for the rated current and duty cycle of the welding machine	AS/NZS 3000
Plug & Primary Cable Supply to the Welding Machine	Check the power supply cable is of the correct rating 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.	AS/NZS 3100
Welding Machine	Inspect the welding machine for obvious damage to the cabinet, power switches, indicator lights or controls.	AS 1966 or AS 3195
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 shall have an insulated brass nut in place. Ensure that all connections are fully insulated and cables are firmly anchored to fittings. For a.c. welding machines check that electrode and work return cables are correctly connected to the welding machine. For d.c. welding machines check polarity and ensure electrode and work cables are correctly connected for the procedure in use and that any other d.c. welding machines in the vicinity are connected with the same polarity.	AS 1674.2
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 shall not be used as a work return path.	AS1995 AS 1674.2
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.	AS 1674.2
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.	AS 2826
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.	AS 1674.2
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.	AS 1674.2
Electrical Inspection Tag	Check that a current electrical inspection tag, traceable to your equipment maintenance register, is attached to the welding machine.	

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 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.

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Appendix D

Members of WTIA Technical Panel 9 Welding Occupational Health and Safety and Environment

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Mr Stan Ambrose – WTIA

Capt Paul Bassett – Australian Army (Dept of Defence)

Dr Bernie Bednarz – CSIRO

Dr Yosi Berger – Australian Workers Union

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Mr John Fennell – Copper Development Association

Mr Alistair Forbes – BOC Ltd

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Mr Bob Johnstone – Ergsafe Design

Mr Chris Jones – The Lincoln Electric Co (Aust) Pty Ltd

Mr Bob Kenyon – WorkCover Authority of NSW

Mr Siufai Lee – ADI Marine

Dr Valerie Linton – University of Adelaide

Mr Peter Livy – Communications Electrical Plumbing Union

Mr Neale Lundberg – (Chairman) BHP Port Kembla Steel

Mr Darren Marinoff – Workplace Services SA

Mr Richard Matheson – ASSDA

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Mr Jim Milligan – AGR Joint Venture

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Mr John Randall – Worksafe Western Australia

Mr Gary Rhyder – WorkCover Authority of NSW

Mr Richard Shaw – Ozone Manufacturing Pty Ltd

Mr Geoff Slater – University of Wollongong

Ms Sue Ward-McGurty – Victorian WorkCover Authority

Expert Technology Tools

These Technical Note, Management System and other Expert Technology Tools may be obtained from the WTIA. Technical advice, training, consultancy and assistance with the implementation of Management Systems is also available through the WTIA's OzWeld Technology Support Centres Network and School of Welding Technology.

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WTIA Technical Notes

TN 1-96 – 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 2-97 – 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 3-94 – 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 4-96 – 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 5-94 – 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.

Flame Cut Surface Replicas

These have been developed to complement Technical Note Number 5 by defining three qualities of flame cut surface. Each set of three is contained in a convenient holder with a summary sheet of main flame cutting data.

TN 6-85 – 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 7-98 – 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 8-79 – 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 9-79 – 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.

TN10-02 – 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 11-98 – Commentary on the Structural Steel Welding Standard AS/NZS 1554

(A joint publication with AISC).

The Note complements AS/NZS 1554 parts 1 to 5, 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 12-96 – 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 13-00 – Stainless Steels for Corrosive Environments

(A Joint publication with ACA)

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

TN 14-84 – Design and Construction of Welded Steel Bins

Written because of the widely expressed need for guidance on the design and fabrication of welded steel bulk solids containers, this Technical Note gathers relevant information on functional design, wall loads, stress analysis, design of welded joints and the fabrication, erection and inspection of steel bins. It also contains a very comprehensive reference list to assist in a further understanding of this very broad subject.

TN 15-96 – 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 16-85 – 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 17-86 – Automation in Arc Welding

Provides information and guidance on all the issues involved with automation in arc welding. The general principles are applicable to automation in any field.

TN 18-87 – 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 19-95 – 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 20-94 – Repair of Steel Pipelines

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

TN 21-99 – 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 22-03 – Welding Electrical Safety

Provides information and guidance on welding electrical safety issues: welding equipment, the human body and the workplace.

TN 23-02 – 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 24-03 – Self-Assessment of Welding Management and Coordination to AS/NZS ISO 3834 and ISO 14731 *(CD-ROM only)*

Provides instruction and guidance to enable Australian companies to:

- Understand the aims and application of these quality standards
- Appreciate the relevance and implications of these standards
- Conduct a self-assessment of quality requirements
- Devise an action plan to meet the quality requirements
- Obtain certification to AS/NZS ISO 3834/ ISO 3834/ EN 729

The CD contains a comprehensive checklist that addresses all the elements of AS/NZS ISO 3834 for an audit or certification purpose. The CD also contains useful checklists for Welding Coordination activities and responsibilities

Binder (holds approximately ten Technical Notes).

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WTIA Management Systems

MS01-TWM-01 Total Welding Management System
Interactive CD-ROM

Welding Occupational Health, Safety & Rehabilitation Management System

MS02-OHS-01 OHS&R Managers Handbook

MS03-OHS-01 OHS&R Procedures

MS04-OHS-01 OHS&R Work Instructions

MS05-OHS-01 OHS&R Forms and Records
Four Expert Technology Tools incorporated into one Interactive CD-ROM

MS06-ENV-01 Welding Environmental Management System
Interactive CD-ROM

WTIA Pocket Guides

These handy sized Pocket Guides are designed to be used on a practical day-to-day basis by welding and other personnel.

PG01-WD-01 Weld Defects

Will assist Welders, Welding Supervisors and others in the identification and detection of defects, their common causes, methods of prevention and in their repair.

PG02-SS-01 Welding of Stainless Steel

A concise guide for Welders, Welding Supervisors to welding processes and procedures for the fabrication of stainless steel including Codes, Standards and specifications, cleaning and surface finishing, good welding practice and precautions.

Other Expert Technology Tools

Contract Review for Welding and Allied Industries *(CD-ROM only)*

Explains how to review design, construction, supply, installation and maintenance contracts in the welding industry. It has been designed for private and government organisations acting in the capacity of a client or a contractor or both.

The CD contains more than 36 checklists covering areas such as structures, pressure equipment, pipelines, non-destructive testing and protective coatings to various Australian Standards.