

Module 1

Welding Health and Safety

PART OF THE CWB CERTIFICATE PROGRAMS



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MODULE 1

**WELDING HEALTH
AND SAFETY**

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Welding Health and Safety

MODULE 1

WELDING HEALTH AND SAFETY

Introduction

This Module in the Welding Institute of Canada's series on "Fundamentals of Welding Technology" is aimed at creating a general awareness of health and safety aspects of welding and related processes. It is intended to provide a background for welders, welding supervisors, technicians, and others that may use or become involved with welding processes. But because safety procedures depend on specific conditions, equipment, or local regulations, the module can only treat the subject in general terms. Different or additional safety practices may be appropriate for specific situations and expert advice may need to be sought.

Objective

After successfully completing this module you should be able to:

- Describe the WHMIS system and understand the meaning of warning labels
- List important hazards in using welding and related processes
- Describe means of avoiding electrical shocks
- Describe how the welder can be protected from arc rays, heat and burns
- Recognize when special ventilation is required to control fumes
- List hazards associated with the use of gases and describe general safety practices
- Explain how fires and explosions can be avoided
- Describe safety practices for welding and cutting in confined spaces
- List some of the hazards associated with less common welding processes.

CREATING A SAFE WORK ENVIRONMENT

Nearly all industrial operations—indeed, virtually all human activities—entail potential risks to health and safety. Welding and related activities expose the worker and those nearby to certain hazards ranging from fire and electric shock to eye damage and long term health effects. Minimizing these hazards is the joint responsibility of the employer and the worker: the employer must inform the worker about the hazards and provide a safe working environment; the worker must use protective equipment and follow safety procedures. Some general rules for promoting a safe working environment are:

- use a safe method of working. If in doubt, ask
- follow health and safety procedures, respect warning signs, and always read safety labels
- use personal protective clothing and equipment where required
- ensure equipment is maintained in a safe condition and report defective or unsafe equipment
- do not use any material or process until the hazards are known
- exercise good housekeeping practices
- do not enter any restricted area unless authorized
- do not defeat the purpose of any safety features of equipment.

Many laws are applicable to health and safety aspects of welding. Legislation varies from place to place and will not be discussed in detail, but several important points will be mentioned. Recent laws embody the idea of the “right to know” of persons in the workplace. The idea is that anyone in the workplace has the right to know about the hazards of materials they may be exposed to or work they may have to undertake. Some laws specifically give the worker the right to refuse to undertake work if he or she has reason to believe that it is unsafe.

Legislation

OSHA

In the USA the Occupational Safety and Health Administration (OSHA) is the federal body that regulates health and safety in the workplace and which the majority of states follow in their legislation. OSHA may, for example, require labels on products that identify carcinogenic potential. OSHA may also set limits for the exposure to specific materials that present a hazard to health.

Canada

In Canada, health and safety in the workplace is subject to provincial legislation except for federally regulated industries such as the national railways. In Ontario, for example, the Occupational Health and Safety Act covers such things as safety committees, rights of workers to be informed about potential hazards, "designated" substances that are regulated in specific ways, and exposure limits.

WHMIS

The health and safety acts of all the provinces have recently been amended to implement the federal "Workplace Hazardous Materials Information System" (WHMIS). This has resulted in a Canada-wide system in effect since 31 October 1988.

Under the idea of "right to know" the objective of WHMIS is to ensure that information on hazardous materials gets to all those in the workplace that could be exposed to the hazard. At the present time it only covers toxins and chemicals but not physical agents such as noise or ultraviolet light. Physical agents, however, may be regulated under the provincial health and safety laws, and it is likely that WHMIS will be extended to cover physical agents in the future.

Under WHMIS, information is conveyed by three methods:

- Product labels
- Material Safety Data Sheets (MSDS)
- Training.

Hazardous Materials

Hazardous materials are those meeting specific criteria (listed on the following page) under the Hazardous Products Act and are called Controlled Products. There is no list of controlled products; anything meeting the criteria is included. Controlled products are assigned to one or more of six classes which are listed on the following page with their corresponding symbols shown in Fig. 1.

Class A: Compressed Gas

Materials such as carbon dioxide, and argon that are gases at room temperature (20°C) and are kept under pressure.

Class B: Flammable and Combustible

Materials that will ignite and continue to burn when exposed to a flame. A flammable liquid is one with a flash point less than 37.8°C (100°F) and a combustible liquid is one with a flash point greater than 37.8°C.

The flash point is the minimum temperature at which the liquid gives off enough vapour to ignite under test conditions.

Examples:

Flammable: gasoline, ethyl alcohol

Combustible: kerosene, creosote.

Class C: Oxidizing

Materials, such as oxygen itself or potassium chlorate, that will cause another to burn.

Class D: Poisonous and Biohazardous Infectious

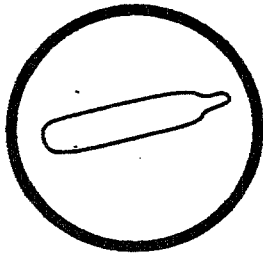
- a) Materials causing immediate serious toxic effects when taken into the body.
- b) Those that cause other toxic effects such as long term effects on health. Carcinogens (cancer causing) are in this class.
- c) Materials (organisms) that may cause infectious diseases. For example, certain bacteria and viruses.

Class E: Corrosive

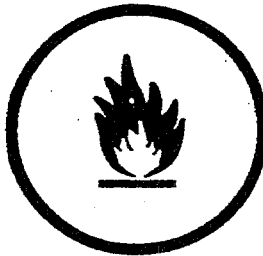
Materials that will destroy human tissue and other materials. For example, sulphuric acid.

Class F: Dangerously Reactive

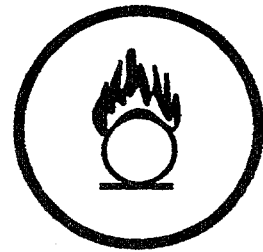
Materials that by chemical reaction with another substance or self-reaction when heated or pressurized may create a hazard. A material that produces a poisonous gas on contact with water would be in this class. But explosives are covered under a separate law—not WHMIS.



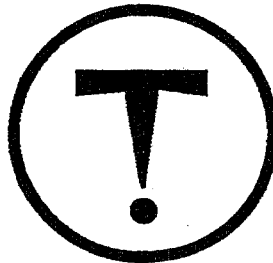
Class A: Compressed Gas



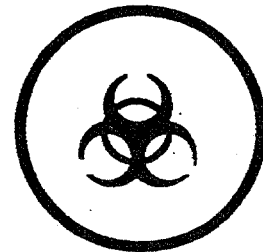
Class B: Flammable and Combustible



Class C: Oxidizing



Class D: Poisonous and Biohazardous Infectious



a) **Materials causing immediate serious toxic effects**

b) **Materials causing other toxic effects such as long term effects**

c) **Materials (organisms) that may cause infectious diseases**



Class E: Corrosive



Class F: Dangerously Reactive

Fig. 1. Hazard symbols and their significance.

WHMIS labels

Many materials used in, or associated with, welding operations may be classified as hazardous and come under WHMIS. Examples are:

- Oxygen and other gases for cutting and welding
- Welding consumables
- Materials to be welded.

Any controlled product coming into or produced in a workplace must have an identifying label (supplier label) affixed to the container or package. In addition, labels are also required in the workplace (workplace labels) to ensure that the information is transmitted to the end user of the material. Workplace labels must also be placed on controlled products decanted from their original containers into another at the workplace.

Supplier labels

Labels must not be altered or destroyed since that would defeat the purpose of WHMIS and might expose someone to a hazard that they were unaware of. WHMIS labels have a characteristic appearance recognizable by the border. The supplier labels (Fig. 2) contain the following information:

- Product identifier (common name, brand name, code, etc.)
- Supplier identifier (name of supplier)
- MSDS statement (says that a Material Safety Data Sheet is available)
- Hazard symbol (one or more of the standard symbols)
- Risk phrases (they describe the effects of exposure, e.g., "spontaneously flammable")
- Precautionary measures (how to avoid the risk, e.g., "store in designated area, no smoking")
- First aid measures (actions to be taken in the event of exposure, e.g., "wash affected area with running water").

Workplace labels

Workplace labels contain less information than supplier labels and only give:

- Product identifier
- Safe handling instructions
- MSDS statement.

PRODUCT IDENTIFIER IDENTIFICATEUR DU PRODUIT		
HAZARD SYMBOL SIGNAL DE DANGER	HAZARD SYMBOL SIGNAL DE DANGER	HAZARD SYMBOL SIGNAL DE DANGER
RISK PHRASES MENTIONS DE RISQUE		
PRECAUTIONARY MEASURES PRÉCAUTIONS À PRENDRE		
FIRST AID MEASURES (WHERE APPLICABLE) PREMIER SOINS À ADMINISTRER (LORSQU'IL Y A LIEU)		
MATERIAL SAFETY DATA SHEET AVAILABLE FICHE SIGNALÉTIQUE EST DISPONIBLE		
SUPPLIER IDENTIFIER IDENTIFICATEUR DE FOURNISSEUR		

In special cases (laboratory samples, laboratory supplies, workplace labels), the WHMIS label may contain less information, as follows:

(a) Laboratory Samples (10 kilograms or less)

1. **PRODUCT IDENTIFIER**
2. **CHEMICAL IDENTITY OR GENERIC CHEMICAL IDENTITY**
3. **"HAZARDOUS LABORATORY SAMPLE. FOR HAZARD INFORMATION OR IN AN EMERGENCY, CALL"**
4. **EMERGENCY TELEPHONE NUMBER OF SUPPLIER**

(b) Laboratory Supplies (10 kilograms or less)

1. **PRODUCT IDENTIFIER**
2. **MATERIAL SAFETY DATA SHEET AVAILABLE (WHERE APPLICABLE)**
3. **RISK PHRASES**
4. **PRECAUTIONARY MEASURES**
5. **FIRST AID MEASURES (WHERE APPLICABLE)**

(c) Workplace Labels

1. **PRODUCT IDENTIFIER**
2. **HAZARD INFORMATION**
3. **MATERIAL SAFETY DATA SHEET IS AVAILABLE**

Fig. 2. Information provided on a WHMIS supplier label.

If a supplier feels that providing this information gives away trade secrets, he may apply to an impartial review commission set up under the Hazardous Materials Information Review Act (HMIRA) for an exemption. The WHMIS supplier label adopted by the Welding Products Manufacturers Association of Canada (WPMAC) is shown in Fig. 3.

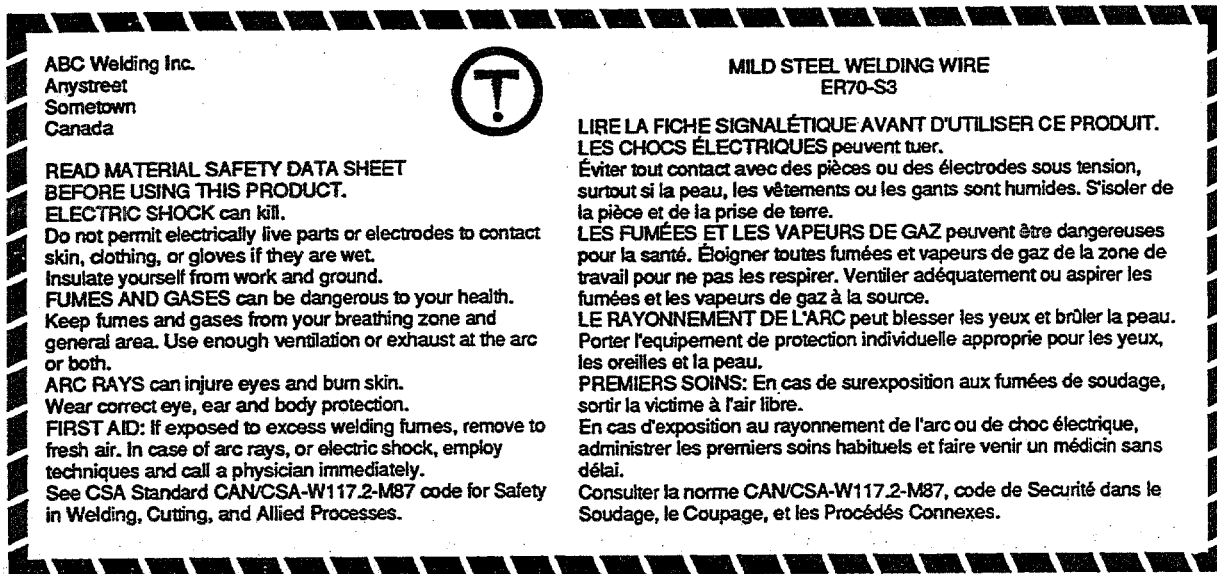


Fig. 3. WHMIS supplier label used for welding products.

MSDS

The WHMIS label alerts the user to a hazard but obviously does not have enough room to provide detailed information. The supplier must, therefore, provide a Material Safety Data Sheet (MSDS) for each controlled product supplied, and this must be accessible to anyone who requires it. The MSDS contains nine categories of information:

- hazardous ingredients
- preparation information
- product information
- physical data
- fire or explosion hazard
- reactivity data
- toxicological properties
- preventive measures
- first aid measures.

While some of the information in an MSDS is likely to be highly technical and would be used by engineers or safety officers, other parts provide valuable safety information. Hence MSDS's must be made

Training

available to all workers who use or may be exposed to controlled products. An example of some of the information in an MSDS used in a welding context is illustrated in Fig. 4.

Under the WHMIS system instruction must be provided for employees who are exposed to controlled products. The training must be tailored to the specific job, materials, and hazards that the worker encounters.

SECTION II — HAZARDOUS INGREDIENTS				
IMPORTANT — This section covers the materials from which these products are manufactured. The fumes and gases produced during welding with normal use of these products are covered by Section V - REACTIVITY DATA. THE TERM "HAZARDOUS" IN HAZARDOUS INGREDIENTS SHOULD BE INTERPRETED AS A TERM REQUIRED AND DEFINED IN THE HAZARDOUS PRODUCTS ACT.				
GROUP A, B & C				
INGREDIENT	CAS No.	% WT.	EXPOSURE LIMIT	
			ACGIH TLV	LD ₅₀ / LC ₅₀
IRON	7439-89-6	30-60	N.A.V.	N.A.V.
MANGANESE	7439-96-5	1-5	5.0 CL*	LD ₅₀ 9.0 gm/kg (oral, Rat)
MICA	12001-26-2	1-5	3.0	N.A.V.
TITANIUM DIOXIDE	13463-67-7	7-13	10.0	N.A.V.
FLUORSPAR	7789-75-5	3-7	2.5 (as F)	LD ₅₀ 4250 mg/kg (oral, Rat)
CHROMIUM	7440-47-3	10-30	0.5	N.A.V.
NICKEL	7440-02-0	7-13	1.0	N.A.V.
FERROSILICON	8049-17-0	0.5-1.5	N.A.V.	N.A.V.
MOLYBDENUM	7439-98-7		10.0	

SECTION VI — TOXICOLOGICAL PROPERTIES/HEALTH HAZARD DATA			
POSSIBLE ROUTE OF ENTRY/EXPOSURE: INHALATION (PRIMARY) - EYE - SKIN			
The ACGIH recommended general limit for welding fume NOC (Not Otherwise Classified), is 5.0 mg/m ³ . The ACGIH TLVs (1988 - 1989) preface states these limits are not fine lines between safe and dangerous concentration and should not be used by anyone untrained in the discipline of industrial hygiene. See Section V for specific fume constituents which may modify this TLV.			
SUBSTANCE	CAS No.	EXPOSURE LIMITS	
		ACGIH TLV	LD ₅₀ / LC ₅₀
WELDING FUMES	NOC*	5.0 mg/m ³	N.A.V.

*NOC = NOT OTHERWISE CLASSIFIED

Electric arc welding may create one or more of the following health hazards: Fumes and Gases can be dangerous to your health. Arc Rays can injure eyes and burn skin. Electric shock can kill.

CARCINOGENICITY: Nickel and chromium must be considered as possible carcinogens under IARC monographs, and are present in all products. Only nickel is present in nickel cast electrodes - Group E.

EFFECTS OF ACUTE OVEREXPOSURE:

Fig. 4. Example of some of the information that may be contained in a Material Safety Data Sheet (MSDS). This one is for a stainless steel electrode.

General Hazards in the Shop

Welding personnel working in a shop will be exposed to potential hazards in addition to those directly associated with welding. For example, overhead cranes may be moving large pieces of steel around, various pieces of machinery may be operating, or radiography may be being performed in a section of the shop. Likewise, other people not directly involved in welding, including occasional visitors to the shop, may be exposed to the hazards of welding, such as arc radiation, spatter, and fume.

Many of the hazards in the shop environment are fairly apparent by their nature. We may call these 'inherent' hazards and examples include:

- machinery operation (mechanical hazards)
- noise, arc radiation
- welding sparks, spatter, open flames
- vehicles, cranes, and moving material.

Less obvious hazards—which we may call 'latent' hazards—may be just as important, but perhaps the worker is less aware of them. Latent hazards might include:

- working with unfamiliar equipment
- work around or in tanks or confined spaces
- fumes and gases
- gas leaks
- improper electrical connections
- unmarked hot metal.

Guidance on Welding Health and Safety.

The following sections in this module cover health and safety aspects of welding and related operations. There are many other sources of information and some of these are listed at the end of the module. Health and safety in welding is also covered by national standards. In Canada: CAN/CSA W117.2 "Safety in Welding, Cutting, and Allied Processes" and in the USA: ANSI/AWS Z49.1-94 "Safety in Welding and Cutting."

Identifying welding hazards

GENERAL HAZARDS IN WELDING AND THEIR CONTROL

The first step in defining safety practices for welding is to define the potential hazards. These, of course, may be different for each situation, but CSA W117.2 provides some guidance on the general hazards that are associated with the common welding processes. Table 1 summarizes this information showing where a major hazard exists for four groups of welding processes.

Table 1. General hazards in welding and cutting.

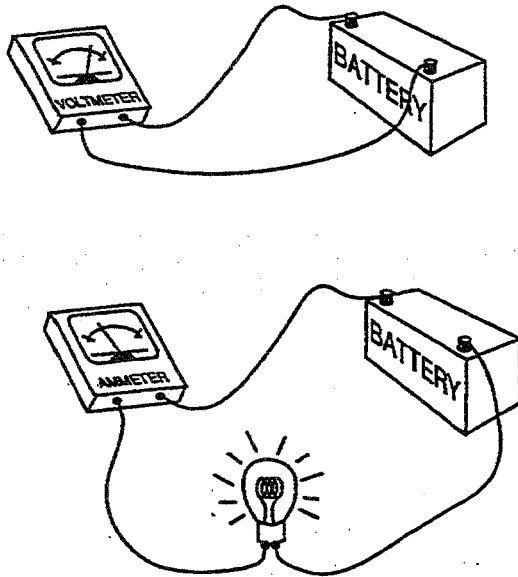
	Oxyfuel	SMAW GTAW GMAW FCAW	SAW	PAW Air carbon Arc cutting
Shock		✓	✓	✓
Fire	✓	✓	✓	✓
Burn	✓	✓	✓	✓
Radiation	✓	✓	(✓)	✓
Heat	✓	✓	✓	✓
Fumes/ Gases	✓	✓	(✓)	✓
Noise		✓		✓

(✓) may be a hazard in some circumstances

Facts about electricity

Before discussing electrical hazards it is worth reviewing some basic facts about electricity. The amount of electricity flowing through a circuit is called the current (given the symbol, I) and is measured in amperes (A). To measure the current an ammeter is placed in the circuit so all the current flows *through* the ammeter. Currents in welding circuits can be very high, usually several hundred amperes.

The electromotive force, or force that is trying to push the current through the circuit, is measured in volts (V). The voltage is measured by placing a voltmeter *across* two points in a circuit. Fig. 5 illustrates how voltage and current are measured. The resistance (R) is a property



*Fig. 5. Measurement of current and voltage in an electrical circuit. Voltage is measured **across** two points in a circuit. Current is the rate of flow of electricity **through** a continuous circuit.*

Resistance

of the material in the circuit and determines how much current is allowed to flow when a given voltage is placed across the circuit. It is measured in ohms (Ω). Materials with very low resistance, such as copper, are called conductors and allow large amounts of current to flow for a given voltage. The voltage, current, and resistance are linked by Ohm's Law:

$$I = V/R$$

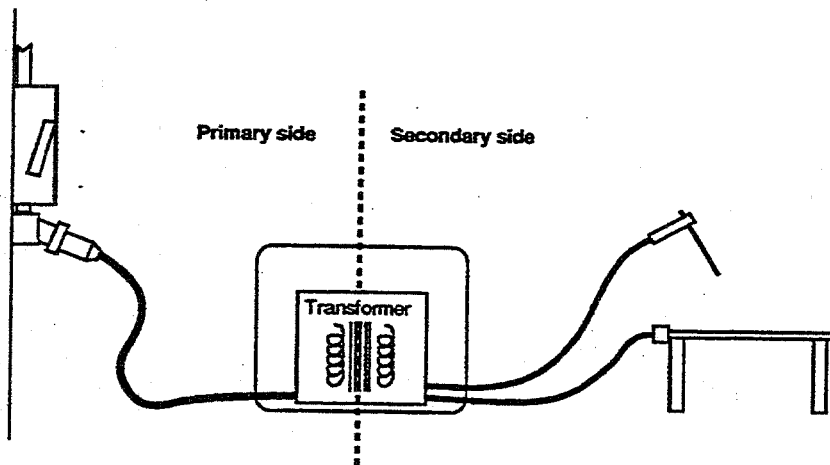


Fig. 6. Illustration of primary and secondary sides in the electrical circuits of welding power sources.

Line voltages

The line or mains voltages available in shops are high: typically 480 V (USA), 575 V (Canada) for three phase, and 240 V and 120 V for single phase. These are the primary voltages that are the inputs to electrical equipment. In most equipment these voltages are “stepped down” by a transformer to provide lower secondary voltages as shown in Fig. 6. The voltage across the output terminals of most welding machines is about 80 V when no current is drawn (the open circuit voltage, OCV) but it drops to 20 to 30 V when the arc is established and current is flowing. Open circuit voltages are limited by the National Electrical Manufacturers Association (NEMA) Standard EW-1 and are given in Table 2.

Table 2. Open circuit voltages of welding power sources (NEMA).

Manual/semi-automatic	
AC	80 volts r.m.s.*
DC > 10% ripple	80 volts r.m.s.
DC < 10% ripple	100 volts avg.
Automatic	
AC	100 volts r.m.s.
DC	100 volts avg.
*root mean square	

It is important to distinguish clearly between the primary and secondary sides of electrical equipment because of the difference in voltages.

Electrical shocks

The human body can conduct electricity. If an external voltage is applied across parts of the body, a current will flow which could result in shock, burns, paralysis, or death. The voltages needed to produce enough current to cause damage are not very high, but the damage depends on many factors such as where the current flows through the body, how effective the contact with the external voltage is, and so forth.

The high voltages on the primary side of welding equipment are the most hazardous, but the open circuit voltages on the secondary side of welding equipment, although limited for safety reasons, may still cause a serious shock under some conditions. Some types of equipment, such as plasma, may employ very high voltages.

In the majority of electrical circuits one part of the circuit is connected to the ground. For example, the white, "neutral" wire entering your house is connected to the ground. The red and black wires are the "hot" or live wires and are not connected to the ground (Fig. 7).

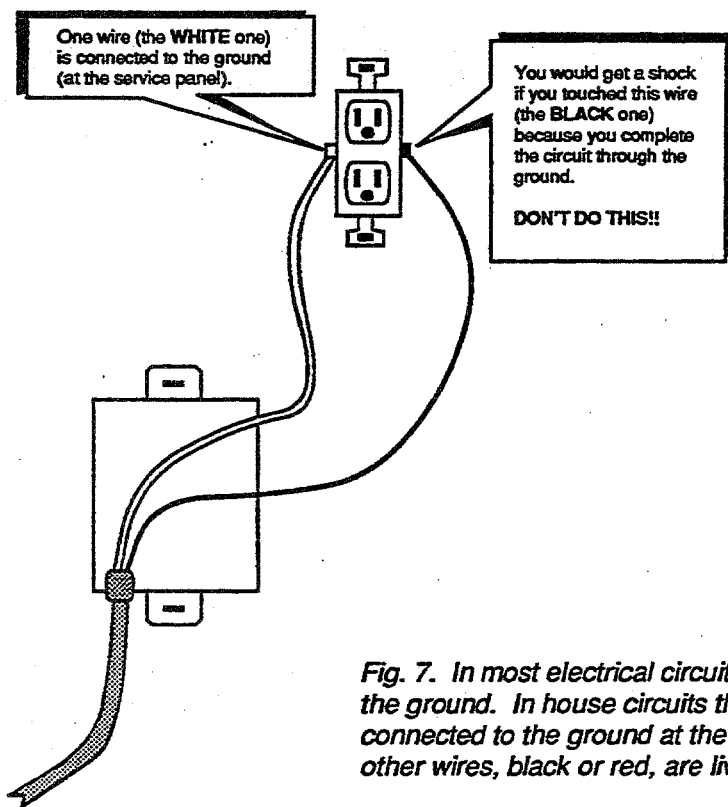


Fig. 7. In most electrical circuits one wire is connected to the ground. In house circuits the white "neutral" wire is connected to the ground at the service entrance. The other wires, black or red, are live.

When one part of an electrical circuit is connected to the ground, it is only necessary for the body to touch *one* live conductor for a current to flow through the body and cause a shock. The current can return through the ground (Fig. 8). Anything that increases the electrical contact with the ground increases the risk of shock. For example, standing in water or working with wet hands.

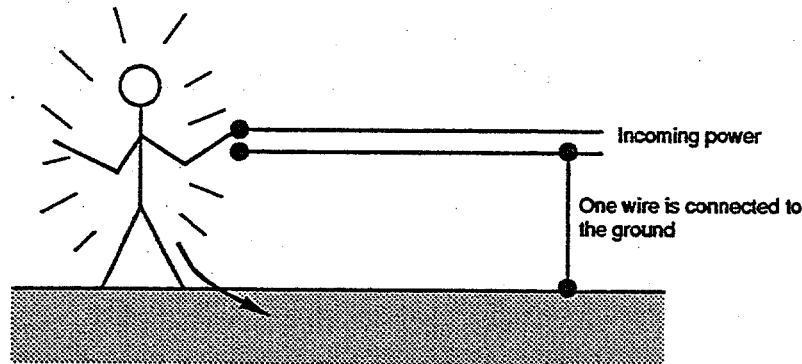


Fig. 8. Completion of an electric circuit through the ground.

Action in the event of shock

There may be secondary hazards associated with electric shocks even when the shock is small and does not cause any direct damage. A sudden jolt could cause the worker to slip and fall, possibly from a high place, or cause some other injury to himself.

If a workmate suffers an electrical shock, these are some of the actions to take:

- Do not try and pull the victim from a live contact (unless there is no alternative).
- Disconnect and turn off the power first then remove the victim from contact.
- If the rescuer must resort to pulling a victim from a live contact, he must insulate himself with gloves or similar protection.
- If the victim is not breathing give artificial respiration. If the victim's heart has stopped and if you have been trained, give CPR (cardiopulmonary resuscitation).
- Call for help and call a physician.
- Keep the victim horizontal and warm.

Avoiding electrical hazards

Do not undertake work for which you have not been trained and are not qualified to do. Any electrical work, including installing plugs and outlets, must be done by a qualified electrician.

The high voltage input cable should be kept short and be protected at all times. Do not, for example, lay steel on it or drive a fork lift over it. Before plugging or unplugging the high voltage input cable, turn the disconnect switch off. When turning the disconnect switch to "on" stand to one side.

Correct electrical connections

Ensure that the welding equipment is correctly connected. One cable from the welding machine is connected to the electrode holder. The current from the power source flows through this cable to the arc then through the workpiece and returns to the welding machine through the work lead. The work lead is *not* the ground lead. It is there to complete the electric circuit. The work piece may be connected to a metal table or something similar which is in turn connected via the work lead to the welding machine. Fig. 9 shows the electrical connections for arc welding.

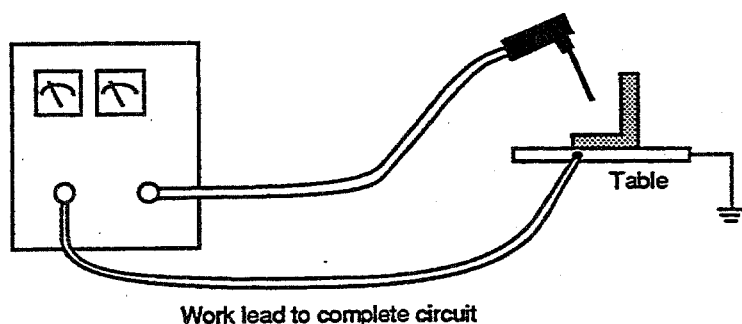


Fig. 9. Electrical connections for arc welding.

It is essential that the work lead make a good electrical contact with the workpiece. If there is a bad connection, the current will try to find another path back to the power source through the grounding system, possibly causing damage. Check that there is no paint or grease preventing a good connection.

Grounding

In some cases the welding current may be allowed to return through a metal structure such as a pipeline. This is not allowed if the pipe carries gases or flammable liquids. Neither must the current be carried across threaded, flanged, bolted, or caulked joints.

Never allow welding current to be carried by cranes, hoists, wire ropes, elevator structures or similar devices, and ensure cables are located where they cannot be physically damaged.

The frames of power sources, control panels, etc., must be connected to an approved ground. The workpiece, too, must be separately grounded, preferably at the workpiece itself but alternately at the welding machine. Grounding of the workpiece prevents it becoming "live" in the event of a fault in the machine transferring high primary voltages to the secondary side. Workpiece grounding also prevents the electrode voltage—relative to ground—"floating" above 80 V under open circuit conditions. If the workpiece is grounded at the machine by a wire to the grounded enclosure, the wire must be smaller than the ground wire (Fig. 10).

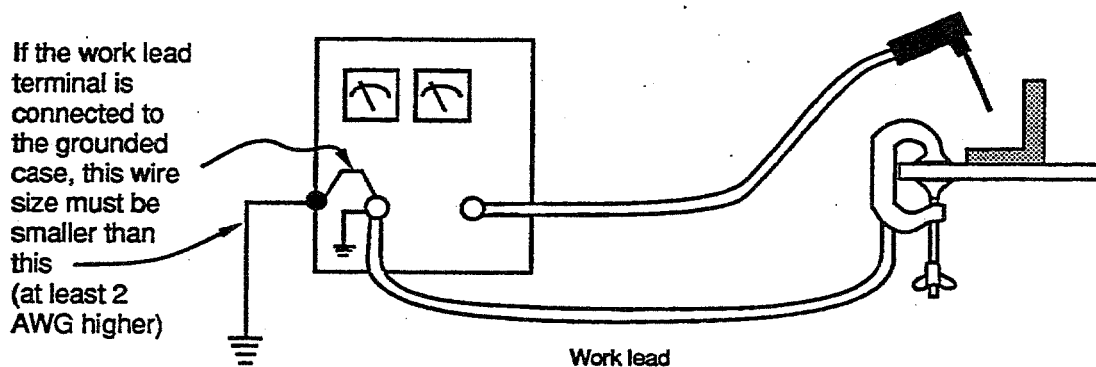


Fig. 10. Grounding at the power source.

Cables

Ensure that all cables are of the correct size to carry the current. This applies to both the welding cable and the work lead. Undersize cables could cause overheating and ignite a fire. The size of cable depends on the duty cycle which is the proportion of time that the current is actually flowing and is defined as the number of minutes that current flows for every ten minute period. Table 3 gives the recommended size for duty cycles up to 60%—typical for manual welding.

Table 3. Cable sizes for average manual metal arc welding duty cycles .

Welding current, A	Copper cable size No.
100	4
200	2
300	1/0
400	2/0
500	4/0
600	4/0

Notes:

Based on safe operating temperatures, average cable length of 38 m. For automatic or semiautomatic welding with duty cycles up to 100%, cables shall be in accordance with CSA C22.2 and C22.1.

Long cables must be larger than short cables, but excessively long cables should be avoided. Use the shortest cable that is practicable. Do not wind the cable around your body (Fig. 11). Keep electrical connections tight, clean, and dry so they do not heat up or cause sparks.



Fig. 11. Do not wind the cable around yourself.

Do not use any water cooled equipment or welding guns if any leaks exist. To prevent condensation on cold water hoses from running into electrical equipment, place a loop in the hose (Fig. 12).

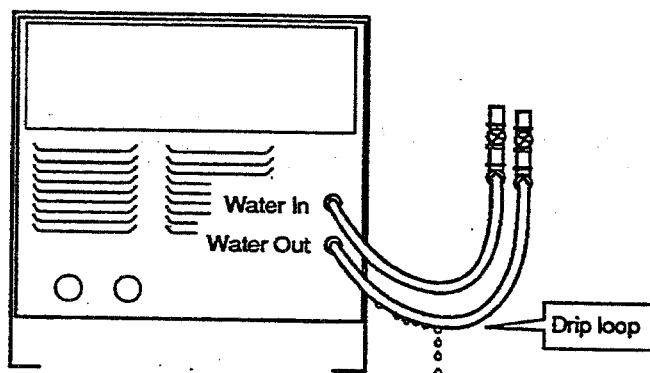


Fig. 12. Use of a drip loop to prevent condensation running into a machine.

Live spools

With automatic welding equipment the welding current is conducted through the electrode wire. The spool of wire is therefore "live" while the arc is burning. It is particularly important to remember this where the wire is fed long distances. For example, wire from a large pay-off pack may be fed over pulleys long distances to a robot. In most equipment the welding current is only turned on by a contactor when the wire is being fed and the arc can burn. In some equipment, such as voltage sensing wire feeders used without contactors, the wire and spool can be "live" without the arc burning or the wire being fed. Under these conditions the operator is exposed to the full open circuit voltage (usually 80 V) of the power source. This hazard can be reduced by installing separate contactors.

Radiation

Radiation is a way in which energy can be transferred from one location to another in the form of electromagnetic waves. The different types of radiation are distinguished by their wavelength or frequency as shown in Fig. 13. Radiation can pose a number of hazards which again depend on the wavelength and also on the intensity.

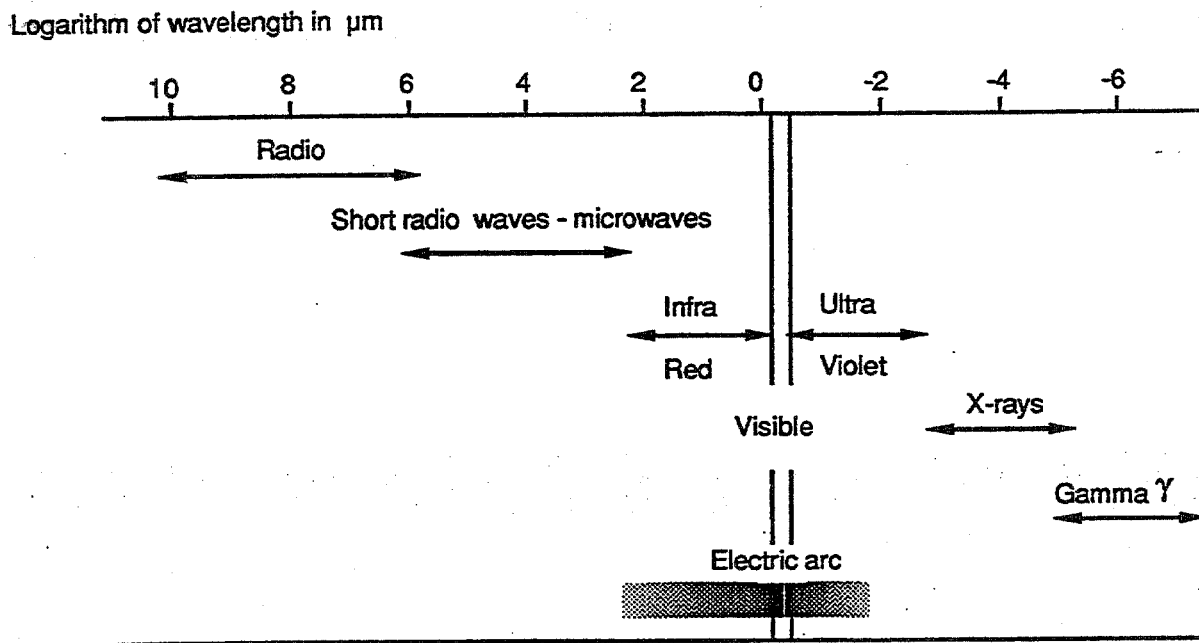


Fig. 13. Electromagnetic spectrum showing how different types of radiation are characterized by their wavelength.

Types of radiation

Radiation may be classed as either ionizing or non-ionizing. The ionizing radiation has a short wavelength and can damage living cells. It can cause serious short term and long term health effects and can be fatal in sufficient doses. X-rays and gamma rays used in the radiography of welds are of the ionizing type and special safety precautions must be taken when using them. These must only be used by specially trained people. The warning symbol for this type of radiation is shown in Fig. 14. Ionizing radiation (X-rays) can also be emitted with certain welding processes such as electron beam welding.

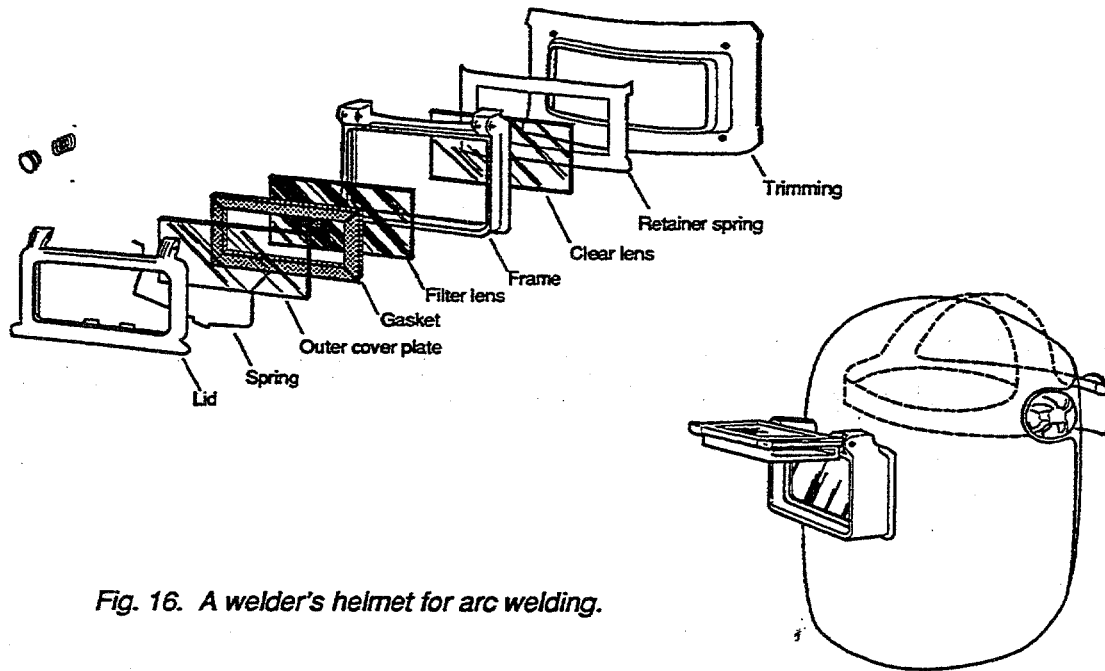


Fig. 16. A welder's helmet for arc welding.

Welder helmets fit over the head and are hinged so that they can be raised after welding. A welder's helmet is shown in Fig. 16 and goggles for gas welding are illustrated in Fig. 17. Hand held shields or masks are available and are useful for observers. In all cases, safety glasses (Fig. 18) should be worn under the helmet to protect the eyes from flying particles (e.g., when removing slag). Safety glasses should have side shields for extra protection.

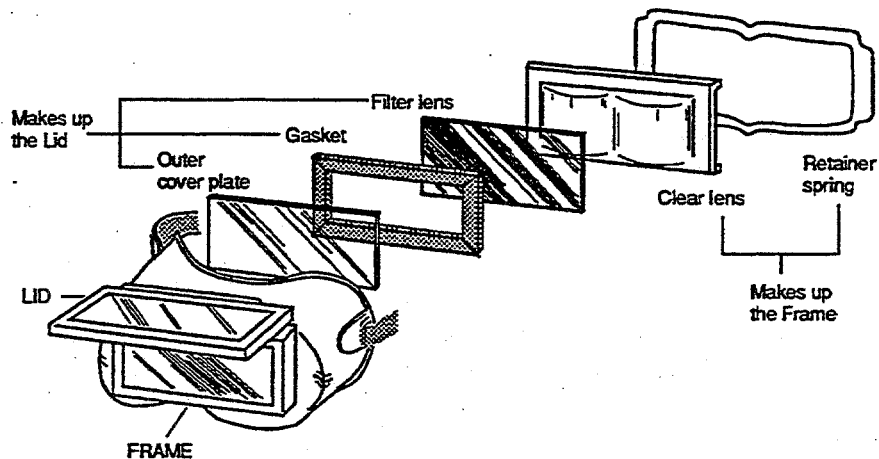


Fig. 17. Goggles for gas welding, brazing, or cutting.

The wearing of contact lenses may not be advisable since dust particles or chemicals may irritate the eye. Reports of contact lenses being "welded" to the cornea as the result of a flash have, however, been refuted.

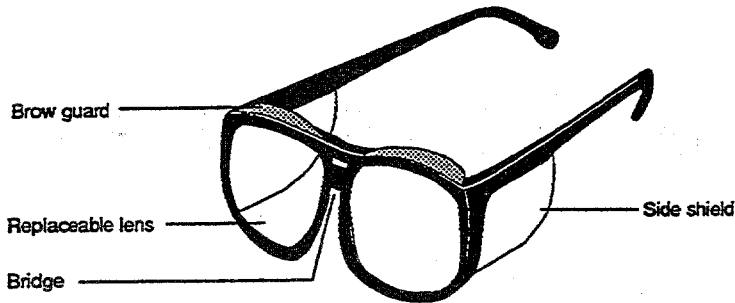


Fig. 18. Safety glasses. They should be worn under a welder's helmet.

Other workers

Welding poses potential hazards to other workers as well as the welder. This is particularly true for the hazards from arc rays. Those around a welding station may inadvertently be looking directly at an arc when it is struck and suffer from arc flash. Just working near a welder may result in skin burns due to the ultraviolet rays emitted. Other workers may be exposed to rays that are reflected from walls or other surfaces. Reflection of ultraviolet radiation is particularly likely when gas tungsten or gas metal arc welding is used on aluminum or stainless steel. Anyone within about 25 m (75 ft) of an unshielded welding area should wear eye protection. It is important to note that not all of the UV, IR, and obviously visible spectrum is absorbed by transparent materials like clear glass or plastic. Therefore, eye protection with a minimum shade should be worn by observers and assistants.

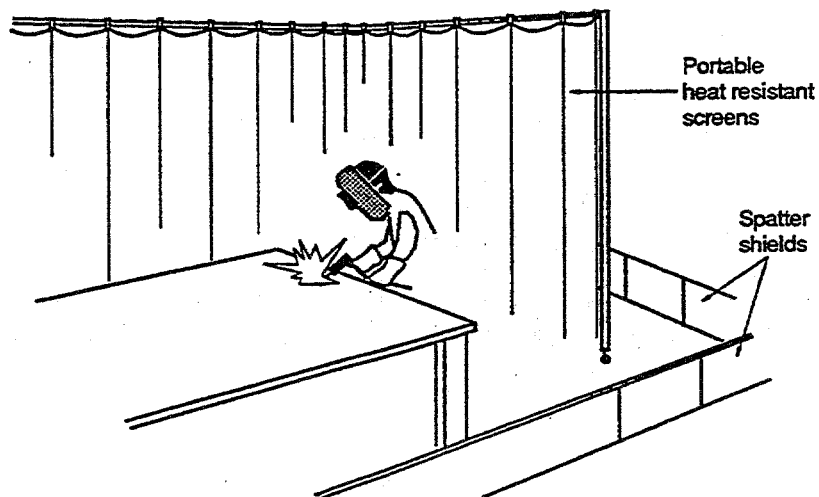
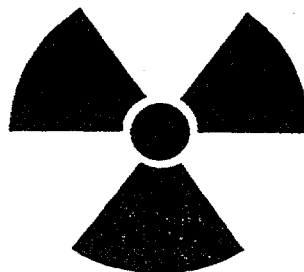


Fig. 19. Typical screens around a welding area.

Fig. 14. Warning symbol for ionizing radiation including X-rays and γ rays (magenta against a yellow background). It is the responsibility of the certified radiographer to designate unsafe areas during the radiography of welds. Watch for and obey these warnings!



Arc rays

The non-ionizing radiation emitted by welding arcs includes visible, ultraviolet, and infrared light (Fig. 15). The hazards from non-ionizing radiation encountered with the common welding processes are mainly burns, skin damage, and eye damage. While skin damage is mainly the result of ultraviolet radiation, eye damage can occur from ultraviolet, visible, and infrared radiation.

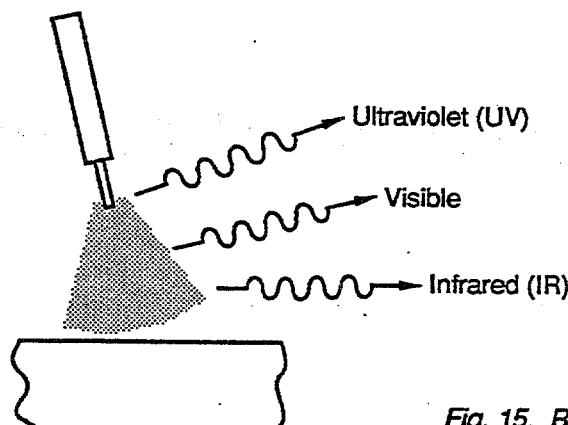


Fig. 15. Radiation emitted by an arc.

Ultraviolet

Skin, exposed to the ultraviolet radiation in arc rays even for a few minutes will suffer burning similar to sun burn. As with sun burn you may not know this is happening at the time, but later the skin will be red and sore.

Arc flash

The most common injury suffered by welders from radiation is damage to the eyes from arc rays. Very short exposures (just a few seconds) can cause damage—often called “arc eye”, “welders’ eye” or “arc flash”. Again, the painful effects may not be felt until several hours after exposure.

Welding Health and Safety

The eyes must always be protected when welding by using a welder's helmet with the correct shade inserted. Table 4 gives a list of recommended shade numbers for welding and cutting operations.

Table 4. Guide for shade numbers for welding (CAN/CSA-W117.2-94).
(Consult original for other processes).

Welding and gouging

Operation	Electrode size, mm	(in)	Arc current A	Minimum protective shade	Suggested shade No. (comfort)
SMAW	less than 2.5	(3/32)	less than 60	7	—
	2.5-4	(3-5/32)	60-160	8	10
	4-6.4	(5-8/32)	160-250	10	12
	more than 6.4	(8/32)	250-550	11	14
GMAW			less than 60	7	—
			60-160	10	11
and			160-250	10	12
FCAW			250-500	10	14
Air carbon arc cutting (light)			less than 500	10	12
Air carbon arc cutting (heavy)			500-1000	11	14

Notes:

- (1) For thermit, laser, and electron beam welding, consult the manufacturer for eye protection recommendations.
- (2) For pulsed GMAW, use peak current for selecting the appropriate shade number.
- (3) For underwater welding, the minimum shade number shown may not necessarily apply.

Cutting

	Plate thickness, mm	(in)	Minimum protective shade	Suggested shade No.
Oxygen cutting (light)	Under 25	(Under 1)	3	4
(medium)	25 to 150	(1 to 6)	4	5
(heavy)	Over 150	(Over 6)	5	6

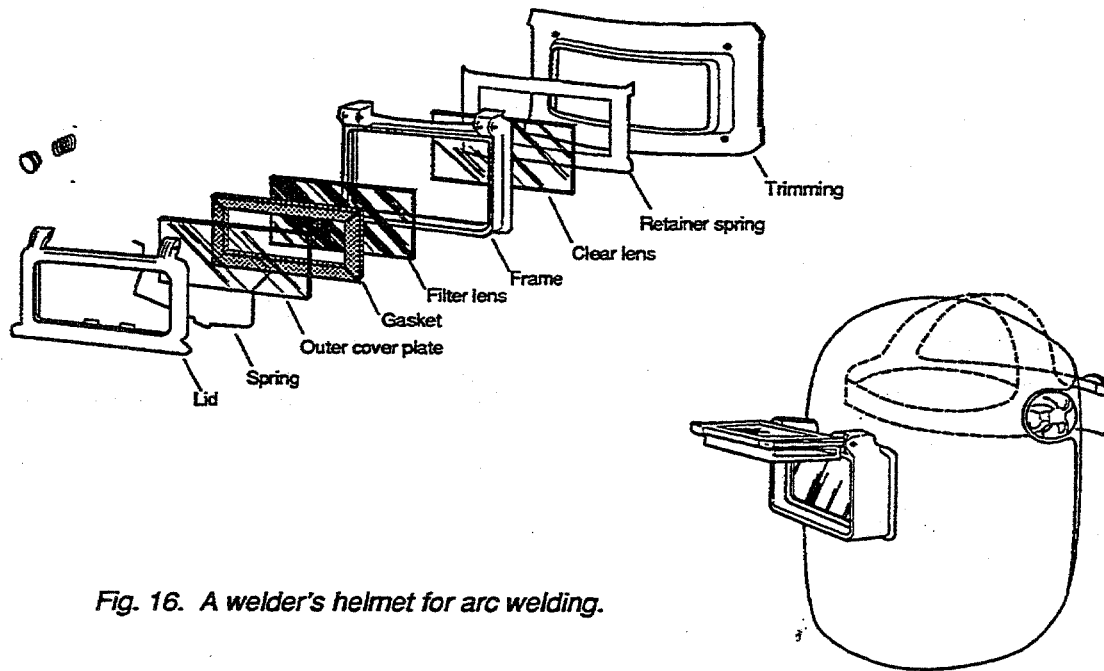


Fig. 16. A welder's helmet for arc welding.

Welder helmets fit over the head and are hinged so that they can be raised after welding. A welder's helmet is shown in Fig. 16 and goggles for gas welding are illustrated in Fig. 17. Hand held shields or masks are available and are useful for observers. In all cases, safety glasses (Fig. 18) should be worn under the helmet to protect the eyes from flying particles (e.g., when removing slag). Safety glasses should have side shields for extra protection.

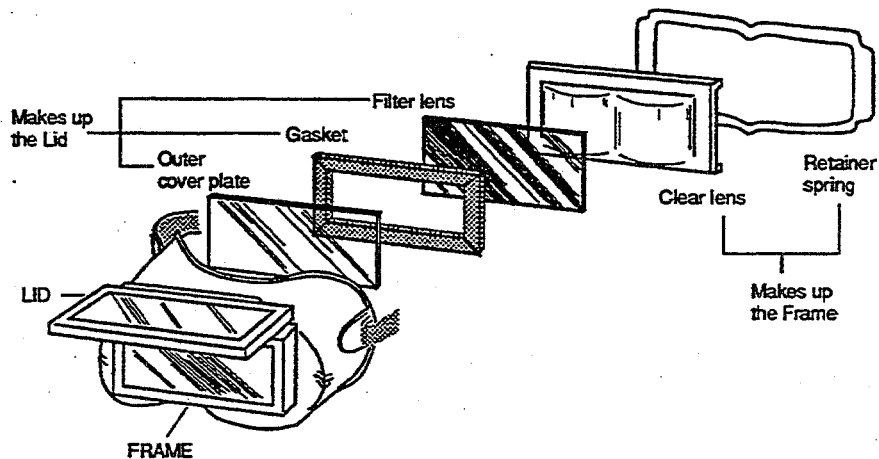


Fig. 17. Goggles for gas welding, brazing, or cutting.

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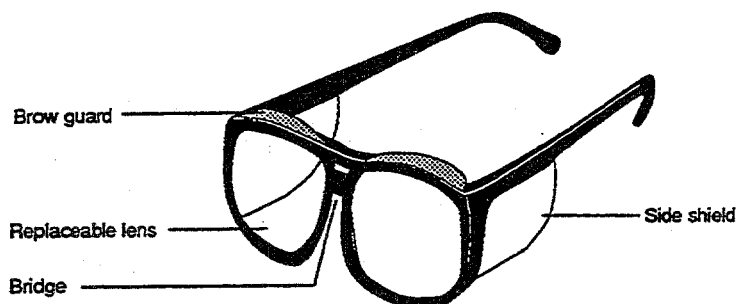


Fig. 18. Safety glasses. They should be worn under a welder's helmet.

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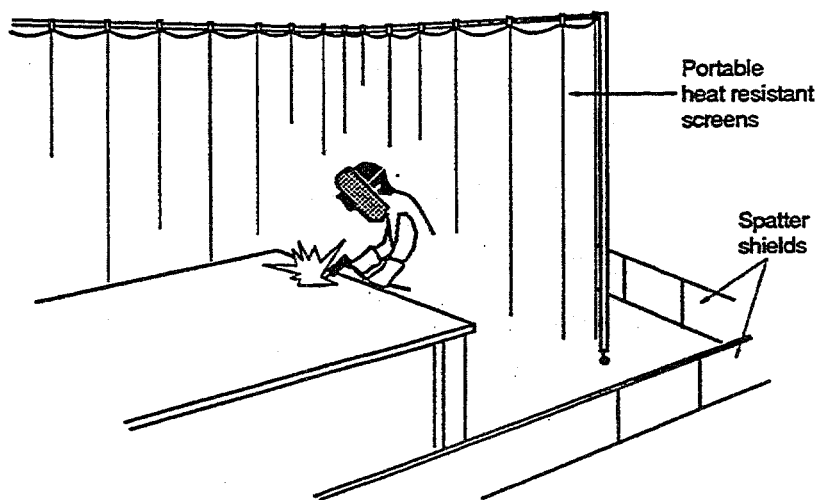


Fig. 19. Typical screens around a welding area.

Burns and fires

Where possible, welding activities should be shielded by using a welding booth, curtains, portable screens and so forth, so as to minimize the risk of other workers being exposed to welding hazards (Fig. 19). Screens and partitions must be specially designed for the purpose, must be fire resistant, and should be finished in a way that minimizes reflections. They should also be open at the bottom to allow ventilation, and separate shields to prevent the escape of spatter from the welding area may be required. Transparent screens are not intended as welding filter plates and should not be used for continuous viewing of the arc.

In addition to the risk of burns from radiation, there is the obvious hazard of burns and fires from hot metal. Most arc welding produces sparks and spatter—small droplets of molten metal ejected from the weld zone (Fig. 20)—which may travel considerable distances. These

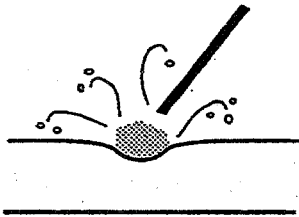
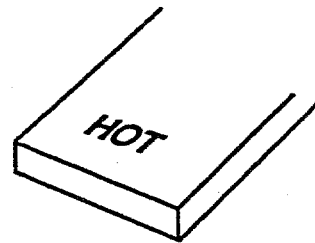


Fig. 20. Spatter. Small droplets of molten metal ejected from the weld zone.

could cause burns if allowed to strike exposed skin, and could ignite fires if they come into contact with flammable materials. In addition, the workpiece will be hot after welding and in some cases may be preheated before welding. It may not be obvious by its appearance that a piece of metal is hot, and hot pieces should be marked (Fig. 21).

Fig. 21. Pieces of hot metal should be so marked to warn others.



Clothing

To reduce the risk of burns from hot metal, proper clothing and gloves must be worn. Protective clothing should be heat and fire resistant, long sleeved, and pants should not have cuffs that could trap hot metal. Gloves should be of the gauntlet type that offer protection to the wrist area. Do not wear rings or jewelry. Fig. 22 illustrates the protective clothing recommended for welding. Ears should also be protected from burns and particulate matter, for example by using ear plugs.

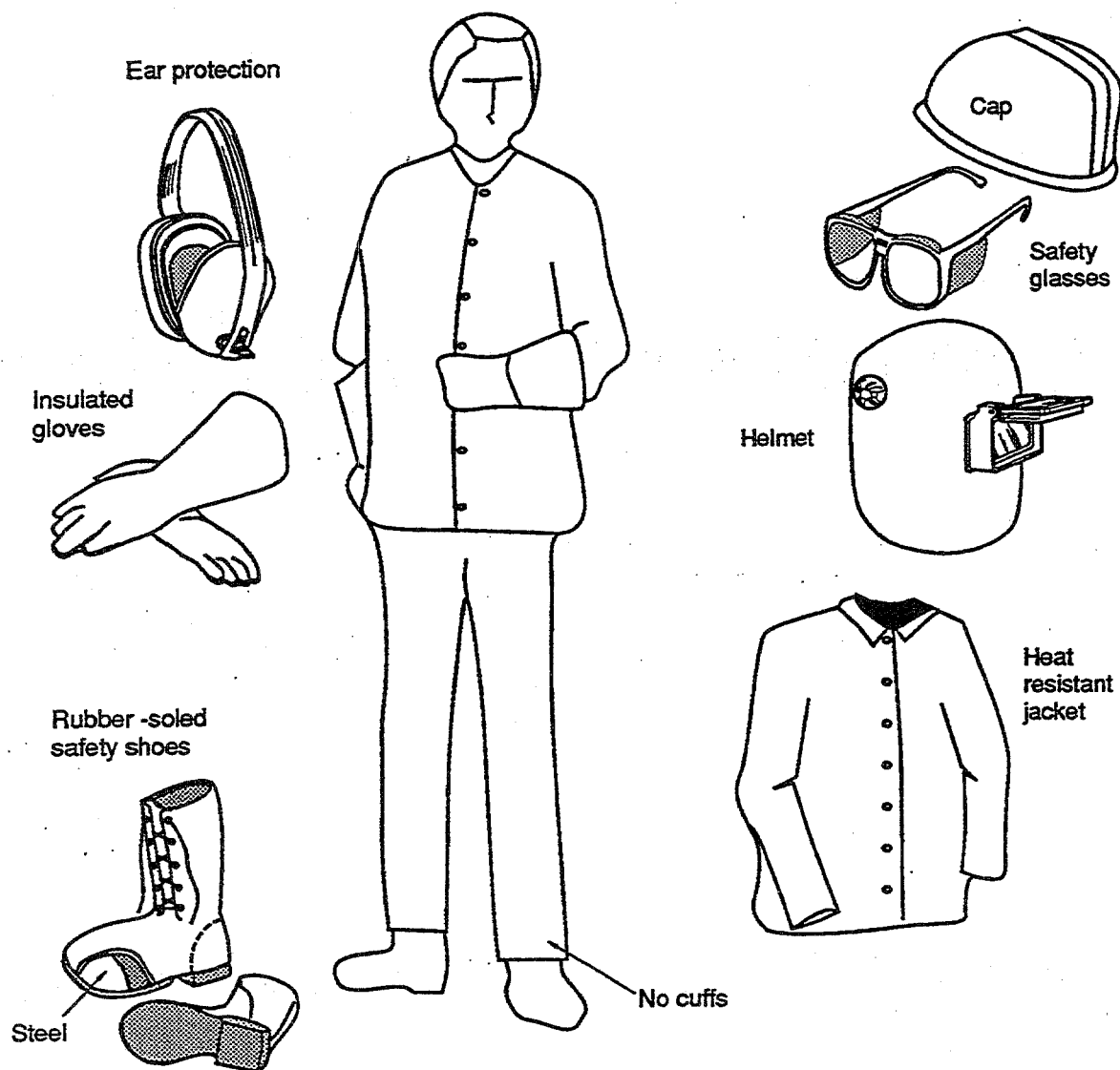


Fig. 22. Protective clothing for welding.

Fires

Hot metal, spatter, and the arc itself may present a risk of igniting a fire or causing an explosion if flammable material is nearby. Ensure that no containers of cleaning fluids or other flammable materials are near the welding station. If welding high up, remember that sparks and spatter can travel great distances and pose a hazard to other workers or

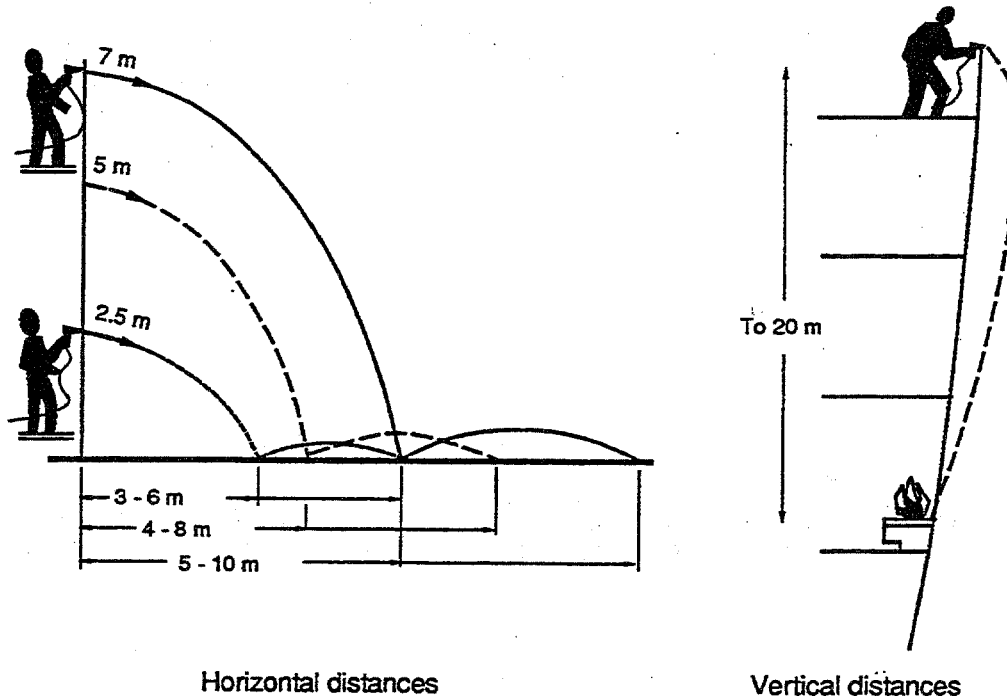


Fig. 23. Typical travel distances for hot metal particles in welding and cutting.

may cause a fire (Fig. 23). When welding you should always be alert to the possibility of fires. Fire extinguishers should be provided and you should know how to operate them. After welding, carefully check the area to ensure there are no smouldering fires, sparks, or hot metal that could ignite a fire. It is not uncommon for fires to ignite in a time period after the welding has been completed.

Fumes

The fume and smoke that is usually seen rising from a welding operation is composed of many tiny particles of solid material that came from the electrode, flux, or metal being welded (Fig. 24). The range of particle sizes is shown compared with other particulates in Fig. 25. The electrode is the greatest contributor. The fume particles will be mixed

Fig. 24. Sources of fumes in arc welding.

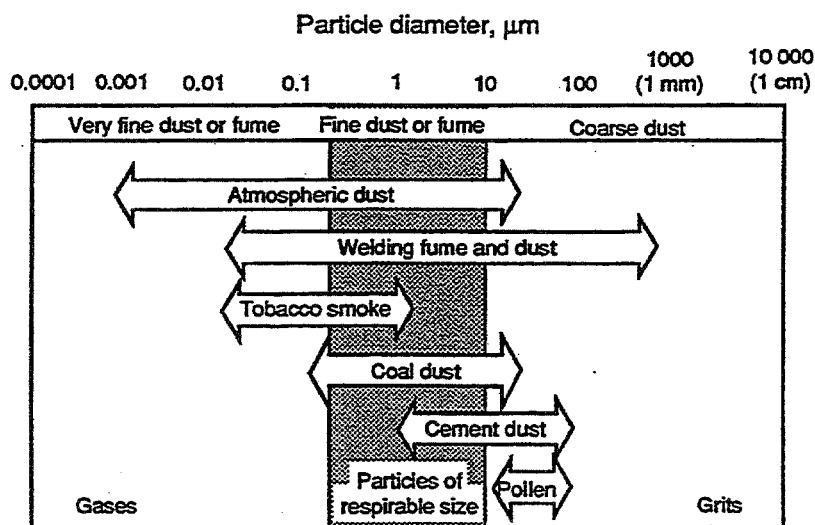
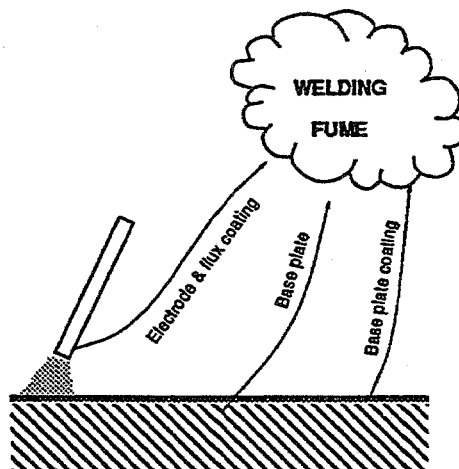


Fig. 25. Typical range of particle sizes for airborne particulates.

Fume components

with various gases. Breathing the fumes may present health hazards ranging from discomfort to long term illness depending on the amount of exposure and the constituents in the fume. Table 5 shows typical analyses of the constituents of welding fume from various types of electrodes. With common structural steels the major component of the fume is iron in the form of oxides, and other components have a

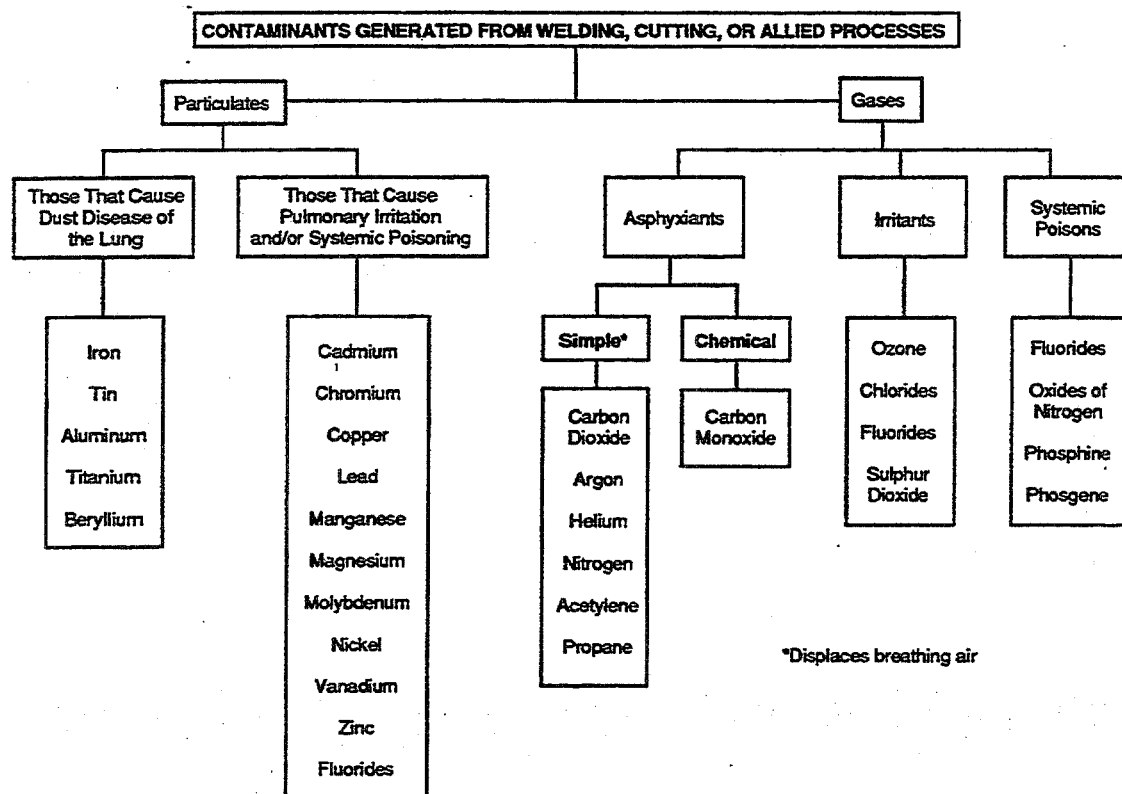
Table 5. Typical analysis of welding fume.

Electrode	Concentration, weight %									
	Fe	Mn	Si	Ni	Cu	Cr	Mo	Al	Mg	F
Carbon and low alloy steel										
E6010	47.5	3.0	5.7	—	—	—	—	—	—	—
E7018	26.1	4.5	<0.2	—	—	—	—	—	—	13.1
E7024	30.2	5.3	18.3	—	—	—	—	—	—	—
E8018C3	45.2	7.2	—	0.3	—	0.1	<0.1	—	—	35.8
E9018B3	21.9	5.9	—	0.1	—	1.6	<0.1	—	—	28.1
Stainless steel and high alloy										
E316-16	10.0	8.8	—	1.5	—	6.5	<0.1	—	—	17.2
E410-16	33.1	5.2	—	<0.1	—	—	—	—	—	—
ENiCu-2	0.1	2.1	—	4.2	6.2	—	—	—	—	—
Inconel 625	0.6	—	—	4.6	0.7	5.9	2.1	—	—	—

(From AWS study)

relatively low concentration. When welding other metals, stainless steel or non-ferrous alloys, other components can form a large proportion of the fume. Some alloy elements may produce particularly toxic components in the fume. For example, some copper alloys contain beryllium which is highly toxic. In addition, there may be toxic components that originate from the consumable that are not present in the base metal. It is therefore essential to know what you are welding and what consumable is being used, and to be sure that the procedures for avoiding exposure to the fume are adequate. The health effects of components found in welding fumes are summarized in Table 6.

Table 6. Summary of possible health effects from components in welding fumes.

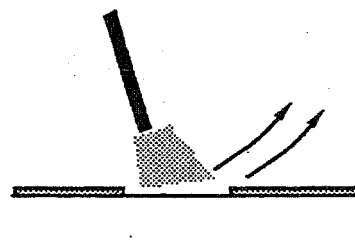


From AWS data

In addition to the metal and the electrode, fumes may be produced from coatings and residues on the metal (Fig. 26). Galvanized sheet, for example, has a coating of zinc which vaporizes when welded. Exposure to zinc fume can result in "zinc fever" or "metal fume fever". This is an acute reaction characterized by flu-like symptoms and chills from which the patient usually recovers in a few days.

Paint or other coatings can produce fumes with harmful components. Cadmium and lead, for example, could be released into the fume

Fig. 26. Coatings on metal may be a source of hazardous fumes.



when welding over certain types of coatings and paints. In these cases the coating should be removed from the weld area where possible to minimize the fume. This could also have a beneficial effect on weld quality by avoiding gases from the coating that could cause porosity in the weld metal.

Fume generation rate

The rate at which welding fume is produced is usually measured in terms of weight per unit time, e.g., g/min. and can be measured in a special fume cabinet such as the one shown in Fig. 27. The fume generation rate depends on many factors, the main ones being the type

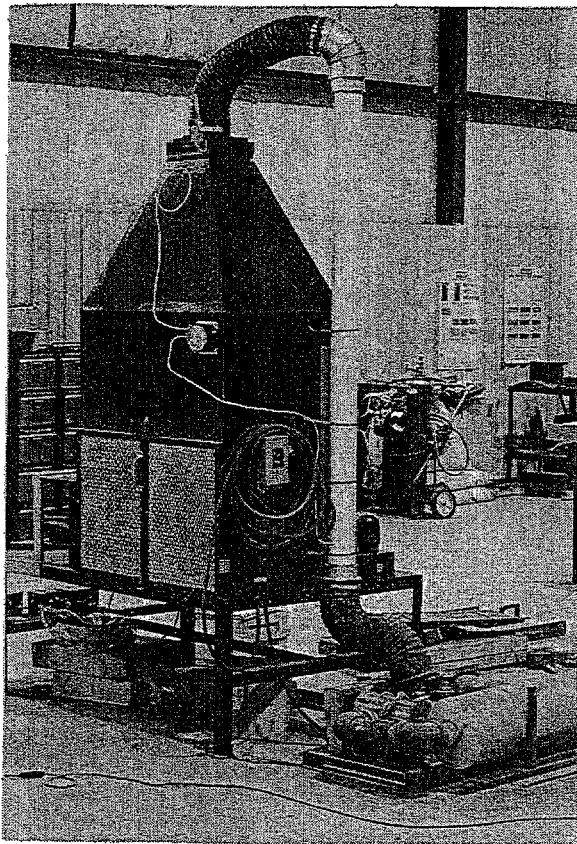


Fig. 27. Fume cabinet for measuring fume generation rates. Welding is carried out inside the cabinet and the atmosphere is exhausted by the pump. Fume is collected on a filter at the top of the cabinet.

of welding process, the consumable, and the current. The submerged arc welding process (SAW) produces very little fume because the arc is covered by granular flux. In contrast, high fume generation rates may be experienced with some shielded metal arc (SMAW) electrodes and flux cored arc welding systems (FCAW). Typical rates for various processes are shown in Table 7 and the effect of current level is shown in Fig. 28. Fig. 29 shows some typical results for the influence of electrode type on fume generation rates for shielded metal arc welding (SMAW).

Table 7. Typical fume generation rates for various processes.

Process	Typical range* (g/min)
SMAW	0.2 - 1.2
FCAW	1.0 - 3.5
GMAW (steel)	0.1 - 0.5
GMAW (aluminum)	0.1 - 1.5

*Actual values will depend on many factors including current and electrode type.

Although the fume generation rate measures the rate at which fume is produced and is useful for comparing processes, it cannot be used directly to determine the amount of fume that someone could be breathing. As the fume is produced it becomes dispersed and the

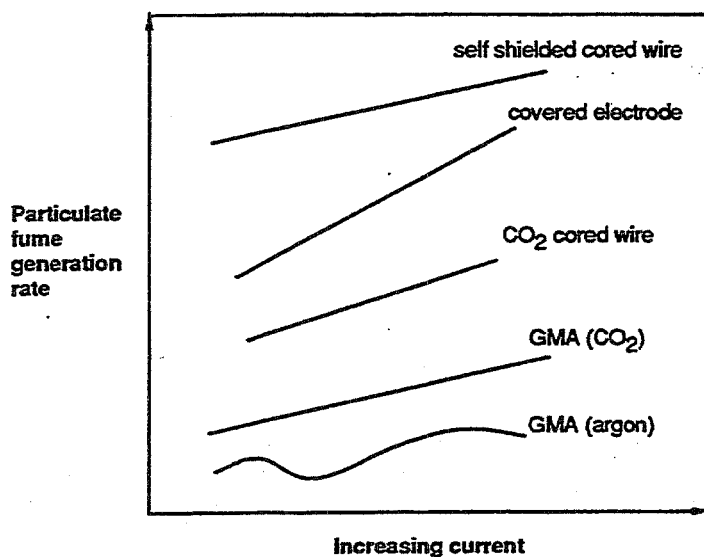
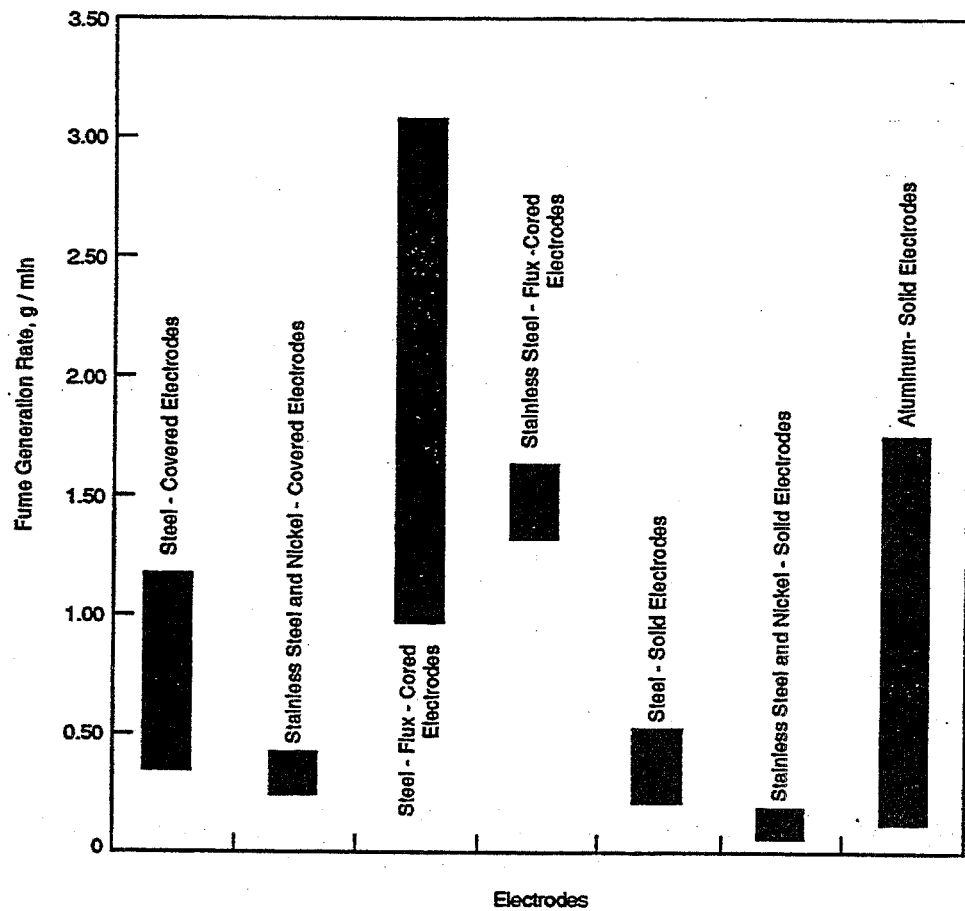


Fig. 28. Typical effect of current on fume generation rate.

Fig. 29. Typical effect of electrode types on fume generation rates.



Concentration

amount that is being breathed depends on the density of the fume cloud. Exposure to fume is therefore measured in terms of the airborne concentration of particulates (Fig. 30) in mg/m^3 or ppm (parts per million).

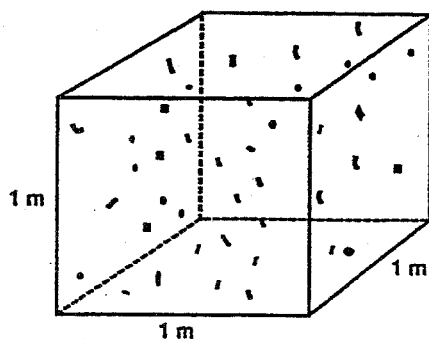


Fig. 30. Exposure to fume is determined by the concentration of fume in the air breathed by the welder. It is usually measured in mg/m^3 or in parts per million (ppm).

During the day the fume concentration will vary as illustrated in Fig. 31 and there are several ways in which the exposure can be characterized: the instantaneous value at any point in time; the average value for a short period (say 15 min); and the time weighted average over a longer period of several hours. The time weighted average (TWA) is

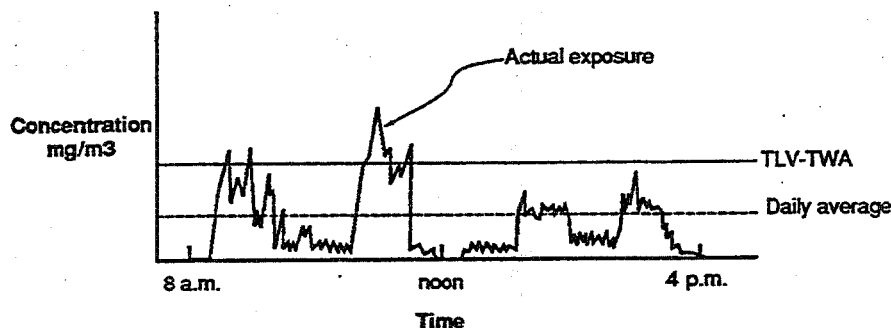


Fig. 31. Illustration of variation of fume concentration during a working day.

the value usually measured and used in determining compliance with limits. It can be determined by sampling air near the welder's breathing zone using small pumps and filter media which are weighed before and after the sampling period (Fig. 32).

Allowable exposure

Allowable levels of exposure to welding fume have been set by several bodies including the U.S. Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the American Conference of Governmental Industrial Hygienists (ACGIH). These allowable limits are recommendations and not necessarily legal limits. Jurisdictions may legislate maximum exposure levels which may or may not be similar to these values. The ACGIH publishes a list of Threshold Limit Values (TLV, which is a registered trade mark of ACGIH) which are guidelines for allowable exposures. The most widely used is the Threshold Limit Value - Time Weighted Average (TLV-TWA). This is the time weighted average concentration for a normal 8 hour work day and a 40 hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects. It is important to remember that the TLV is not a fine line between safe and dangerous

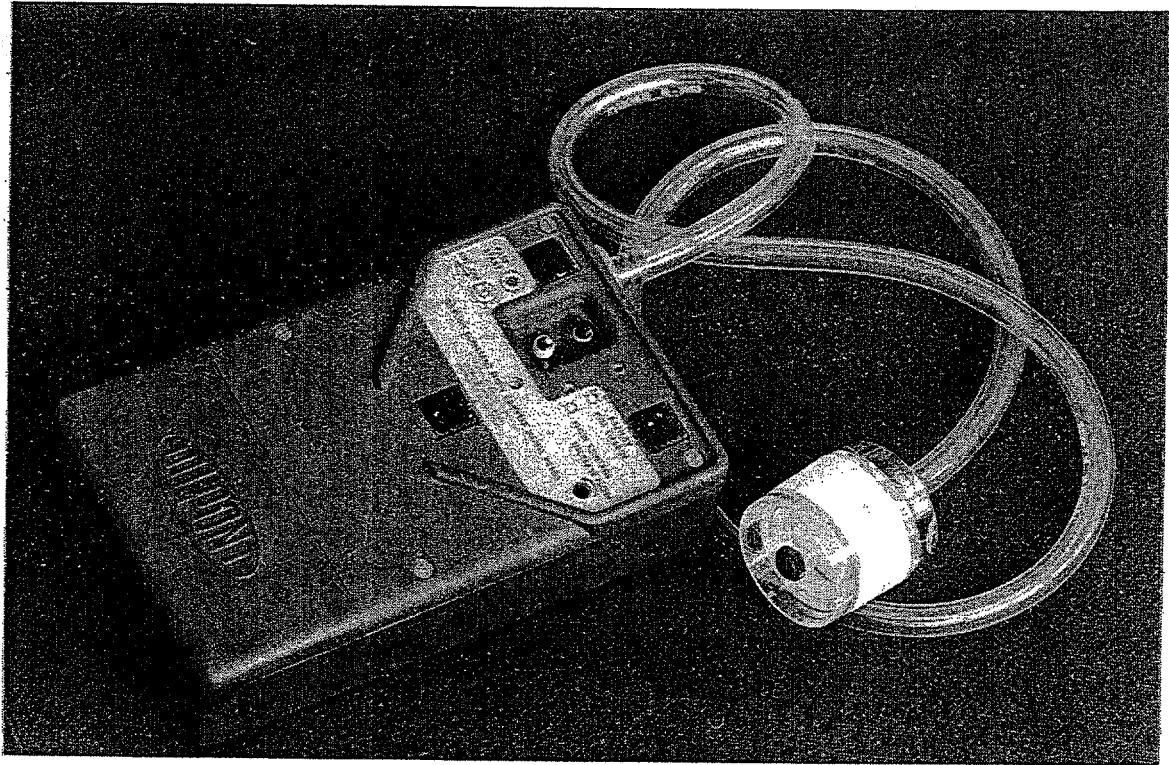
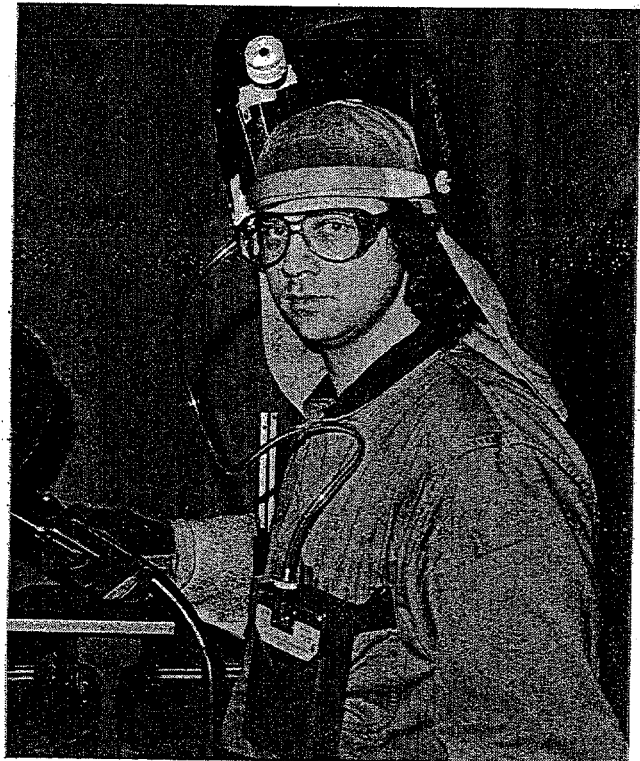


Fig. 32. Example of device (above) used for air sampling to determine exposure to welding fume. A constant flow pump draws air from the welder's breathing zone through a filter seen mounted in the helmet at right.



concentrations and should not be used by anyone untrained in the discipline of industrial hygiene.

Since the time weighted average allows a swing in the actual concentration, ACGIH also lists Short Term Exposure Limits (STEL) and Ceiling (C) values for many substances. The TLV-STEL is the concentration to which a worker can be exposed continuously (provided the TWA is not exceeded) for a short period of time without suffering from:

- irritation
- chronic or irreversible tissue damage
- narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency.

It is based on a 15 minute time weighted average which should not be exceeded at any time during the work day. Only four exposures per day at the STEL are allowed and a minimum of 60 minutes is required between exposures. The ceiling value (TLV-C) is the (instantaneous) concentration that should not be exceeded at any time during the work day, even for short exposures.

TLVs for a number of components that could be present in welding fume are given in Table 8. TLVs are given for welding fume as a total mixture as well as for individual components found in welding fume. In many cases where no toxic elements are present in the welding materials, the total fume TLV will be adequate to determine allowable exposure, but in some cases the concentration of the individual components may dictate the allowable exposure. As an approximate guide, for structural steels with alloying elements less than 5% and chromium content less than 3%, the total fume dictates allowable exposure, and the TLV of 5 mg/m³ is applicable. For steels with higher alloy contents, and particularly for stainless steels, the concentration of the individual components determine the TLV.

If it is assumed that the effects of individual components are additive (not independent and not synergistic) then the TLV for the mixture is:

$$\sum \frac{C_n}{T_n} < 1$$

where C_n is the concentration of the nth component and T_n its individual

TLVs for welding
fume

Table 8. TLVs for various fume components (from ACGIH 1994-95)

Substance	TWA mg/m ³
Welding fume not otherwise classified	5
Welding fume (aluminum)	5
Barium, soluble compounds, as Ba	0.5
Beryllium and compounds	0.002, A2
Cadmium oxide, total fume as Cd	0.01, A2
Cadmium oxide, respirable dust	0.002, A2
Calcium oxide	2
Carbon dioxide	9 000
Carbon monoxide	55
Chromium metal, Cr(II), Cr(III) compounds, as Cr	0.5, A4
Chromium (VI) compounds, water soluble, as Cr	0.05, A1
Chromium (VI) compounds, water insoluble, as Cr	0.01, A1
Copper fume	0.2
Fluorides, as F	2.5
Iron oxide fume, as Fe	5
Magnesium oxide fume	10
Manganese, dust and compounds, as Mn	5*
Manganese, fume	1*
Nickel, soluble compounds, as Ni	0.1*
Nitrogen dioxide	6
Ozone	0.2 (Ceiling)
Phosgene (carbonyl chloride)	0.4
Phosphine (hydrogen phosphide)	0.4
Silica, fused, respirable dust	0.1
Titanium dioxide	10
Zinc oxide, fume	5

Notes: TLV's are reviewed every year. Refer to the current ACGIH Threshold Limit Values publication for current values.

A1 Confirmed Human Carcinogen

A2 Suspected Human Carcinogen

A4 Not classifiable as a Human Carcinogen

** Indicates that a proposed change to the TLV has been made but is as yet unadopted. Refer to current TLV publication to see if the value has changed.*

TLV. In applying this to welding fume it is clear that the fume must be quantitatively analysed to determine the components. The sidebar on the next page shows the application of this formula to fume from two types of electrodes.

Total fume or individual components?

Suppose an E7018 electrode and an E316-16 stainless steel electrode both produce a total fume concentration of 5 mg/m³. Does the total fume concentration or the individual components dictate the exposure? A typical analysis of the fume might give the following values:

	TLV mg/m ³	E7018 electrode		E316-16 electrode	
		% component	concentration mg/m ³	% component	concentration mg/m ³
Fe	5	29	1.45	10	0.5
Mn	1	4	0.2	9	0.45
Ni	0.1	-	-	1.5	0.075
Cr	0.05	-	-	6.5	0.325
F	2.5	14	0.7	17	0.85

Mild steel: $\Sigma C_n/T_n = 1.45/5 + 0.2/1 + 0.7/2.5 = 0.77 < 1$

Stainless steel: $\Sigma C_n/T_n = 0.5/5 + 0.45/1 + 0.075/0.1 + 0.325/0.05 + 0.85/2.5 = 8.14 > 1$

Since the sum C_n/T_n is less than one for the mild steel electrode, the total fume concentration determines the exposure and the appropriate TLV is 5 mg/m³.

For the stainless steel electrode the sum C_n/T_n greatly exceeds one, and so the TLV is exceeded based on the individual components. In this case the total fume TLV of 5 mg/m³ is not appropriate.

If a component with a low TLV is present in welding fume the point at which the total fume concentration no longer controls exposure is given approximately by:

$$\frac{\% \text{ of component } x \text{ in fume}}{\text{TLV of component } x} > 20$$

For example, hexavalent Cr has TLV = 0.05 mg/m³ so the total fume concentration would only control exposure when

$$\%Cr < 20 \times 0.05 < 1\%$$

Only the TLV-TWA (time weighted average) is given for total welding fume and therefore there is no short term exposure limit (STEL) recommended. If, however, the individual fume components dictate the exposure then STELs as well as TWAs might apply. Clearly the application of TLVs to welding fume in which individual components control exposure limits can be very complex. To simplify this and to minimize expensive chemical analyses, attempts have been made to establish total fume exposure limits for specific processes and materials where the total fume limit is adjusted to take account of the likely differences in fume composition. As an example, those proposed in Denmark are shown in Table 9.

Table 9. Proposed process dependent exposure limits for total fume.

Process	Metal	Exposure limit mg/m ³
SMAW	MS	3.4
GMAW	MS	3.1
Oxyfuel cutting	MS	2.8
GTAW	SS	2.7
SMAW	SS	1.6

Control of exposure to welding fume.

The first approach in controlling fume is to limit the amount of fume produced at source. This may not always be possible but careful selection of the welding process and materials may help to minimize the amount of fume generated. A second approach is to reduce the exposure to the fume by removing it and a third by protecting the welder. Because welding can involve so many different conditions there is no single means of controlling fume exposure. Rather, a control strategy must be devised for each case. Some general guidelines, however, have been developed and these are published in standards such as CSA W117.2 "Safety in Welding, Cutting, and Allied Processes." Tables 10 and 11 summarize these.

Useful guidance is also provided in the "Fume Information Sheets for Welders" published by the International Institute of Welding (IIW) based on sheets proposed by the Technical Advisory Group on Health and Safety in Welding of Ontario Hydro. Examples of these for low alloy steel, stainless, and aluminum consumables are shown in the side bars on pages 42 to 45.

Table 10. Summary of guidelines for control of fume exposure (steel).

Ventilation Guidelines for Welding of Uncoated Low-Carbon Steels (1)					
Process	Production level (2)	Degree of confinement in work area (3)			
		Out door (4)	Open work space	Limited work space	Confined space
Gas preheating	Normal	N	N or M	M	LE
Gas welding	High	N	LE	LE	LE
Gas tungsten arc welding (GTAW)					
Brazing and soldering		N	N or M	M	LE
Flame cutting					
Flame gouging	Normal	N	N or M	M	LE
Gas metal arc welding (GMAW)	Normal	N	N or M	LE	M & LE
	High	N	LE	LE	M & LE
Flux-cored arc welding (FCAW)	Normal	N	N or M	LE	M & LE
	High	N	LE	LE	M & LE
Shielded metal arc welding (SMAW)					
Plasma arc cutting (Assessment by air sampling is often needed in limited or confined spaces)	Normal	N	LE	LE	LE
	High	N	LE or water table	LE or water table	LE & PRP
Submerged arc welding (SAW)	Normal	N	N	N	M
	High	N	N	N	M
Electroslag welding					
Electrogas welding					
Thermit welding	Normal	N	M	LE	LE
Air carbon arc gouging	High	N	LE	LE & PRP	LE & PRP
Resistance welding	Normal	N	N	M	LE
	High	N	M	M	LE

Notes:

(1) N—natural ventilation, See Clause 10.1. (CSA W117.2-94)

M—mechanical ventilation, see Clauses 10.2, 10.3.

LE—local exhaust ventilation, see Clause 10.4.

PRP—personal respiratory protection, see Clause 9.4.

(2) High production refers to duty cycles exceeding approximately 40% or high amperage processes exceeding 350 A, or both.

(3) Degree of confinement is defined as follows:

Open—large work area without obstructions

—open to outdoors and wind

—fume is free to escape

Limited—a work area that does not fit the definition of open

—fume is hindered from escaping

—an open area may become limited when doors and windows are closed during cold weather

Confined—inside small compartments entered through manholes, e.g., tank, chamber, boiler pressure vessel

—fume cannot escape

(4) Where mechanical ventilation is recommended for welding outdoors, a fan may be used to disperse fumes before they enter the breathing zone as long as the fumes are not contaminating an adjacent work area.

Table 11. Summary of guidelines for control of fume exposure (nonferrous).

Ventilation Guidelines for Welding of Nonferrous Materials (1)							
Material	Contaminant (4)	Production level (2), (5)	Degree of confinement in work area (3)				Recirculation of exhaust air (8)
			Out door (6)	Open work space	Limited work space	Confined space	
Aluminum	Aluminum oxides, ozone	Normal	N	M	LE	LE	—
		High (GTAW)	—	M	M	LE	—
		High (GMAW)	—	M	M & LE	LE & PRP	No
Barium	Barium oxides and fume	Normal (FCAW)	LE or PRP	LE	LE	LE & PRP	No
Beryllium	Beryllium oxides and fume	Any	All locations LE & PRP or special glove box.				No
Cadmium	Cadmium oxide	Any	LE or PRP	LE	LE & PRP or special glove box		No
Chromium	Chromium VI oxide	Normal	M	LE	LE	LE & PRP	No
		High	LE or PRP	LE	LE	LE & PRP	No
		High (SAW)	—	N	M	LE	No
Copper	Copper oxides	Normal	M	M	LE	LE & PRP	—
		High	LE or PRP	LE	LE	LE & PRP	No
Fluorine	Fluorides (of calcium, sodium, potassium)	Normal	N	N	M	LE	Yes
		High	—	M	LE	LE	Yes
		High (SAW)	—	N	N	LE	Yes
Lead	Lead fumes	Normal	M	M	LE	LE & PRP	No
		High	LE or PRP	LE	LE	LE & PRP	No
Manganese	Manganese oxides	Any	N	M	LE	LE & PRP	—
Nickel (7)	Nickel fumes	Normal	M	LE	LE	LE & PRP	No
		High	LE or PRP	LE	LE	LE & PRP	No
		High (SAW)	—	N	N	LE & PRP	No
Zinc	Zinc oxide	Any	N	M	LE	LE	Yes

Notes:

(1) N—natural ventilation, See Clause 10.1.

M—mechanical ventilation, see Clauses 10.2, 10.3.

LE—local exhaust ventilation, see Clause 10.4.

PRP—personal respiratory protection, see Clause 9.4.

(2) Unless otherwise specified, all processes are included. High production refers to duty cycles exceeding approximately 40% or high amperage processes exceeding 350 A, or both.

(3) Degree of confinement is defined as follows:

Open—large work area without obstructions

—open to outdoors and wind

—fumes are free to escape

Limited—a work area that does not fit the definition of open

—fume is hindered from escaping

—an open area may become limited when doors and windows are closed during cold weather

Confined—inside small compartments entered through manholes, e.g., tank, chamber, boiler pressure vessel

fume cannot escape

(4) For more detail on the origin of these contaminants, refer to Clause 4.

(5) SMAW—shielded metal arc welding

GMAW—gas metal arc welding (MIG)

GTAW—Gas tungsten arc welding (TIG)

FCAW—Flux-cored arc welding

SAW—submerged arc welding

(6) Where mechanical ventilation is recommended for welding outdoors, a fan may be used to disperse fumes before they enter the breathing zone as long as the fumes are not contaminating an adjacent work area.

(7) When nickel and chromium occur together (e.g. stainless steel), ventilate for chromium.

(8) See Clause 10.4.

Fume Data Sheet for

LOW ALLOY STEEL WELDING

CONSUMABLES

(Steel alloys having a total chromium, manganese, copper and nickel content less than 10%—typical welding electrode designations include E8018-C2, E9018-B3)

POTENTIAL HEALTH HAZARDS

PRECAUTIONS

1

The welding of low alloy steels produces fumes containing relatively low concentrations of toxic metals such as chromium and nickel. Prolonged or repeated exposure to fume may produce respiratory irritation and cough.

See page 45 for general precautionary measures for fume control.

2

Excessive fume levels can be generated in low alloy steel welding, particularly for flux cored arc welding (FCAW) and for shielded metal arc welding (SMAW) at high current levels (for example with large diameter (3/16") electrodes).

Use local exhaust equipment when welding in an open shop or similar work area with the flux cored arc process or when using large diameter electrodes and high current with the shielded metal arc process.

3

Certain self-shielded FCAW electrodes contain barium compounds, which can produce high concentrations of this toxic agent in the welding fume. Symptoms of overexposure may include chest and stomach pain, cough, headache, and muscle tremor or twitch.

Use local exhaust equipment or respiratory protection when barium-containing self-shielded flux cored arc welding electrodes are involved. Follow manufacturer's instructions on proper use of these electrodes.

(Based on the sheets from the Technical Advisory Group on Health and Safety in Welding of Ontario Hydro and IIW)

Fume Data Sheet for

ALUMINUM WELDING

CONSUMABLES

POTENTIAL HEALTH HAZARDS

PRECAUTIONS

1

The gas metal arc welding (GMAW) of aluminum with magnesium (Mg) bearing wire (for example, ER5356) generates large volumes of welding fume, although no specific toxic agents are present in the fume. Much less ozone is generated than with silicon (Si) bearing wire.

Use local exhaust equipment in an open shop or similar work area when welding aluminum with the GMAW process and magnesium-bearing filler wire.

2

Aluminum GMAW with silicon (Si) bearing wire (for example, ER4043) can generate high levels of ozone gas. Ozone can cause severe irritation of the nose, throat and eyes as well as chest congestion and pain.

Avoid use of silicon-bearing aluminum welding wire when the GMAW process is employed. If this is unavoidable, ensure fumes are removed from the work area by mechanical or natural ventilation. The use of an air-supplied respirator or hood is required when welding in confined spaces or poorly ventilated areas.

Unlike welding fumes, ozone can be generated away from the arc, by the action of arc radiation on the surrounding air.

Apply similar precautions to other personnel working in the immediate area.

3

The gas tungsten arc welding (GTAW) of aluminum produces relatively low levels of ozone and fume. Filler wire composition has no influence on the amount of ozone or fume generated in GTA welding of aluminum.

No special precautions are required when welding aluminum with the GTAW process.

Fume Data Sheet for

STAINLESS STEEL WELDING

CONSUMABLES

POTENTIAL HEALTH HAZARDS

1

The welding of stainless steels produces fumes containing toxic metals, particularly chromium and, to a lesser extent, nickel. Symptoms of overexposure include nosebleed and respiratory tract irritation.

Certain chromium compounds (hexavalent chromium or chrome 6) are suspected of being cancer-causing agents. The fumes from shielded metal arc (SMAW) and flux cored arc (FCAW) stainless steel welding consumables contain chrome 6 compounds. However, the hazardous nature of these fumes has not been established.

2

The gas metal arc welding (GMAW) of stainless steels generally produces less fume than SMAW or FCAW, but this fume is somewhat richer in chromium and nickel. However, hexavalent chromium compounds are not found in GMAW fume.

GMAW of stainless steel can produce elevated levels of ozone gas, also a respiratory irritant.

3

The gas tungsten arc welding (GTAW) of stainless steels produces relatively low levels of fume or ozone.

PRECAUTIONS

Special precautions are required when welding stainless steels, particularly by the SMAW or FCAW processes. Proper implementation of these precautionary measures will minimize the potential health risk.

Every effort should be made to position the welder's head away from the fume plume. If general ventilation conditions do not carry fumes away from personnel, use local exhaust equipment or respiratory protection.

In confined spaces or poorly ventilated areas, both local exhaust and respiratory protection are required when welding stainless steel with the SMAW or FCAW processes.

If general ventilation conditions do not carry fumes away from personnel, use local exhaust equipment or respiratory protection.

If ozone appears to be a problem, use an air-supplied respirator or hood.

No special precautions are required for GTAW of stainless steel outdoors or in well ventilated areas. Use local exhaust equipment or a metal fume respirator in confined spaces or poorly ventilated areas.

General Health Hazards Associated with Welding Fumes

NOTE: Under most conditions, welding fumes are not toxic, particularly in situations of short or intermittent exposure of the welder or operator. However, under certain conditions, hazardous concentrations of welding fumes can be encountered. The following lists precautionary measures to be taken when welding in general. Specific hazards and appropriate precautionary measures are given in the preceding pages.

POTENTIAL HEALTH HAZARDS

PRECAUTIONS

1

The hazardous effect of welding fumes depends on the fume generation rate (or the amount of fume produced in a unit of time), the number of welding arcs, the fume composition, and the working conditions or environment. References to specific hazards are found in the preceding pages.

It should be recognized that although the fume generation rate of gas metal arc welding may be less than for other welding processes, the concentration of toxic agents in the fume can be substantially higher.

Welding outdoors or in a well ventilated area requires no special fume removal measures. However, the welder or welding operator should attempt to position himself such that the smoke plume from the arc does not enter his breathing zone.

Use local exhaust equipment or respiratory protection when welding in confined spaces or poorly ventilated areas with the shielded metal arc, gas metal arc, or flux cored arc processes.*

It is good practice to use local exhaust equipment when welding in a shop or similar work area.

2

The welding fume generation rate with shielded metal arc welding increases as the welding current or amperage increases. Unacceptable levels of fume may be encountered when welding at the upper current level for a particular electrode.

Maintain welding current around the middle of the recommended current range for a given electrode. Higher deposition rates and greater heat input can be achieved by using a larger electrode (at the mid-amperage range) without a significant increase in fume generation — ie. the fume generation rate of 1/8 inch diameter electrode being used at a high amperage level is greater than that of a 5/32 inch diameter electrode being used at the mid-amperage level.

3

Painted or plated surfaces, or coatings of zinc or copper may release toxic emissions upon heating with a welding arc.

Remove painted or plated coatings near the weld area by grinding or other means prior to welding.

4

Arc welding near chlorinated solvents may produce toxic emissions when the solvent or the vapours of the solvent are exposed to the ultra-violet light of the welding arc.

Do not conduct cleaning or degreasing operations at the same time as welding in a given work area. Store chlorinated solvents in closed containers away from the welding area. Remove all solvent residue from any components to be welded.

Emergency

If illness occurs due to fume inhalation:

- Move to fresh air
- Get medical attention if symptoms persist.

* Respiratory Protection

Respiratory protection can be provided in several ways. These include, in order of increasing protection factor:

- 1 - Metal fume or dust (cartridge type) respirator
- 2 - Filtered air supplied helmet
- 3 - Breathing quality air supplied respirator or hood.

Work habits

Since fume forms a visible plume which rises from the welding zone, an obvious practice is to keep the head and breathing zone out of the plume (Fig. 33). This reduces the exposure of the welder to the fumes, but it does not remove the fumes and they could build up, particularly if welding in a confined space.

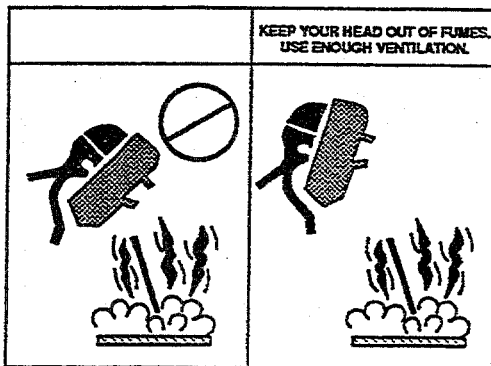


Fig. 33. To reduce exposure to fume keep your head out of the fume plume.

General ventilation

General ventilation of the welding area may provide enough air movement to dilute the fume concentration to acceptable levels. General, or dilution ventilation, may be natural or mechanical. For natural ventilation advantage can be taken of open windows and so forth to reduce the fume concentration (Fig. 34). For welding outside it cannot always be assumed that natural ventilation is adequate. There are many outdoor situations where welding is confined and fume build-up can occur.

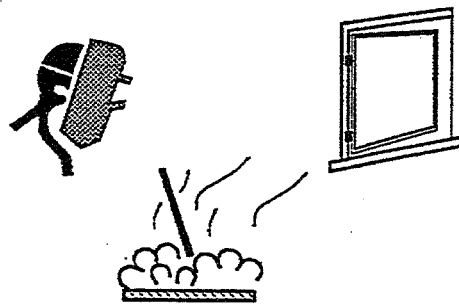


Fig. 34. Take advantage of natural ventilation.

Mechanical ventilation may involve simply using portable fans near the welding station or a more sophisticated system. The amount of air exchange required depends on many factors but a value of 2,000 cubic feet per minute per welder has typically been used as a rough guide. An example of an arrangement for mechanical general ventilation is shown in Fig. 35.

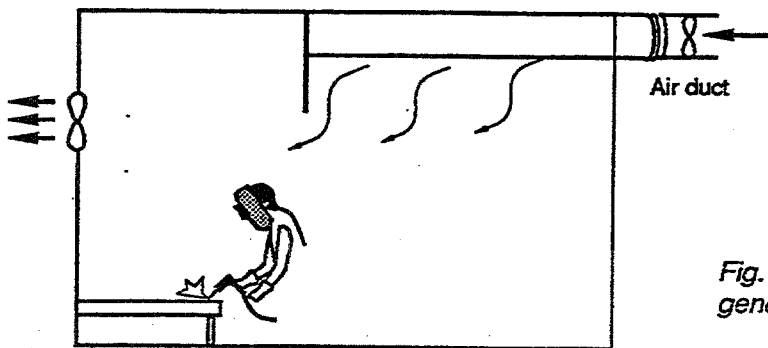


Fig. 35. Example of arrangement for general ventilation.

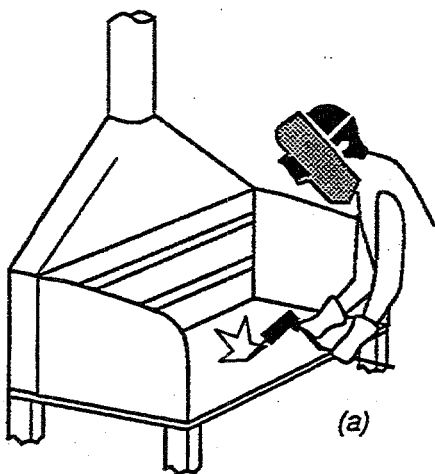
Local exhaust

Local exhaust involves capturing the fume at source and is preferred to dilution ventilation because the plume does not rise up past the welder's breathing zone. There are three types of local exhaust systems:

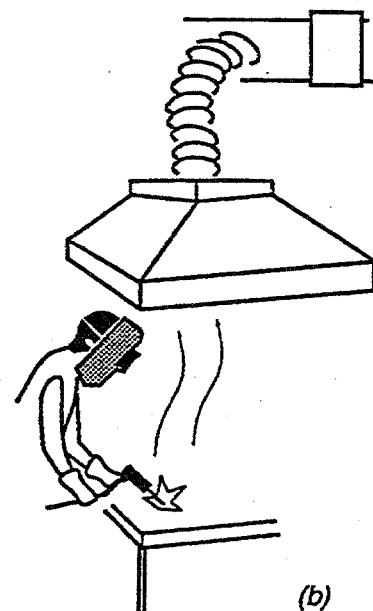
- A fixed extraction system built into the welding bench
- A portable hood with flexible ducting
- Fume extracting guns or attachments.

Fig. 36(a) shows a built-in system and Fig. 36(b) an intermediate system that is neither local exhaust nor general ventilation. These systems are only suitable for welding small components that can be brought to the bench.

In order to capture fume the air velocity across the arc should be about 0.5 m/s (100 ft/min). Very high air velocities may disrupt the arc shielding and cause poor weld quality.



(a)



(b)

Fig. 36. Fume extraction systems. (a) shows a welding bench with built-in extraction system. (b) shows a fixed hood over the bench.

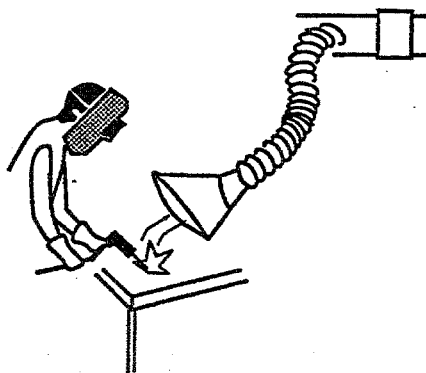


Fig. 37. Hood with flexible duct connected to permanent installation.

Portable units

A wide range of flexible hood systems are available. Some connect to permanent duct installations that exhaust to the outside of the building (Fig. 37) and others are portable units containing filters and recirculate the air (Fig. 38).

Local exhaust systems, however, must be operated correctly—particularly the placement of the hood—if they are to be effective. Fig. 39 shows the effect of hood placement on fume capture.

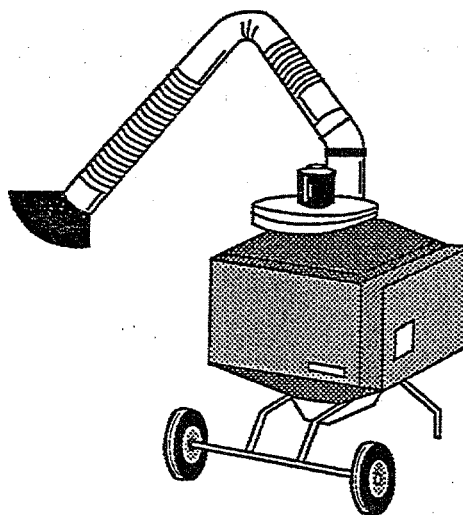


Fig. 38. Portable unit that recirculates filtered air.

Personal protection devices

A typical fume extractor gun is illustrated in Fig. 40.

In some situations ventilation and exhaust will not be enough to control exposure or may not be practical. Under these circumstances personal protection devices such as masks and respirators may be necessary. The selection and use of respirators is covered by CSA Standard Z94.4, but expert advice will generally be required, and a proper management and administration system should be in place.

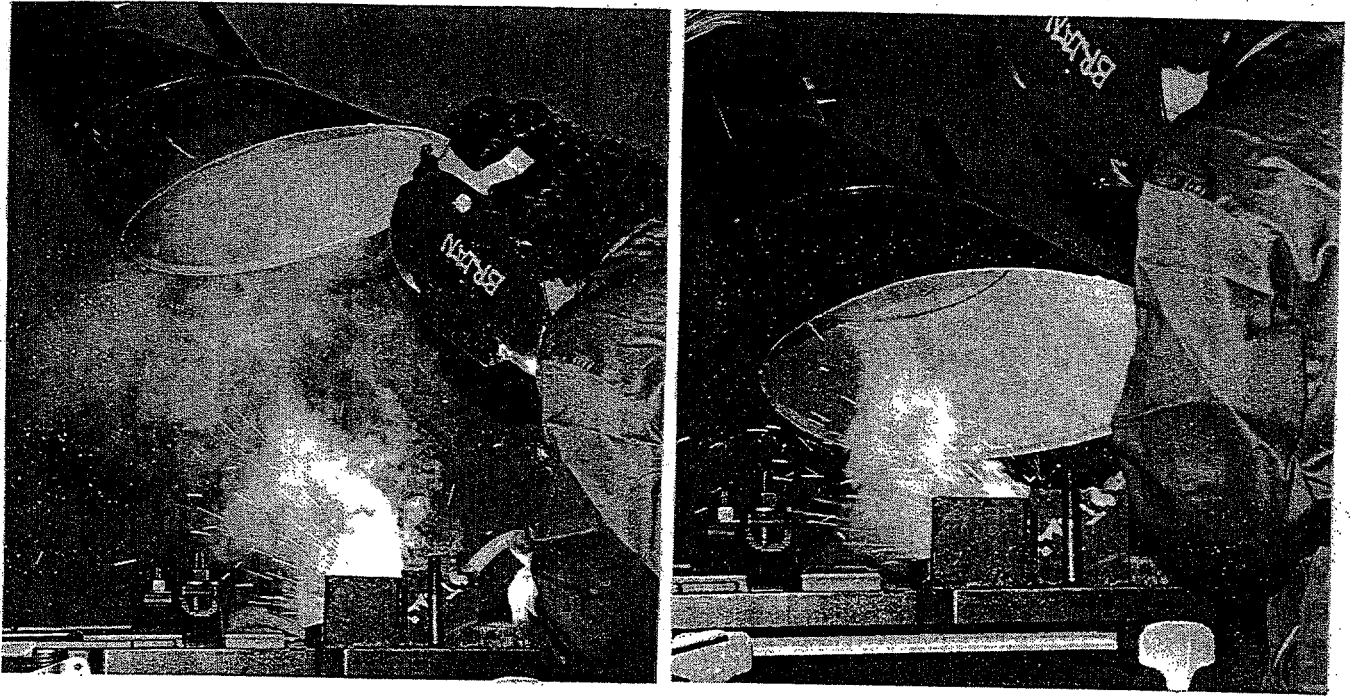


Fig. 39. In the (left) picture the hood is placed too far from the welding zone and does not effectively capture the fume. In the other picture the hood is correctly placed.

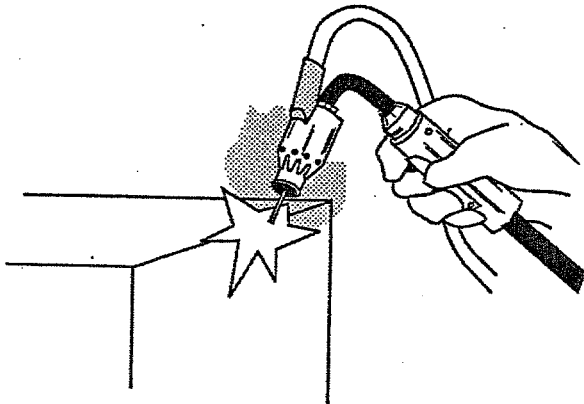


Fig. 40. Fume extracting welding gun.

For many routine situations a simple facepiece respirator mask (Fig. 41) will provide adequate protection. This consists of a mask covering half the face with a replaceable filter that removes particulate matter such as fumes and dust. To be effective there must be a good seal around the rim, and beards and moustaches should not be worn. These masks do not provide additional air nor do the mechanical filters remove gases. Thus

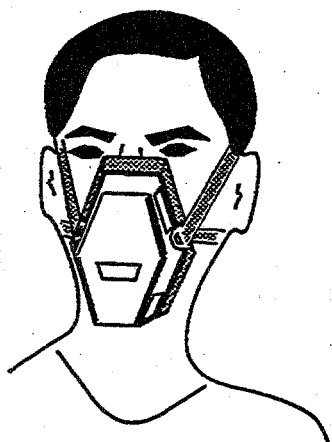


Fig. 41. Common type of facepiece respirator half-face mask containing a replaceable filter.

they do not offer any protection if the atmosphere is low in oxygen or contains hazardous gases. Disposable, single-use dust masks may give limited protection from welding fume but they are not generally recommended, particularly when the fume has toxic components.

Respirators

A variety of respirators providing air from a remote source are available. These include the hose mask respirator comprising a mask connected to a hose which may have a blower to assist the flow of air and the air line respirator which contains a control valve to control the flow of air to the breathing zone (Fig. 42). None of these devices should be relied upon where the atmosphere is above the "immediately dangerous to life or health" (IDLH) level. For extreme conditions various types of self-contained breathing apparatus (SCBA) are available.

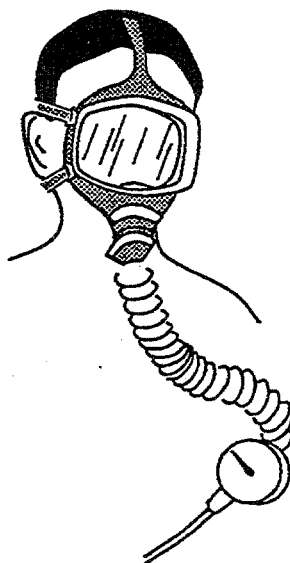


Fig. 42. A supplied air respirator. A control valve controls the air flow to the face mask.

Gases

There are two classes of gases that are of interest: those used for welding, cutting, and shielding; and those produced during the welding or cutting process. Health and Safety aspects of gases for cutting and handling of cylinders are discussed in a separate section while aspects of exposure to gases are discussed here. Table 12 lists a number of important gases used or produced during welding. It is important to use the correct name for each gas. Do not call oxygen, "air," for example.

Table 12. Important gases used or produced in welding.

Gases used	Gases produced
oxygen	ozone
<i>Fuel gases</i>	nitrogen dioxide
acetylene	carbon monoxide
natural gas	carbon dioxide
hydrogen	hydrogen chloride
propane	phosgene
butane	
<i>Shielding gases</i>	
argon	
helium	
carbon dioxide	
nitrogen	

Hazards from gases

The main hazards from gases are: asphyxiation, fire or explosions, and toxicity (Table 13). Some of the gases are relatively harmless in small quantities (carbon dioxide for example) but in large quantities may dilute the oxygen in the air enough to cause suffocation (asphyxiation). Air is a mixture of roughly 21% oxygen and 79% nitrogen with very small quantities of a few other gases. We need at least 18% oxygen in the air to breathe properly. Breathing air with less than 18% oxygen can cause dizziness, unconsciousness, or even death if the oxygen content drops low enough. Some authorities specify 19.5% as the minimum acceptable oxygen content. Oxygen contents above the normal 21% present a danger of over supply as well as increasing the risk of fire and explosions.

Shielding gases such as carbon dioxide, helium, and argon freely enter the air after performing their function as a shield around the arc, and other gases may enter the air from leaks. As gases build up they

Table 13. Hazards and health effects of gases.

Gas	Effect
Ozone	Irritation of nose, throat, lungs Excess mucous secretion, coughing.
Nitrogen oxides	Delayed irritation and toxic effect on upper respiratory tract Excess fluid in lungs.
Carbon monoxide	Oxygen deficiency Drowsiness, headache, nausea Fatal oxygen starvation.
Carbon dioxide	Oxygen deficiency Asphyxiation.
Hydrogen chloride	Delayed irritation and toxic effect on upper respiratory tract Excess fluid in lungs.
Phosgene	Delayed irritation and toxic effect on upper respiratory tract Excess fluid in lungs.
Argon	Asphyxiation
Helium	Asphyxiation
Nitrogen	Asphyxiation
Hydrogen	Explosion, fire, asphyxiation
Fuel gases	Explosion, fire, asphyxiation

Precautions with shielding gases

displace the air. Precautions must be taken to ensure the air being breathed does not become low in oxygen. Some points to note are:

- Argon is heavier than air and will tend to sink. It will tend to accumulate in the lower portion of a confined space (Fig. 43).
- Helium is lighter than air with a tendency to rise. It will collect in the upper portion of a confined space.
- Do not bring shielding gas cylinders into a confined space for welding.
- Ensure that adequate ventilation is provided.

Some gases produced during welding are highly toxic with low TLVs. These must be considered along with the fume in determining precautions to take to ensure exposure is acceptable.

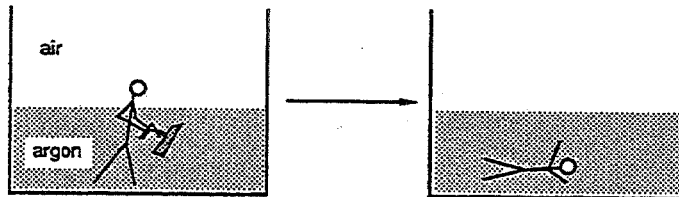
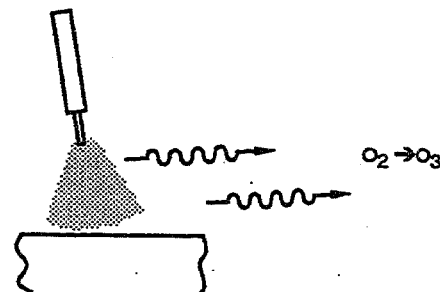


Fig. 43. Argon is heavier than air and could collect in the lower portion of a confined space displacing the air.

Ozone

Ozone is formed by the interaction of ultraviolet light, emitted from the arc, with oxygen in the air (Fig. 44). It has a pungent smell and is a respiratory irritant. Exposure can produce headaches, chest pain, shortage of breath and in high doses can produce pulmonary edema (fluid in the lungs) or death. Although the pungent smell is very noticeable on first exposure to ozone, continued exposure deadens the sense of smell so that the welder may be unaware of the extent of exposure.

Fig. 44. Ozone is formed from the action of ultraviolet light on oxygen.



TLV for ozone

The TLV-TWA for ozone is currently 0.1 ppm with a STEL of 0.3 ppm, but it is intended to make the value of 0.1 ppm a ceiling limit. This TLV (0.1 ppm or 0.2 mg/m³) is quite low and may easily be exceeded even though the total fume concentration is below the TLV of 5 mg/m³. Ozone may also be difficult to control because it can form well away from the arc. It does, however, naturally decompose back to oxygen when welding stops. Some of the factors which promote ozone formation are shown in Table 14 and Fig. 45 shows schematically the effect of voltage. Ozone is most likely to be a problem with gas metal arc welding (GMAW) of aluminum, particularly the 4043 aluminum-silicon filler alloy, but significant levels of ozone may be encountered

Table 14. Factors influencing ozone formation.

Factor	Worst case
Base plate Alloying elements Welding process Current Voltage Shielding gas	Aluminum Silicon (in 4043 Al) GMAW High current High voltage—long arc Argon

when welding stainless steel. Ozone is not usually a major problem in welding structural steels when total fume concentrations are below the 5 mg/m³ TLV.

Control of ozone

Because ozone can form remote from the arc area, local extraction may not be effective. A cross draft can be beneficial provided the gas shield is not disturbed and no workers are positioned downstream of the contaminated air flow. It may be possible to control ozone by changing the consumable or the welding procedure. If it is possible to substitute 5356 aluminum filler alloy for 4043 a significant reduction in ozone could be achieved. Helium shielding gas produces less ozone than argon and lower welding current is beneficial. These measures, however, are often not practical and good ventilation and personal respiratory devices (supplemental fresh air) might be needed. Ozone potential can also be reduced by minimizing reflected ultraviolet light and in automatic welding by surrounding the arc with glass or plastic to absorb ultraviolet radiation.

Other gases

A number of other potentially hazardous gases can be produced in welding. When carbon dioxide is used as a shielding gas, reaction with the hot metal can produce carbon monoxide. Nitrogen oxides may also be produced from the high temperature reaction of oxygen and nitrogen in the air around the arc. Adequate ventilation is required to keep the exposure to such gases down to permissible levels.

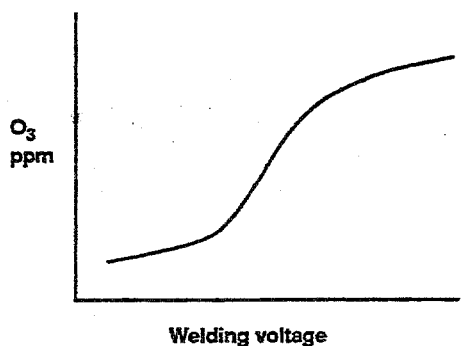


Fig. 45. Effect of arc voltage on the formation of ozone.

Gases from coated metals

Metals coated with primers, paints, or other protective coatings may produce toxic gases if the coating is not first removed. The type of gas produced depends on the composition of the coating but some examples are:

- Polyurethane coatings may produce formaldehyde and toluene diisocyanate.
- Epoxy resins may produce hydrogen cyanide and carbon monoxide.
- Vinyl may release hydrogen chloride.
- Rust inhibitors may release phosphine.

In addition, as previously discussed, certain metal coatings and paints can release toxic fumes containing such elements as cadmium, mercury, and lead.

In many cases welding over coatings would not be permitted because of the resulting poor weld quality. But burning and cutting of coated material is very likely, particularly in repair or demolition work. In such cases adequate ventilation or personal protection will be necessary. Do not weld or cut any material that has an unknown coating.

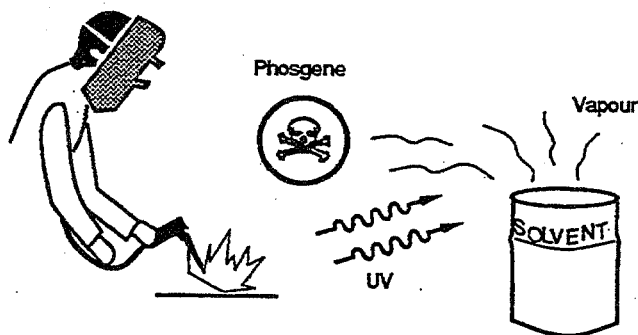


Fig. 46. Formation of phosgene from the action of ultraviolet light on the vapour of a chlorinated hydrocarbon solvent.

Gases from solvents

Toxic gases, particularly phosgene, can be produced from the photochemical action of ultraviolet light on chlorinated hydrocarbon vapours (Fig. 46). The vapour from degreasing solvents such as carbon tetrachloride, trichloroethylene and perchloroethylene may react with ultraviolet rays to give phosgene, and hydrogen chloride. Such gases can do extensive damage to the respiratory system, often before any symptoms appear. The TLV for phosgene is 0.1 ppm (0.4 mg/m³) which is very low. Phosgene is of particular concern because being heavier than air it may not dissipate easily. The amount of phosgene produced depends on the solvent, and there are some solvents that produce

Noise

relatively low levels of phosgene.

Control of the problem is straightforward: do not perform any welding with cleaning solvents in the same working area. Do not weld near painting operations where solvents could be present. Remove all containers of solvents from the welding area and ensure there is adequate ventilation. Ensure that all solvents are removed from the workpiece if it has been degreased before welding.

Many activities associated with welding and metal fabrication are noisy. Excessive noise can be detrimental to health. In some jurisdictions regulations are in place (e.g., in Ontario the Regulations for Industrial Establishments made under the Occupational Health and Safety Act) that outline the limits of exposure to noise. This means in the workplace there are legal maximum noise levels above which a worker's exposure is prohibited. Continual exposure to high noise levels can cause gradual loss of hearing.

The typical level of noise from various sources is given in Table 15. The intensity of noise or sound is measured in units of decibels. In Table 16 some typical noise levels produced by various welding and associated operations are given. The sidebar explains the units of noise.

Table 15. Typical noise levels from various sources.

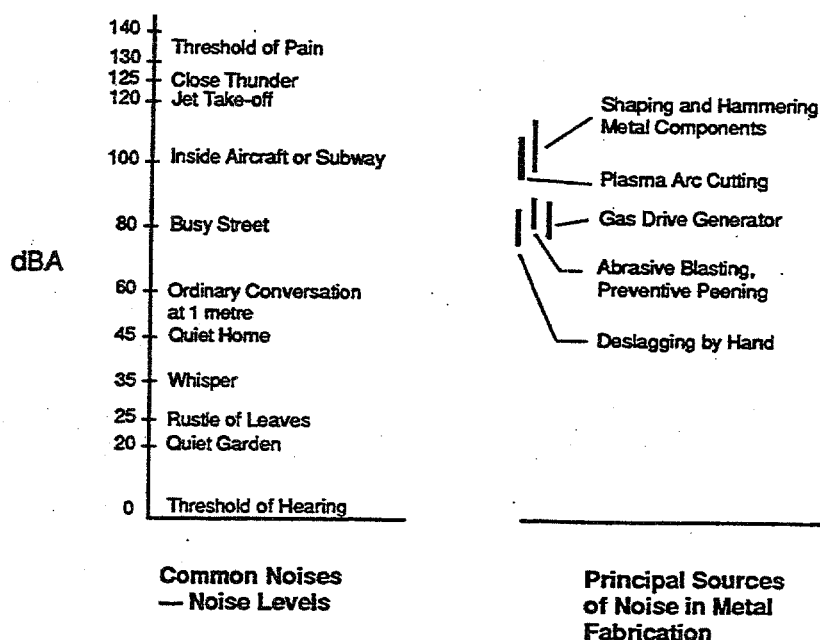


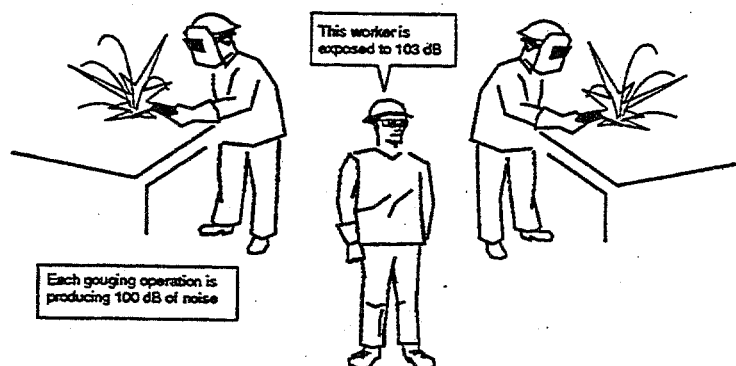
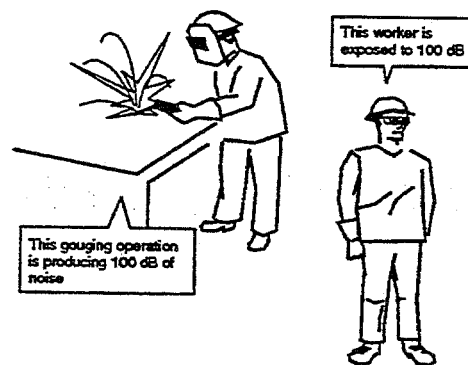
Table 16. Typical noise levels from welding operations.

GTAW	50 - 60 dBA
FCAW	50 - 86
Oxyfuel	<70
SMAW	62 - 82
PAW	80 - 91
Air carbon arc	96 - 116
GMAW	70 - 82

Units of noise

The bel is the ratio of the logarithm of two energy levels and the decibel is one tenth of a bel. Since the decibel is a logarithmic unit, an increase of 3 dB actual represents a twofold increase in sound energy.

The notation dBA refers to the sound level in decibels measured on a sound meter conforming to the American National Standard Specifications for Sound Level Meters, S1.4 (1971) Type S2A and set to use the A-weighted network with slow meter response. The A-weighting is a method by which the meter takes into account the response of the human ear to different frequencies.



The ACGIH publishes threshold limit values for noise that have similar meanings to the values given for airborne particulate substances and gases. The TLVs for noise are shown in Table 17 but other jurisdictions may set different values. No exposure, either continuous or intermittent, is allowed for sound levels exceeding 115 dBA.

Duration per day hours	Sound level dBA
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115*

Table 17. Threshold Limit Values for noise (ACGIH).

*No exposure >115 dBA

Mixtures of noise levels

Since the sound level during the day is not constant the worker is, in effect, exposed to a mixture, and the rule for summing the component exposures applies. In order to be below the threshold limit value, the sum of the fractions:

$$\sum \frac{C_n}{T_n}$$

must be less than one. C_n is the total duration of exposure at the nth noise level and T_n is the duration of permitted exposure at that level. All noise exposures exceeding 80 dBA should be included. This equation is used in a manner similar to that for fume components as described on page 38.

Hearing protection

In most cases the noise produced by fabrication operations cannot be reduced, although it should be remarked that the early progress of welding in replacing riveting as the prime metal joining method was often on account of noise reduction. The modern shop is certainly less noisy than the shop of sixty years ago. To limit exposure of the modern worker to noise some form of personal protection is required. A number of devices are available including:

- Moldable insert ear plugs (Fig. 47). These are made of some type of soft material (rubber, silicone, plastic) that can be molded to fit the ear canal of the worker. They are disposable.
- Pre-molded ear plugs (Fig. 48). These would be available in various

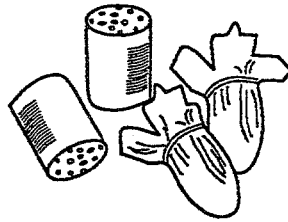


Fig. 47. Disposable earplugs.

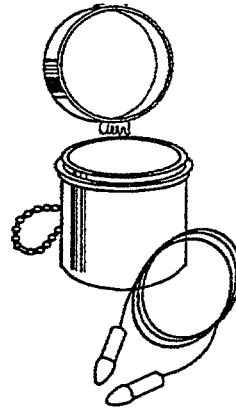


Fig. 48. Re-usable earplugs.

sizes to allow an appropriate size to be selected for each individual welder.

- Ear muffs (Fig. 49). These cover the entire ear like headphones and do not need to be specially fitted. For a welder it is important to use ear protection that does not interfere with the welding helmet.



Fig. 49. Earmuffs.

Guidance

Guidance on the type of ear protection to be used is given in CSA Standard Z94.2, "Hearing Protectors." Hearing protectors are classed as A, B, or C according to their ability to attenuate noise, with A giving the highest attenuation. Table 18 provides guidelines on the type of hearing protector to use based on Equivalent Noise Level (or L_{eq}).

Table 18. Guidelines for hearing protectors.

Equivalent Noise Level (L_{eq}) dBA	Recommended class
<85	None
89	Class C
95	Class B
105	Class A
110	Class A plug + Class A or B muff
>110	Class A plug + Class A or B muff + limited exposure

Gas welding, cutting and heating

HEALTH AND SAFETY FOR SPECIFIC OPERATIONS

In this section we discuss safety and health aspects related to the use of fuel gases and oxygen for gas welding, cutting, and heating. The main topic will be avoiding the hazards of fires or explosions. First let us consider the properties of some of these gases.

Table 19 shows the vapour density relative to air of a number of common fuel gases. Note that acetylene and natural gas are lighter than air and have a tendency to rise (Fig. 50). The others are heavier than air and sink, collecting in the lower part of confined spaces. Provide adequate ventilation to prevent the build-up of gases from unexpected leaks.

Table 19. Vapour density of fuel gases relative to air.

Natural gas	0.55	↑ Lighter than air
Acetylene	0.91	
Air	1.00	
Propylene	1.42	
MAPP	1.48	↓ Heavier than air
Propane	1.56	
Butane	2.05	

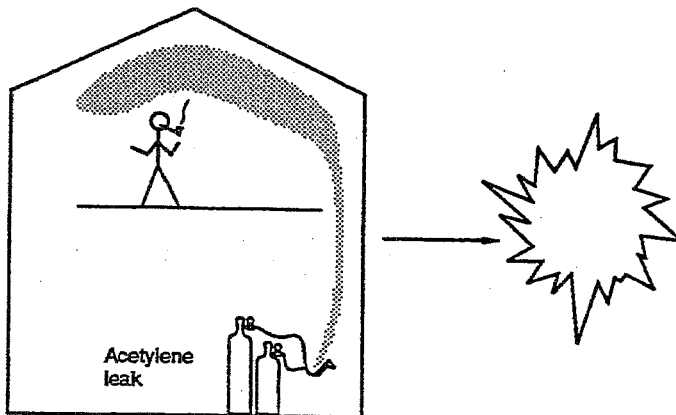


Fig. 50. Acetylene is lighter than air and can collect in the upper part of confined spaces.

Relatively small quantities of these fuel gases produce flammable or explosive mixtures when mixed with air. Table 20 shows the approximate ranges over which mixtures are flammable. The very wide range for acetylene shows that this gas is one of the most flammable. Almost any concentration in air will produce a dangerous mixture which could explode if ignited.

Table 20. Approximate flammable range of fuel gases mixed with air.

Acetylene	2.3	to	80	%
Natural gas	2.8		17	
Propylene	2.0		11.1	
MAPP	3.4		10.8	
Propane	2.1		9.5	
Butane	1.7		8.5	

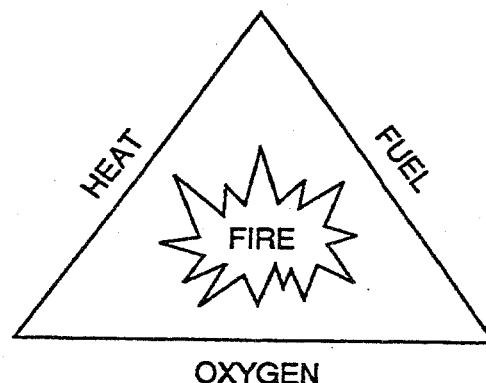
Fire triangle

A useful diagram for understanding aspects of fire and explosions is the "fire triangle" shown in Fig. 51. This shows that three things are needed to start a fire: a fuel, oxygen, and a source of heat or ignition.

Once a fire starts it creates its own heat and the fire will continue as long as fuel and oxygen are available. Air comprises about 21% oxygen so air can be the source of oxygen for a fire.

If a flammable combination of fuel and oxygen exists, there are many things which could ignite a fire: welding arcs, flames, sparks, spatter, hot slag, cigarettes, static discharges, and even small sparks in electrical equipment such as relays and thermostats. Fatal explosions have been ignited from the hot filament of an electric lamp that accidentally shattered.

Fig. 51. The fire triangle. Three things are necessary for a fire or explosion to occur: Heat, Fuel, and Oxygen.



Oxygen

Oxygen is not flammable itself but, as the fire triangle shows, it is essential in causing other materials to burn. It is a hazardous gas because it allows things to burn much more rapidly than they would in air which only contains about 21% oxygen. Many materials which may not appear to be very flammable become highly flammable in the presence of oxygen. Oxygen is supplied in compressed gas cylinders at a pressure of about 13,800 kPa (2,000 psig). Here are some precautions to minimize the fire hazard when using oxygen:

- Never substitute oxygen for air. Always call it "oxygen". Do not use it in compressed air lines, pneumatic tools, for cleaning off dust, blowing on clothes, or for ventilation.
- Do not let your clothes get saturated by oxygen. They could easily ignite and result in serious burns.
- Never use any lubricants on oxy-fuel gas equipment. Lubricants can catch fire or explode in the presence of oxygen. Oxy-fuel gas equipment is designed so that the connections seal without lubricants or sealants.
- Keep all oxy-fuel gas equipment free of grease, dust, oil, or other combustibles. An oxygen regulator fire could result in serious explosions. Some oxygen regulators are specifically designed to contain fires. Fires can be induced by the heat from the sudden compression of oxygen when the cylinder valve is opened. Always release the pressure adjusting screw (turn counterclockwise) before opening the cylinder valve. Open the cylinder valve slowly.
- Never handle oxygen cylinders in the same area as oil or grease. Do not handle oxygen cylinders or apparatus with oily or greasy hands or gloves.

Storage of gas cylinders

Correct procedures for the storing and handling of compressed gas cylinders are essential to minimize the risk of fire and explosion or other hazards. If the valve head of a compressed gas cylinder is fractured, the cylinder could become a missile and cause severe damage. Careful handling and storage of cylinders is essential. The following list provides some generally recognized practices, but there may be other requirements in your jurisdiction or safety practices recommended for specific pieces of equipment.

- Store cylinders in a clearly identified storage area away from doorways, aisles, elevators, and stairs. Mark the area with no smoking signs. The area should be dry and well ventilated.
- Protect cylinders from ground contact, ice or snow, water, salt and corrosion, and high temperatures. Never use a flame or boiling

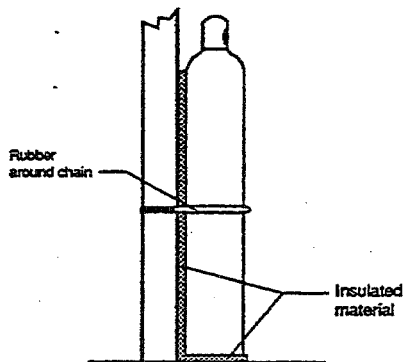


Fig. 52. Store cylinders in the upright position.

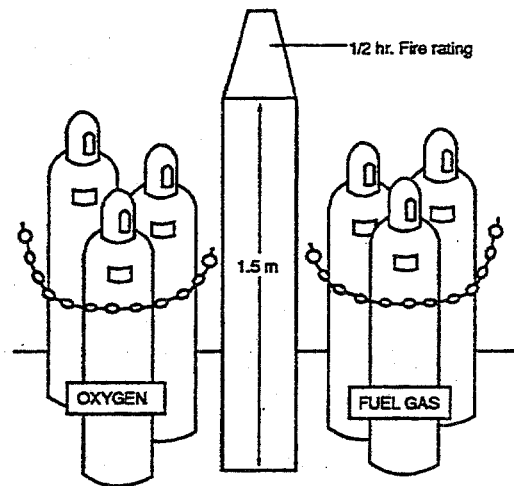
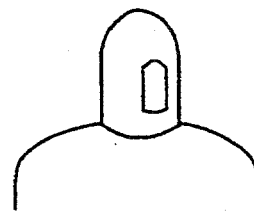


Fig. 53. Use separate storage for oxygen and fuel gas or separate with a fire wall.

water for thawing a frozen valve. Valves or cylinder heads contain fusible plugs which can melt as low as 74°C (165°F) on some cylinders. Use warm water.

- Store cylinders in the upright position secured with a chain (Fig. 52).
- Oxygen and fuel gas should be separated by at least 6m (20 ft) or else by a 1.5m (5 ft) high wall with a 1/2 hour fire resistance rating (Fig. 53).
- Do not place cylinders where they might become part of an electrical circuit. Never use them for a ground connection. Do not fasten them to a work table where they could become part of the circuit. They should be electrically isolated by suitable insulation. Never strike an arc on a cylinder.
- Store full and empty cylinders separately. Return empties to the supplier as soon as possible. Mark empty cylinders as such.
- Store with regulators removed and protective caps in place (Fig. 54). Ensure cylinders have identifying labels. Do not use a cylinder if it is not identified or the label is not legible. Never guess the contents of the cylinder from the paint colour or otherwise.
- Store cylinders and fittings where they cannot become contaminated with grease.

Fig. 54. Protective cap for cylinder valve.



Handling

- Use suitable racks and trolleys for moving cylinders (Fig. 55). Do not lift by the valve cap. Use proper cradles. Do not sling with ropes or chains (Fig. 56).
- Do not transport leaky cylinders. Do not transport cylinders in an enclosed vehicle.

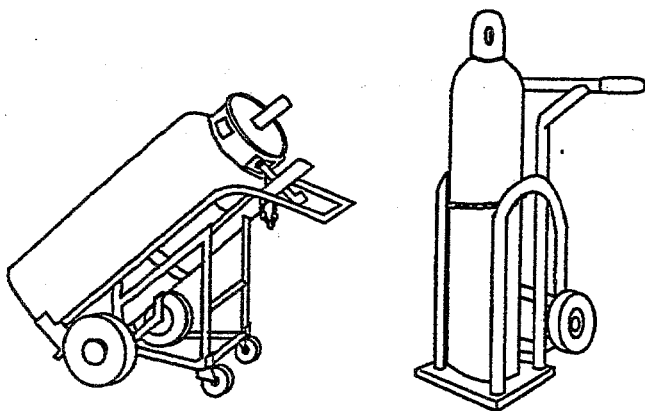


Fig. 55. Trolleys for moving gas cylinders.

- Handle cylinders carefully. Do not drag, slide, or drop them. For short distances roll them on the base as in Fig. 57.
- Never use cylinders as rollers to move equipment.
- Never try to refill a cylinder or mix gases in a cylinder.
- Be sure valve cap is in place before moving. Never move cylinders with regulators attached.

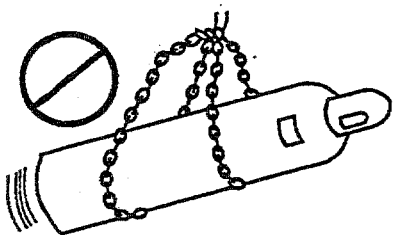


Fig. 56. Do not sling cylinders.

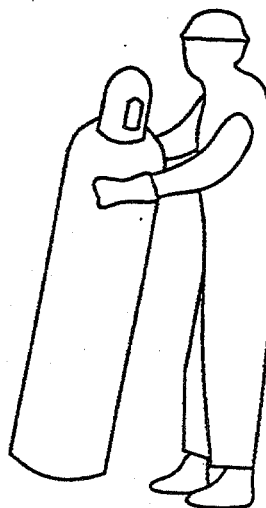
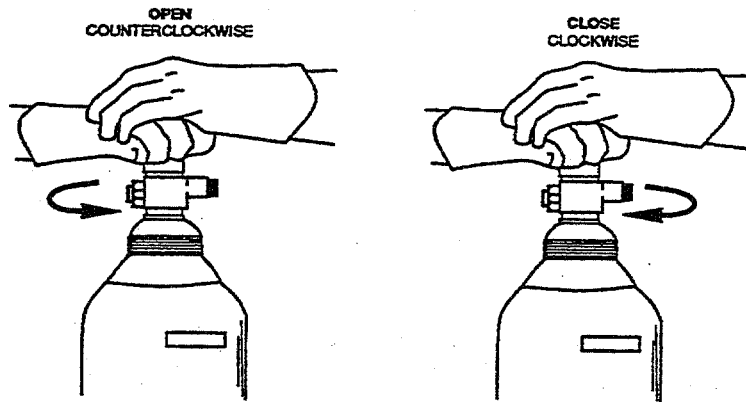


Fig. 57. For short distances cylinders can be rolled on the base.

Fig. 58. "Cracking" a gas cylinder by momentarily opening the valve to blow out dirt.



Using gases

- Ensure cylinders are secured in the upright position. Keep a clear space between the cylinder and the work so that access to the cylinder is not restricted.
- Before attaching the regulators, "crack" the cylinder by momentarily opening the valve slightly then closing immediately as shown in Fig. 58. This blows out dust or dirt. Use two hands on the valve and do not stand directly in front of or behind the valve.
- Do not use gas cylinders without a regulator. Install the correct regulator. Ensure the regulator is clean, free of grease, with a clean filter on the inlet nipple. A typical regulator is illustrated in Fig. 59.

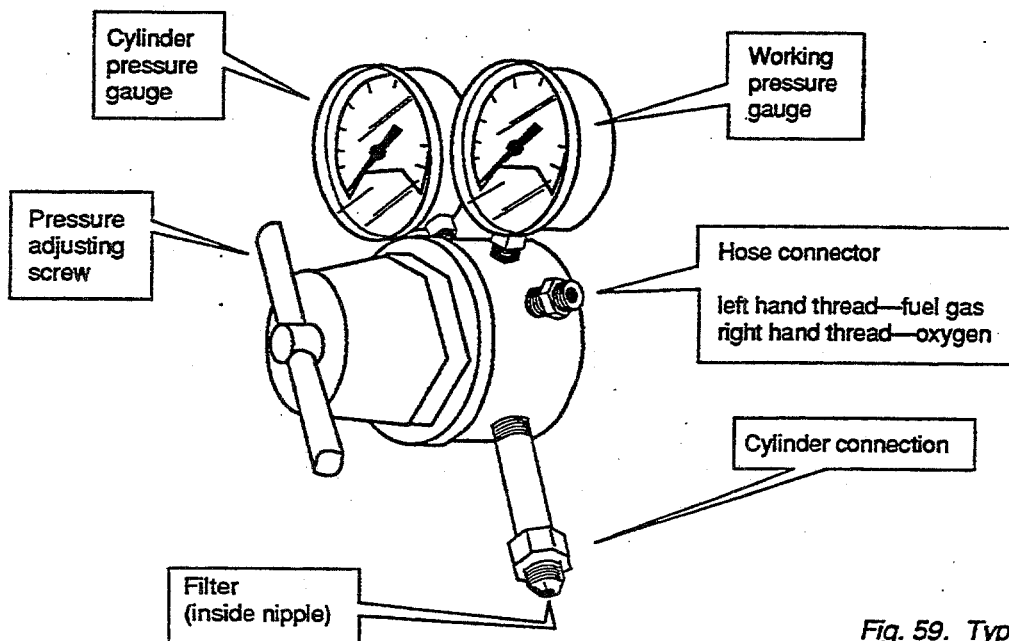


Fig. 59. Typical gas regulator.

Connections

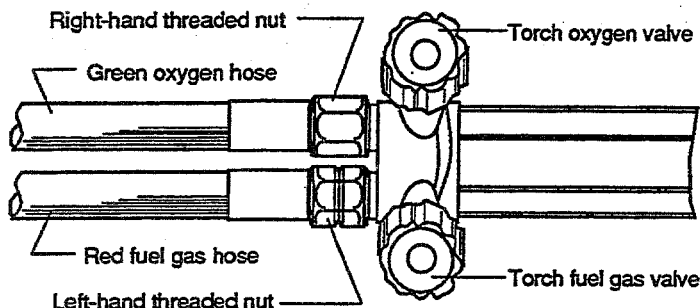


Fig. 60. Oxygen and fuel gas hoses and their connections.

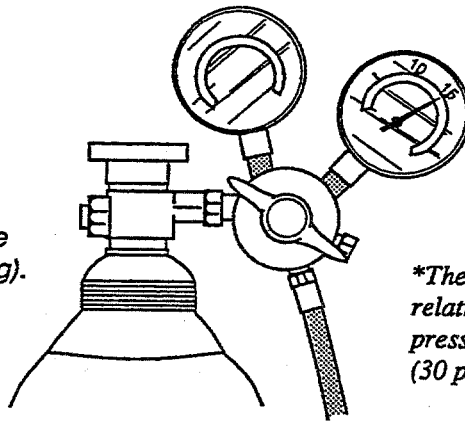


Fig. 61. Release the pressure adjusting screw by turning counterclockwise before opening the cylinder valve. Stand to one side when opening the cylinder valve.

Acetylene

- Use the correct hoses and fittings. Oxygen hoses are usually green with right hand thread connections. Fuel gas hoses are red with left hand thread connections. A groove in the nut indicates a left hand thread (Fig. 60). This system is intended to prevent incorrect connection of hoses. Do not force the connection if it does not seem to fit. Tighten nuts with the correct wrench after first finger tightening.
- Check hoses for damage before use. Replace a leaky hose. Do not tape a leaky hose to stop the leak. Prevent kinks in the hose. Use the right length of hose for your needs and do not use hoses longer than necessary. Test for leaks with proper test kit.
- Before the cylinder valve is opened, the regulator pressure adjusting screw must be released by turning it counterclockwise until it turns freely (Fig. 61). This closes the regulator valve and prevents damage or fire from a sudden surge of gas when the cylinder valve is opened. Open cylinder valves slowly. When the high pressure gauge indicates maximum pressure, open the cylinder valve fully. If required, use the proper valve wrench and leave it in place to permit an emergency shut off if necessary.
- Acetylene cylinders should be stored, handled, and used in the upright position.
- The gauge pressure* for acetylene must not exceed 103 kPa (15 psig). Acetylene can be unstable and higher pressure may lead to explosions (see Fig. 62).
- For acetylene cylinders equipped with a packed gland (or "o" ring) valve, do not open the valve more than 1 1/2 times and leave the T-wrench in place. Some acetylene cylinders may be equipped with a backstop valve which must be opened fully (just like on an oxygen cylinder). Make sure to find out which valve type you have and use the correct procedure.

Fig. 62. Do not use acetylene at more than 103 kPa (15 psig).



**The gauge pressure is the pressure of the gas relative to atmospheric pressure. A gauge pressure of 103 kPa (15 psig) is about 210 kPa (30 psig) absolute pressure.*

Safety problems with torches

- Ensure there is adequate fuel gas and oxygen in the cylinders to complete the job. If cylinders must be changed, hose lines must be thoroughly purged before relighting the torch. Do not allow the oxygen cylinder pressure to fall below 175-350 kPa (25-50 psig). Never use matches to light up; use a spark lighter.
- When shutting down, close valves at the torch then close the cylinder valve. Then open the torch valves to release pressure in the lines and close again. Next, release the pressure adjusting screw on the regulator (turn counterclockwise). Check that the inlet gauge pressure is at zero and that the cylinder valve is closed.

The improper use of the oxy-fuel gas torch can lead to several safety problems.

- A backfire is the momentary return of the flame into the tip and flame extinction during operation due to insufficient gas velocity at the tip. A backfire is accompanied by popping sounds. A backfire by itself is not dangerous but it is a good indication that a more severe problem such as a sustained backfire or flashback could occur. Check for the causes of backfires such as inadequate pressure, leaking hoses, etc., before resuming work.
- A sustained backfire occurs when the flame travels back into the torch and burns continuously at or near the point of mixing. It is accompanied by a loud hissing or squealing noise. If a sustained backfire occurs, shut off the torch immediately—oxygen first, then the fuel gas. Allow the torch to cool. Visually inspect the torch and replace any discoloured, distorted and damaged components. Check pressure settings, cylinder pressure, equipment flow requirements, hose diameter, length and leaks.
- A flashback occurs when the flame progresses back through the torch and to the supply equipment due to gas flow or overheating of the torch head or insufficient gas pressure. In case of a flashback, immediately close both the fuel gas and oxygen cylinder valves.

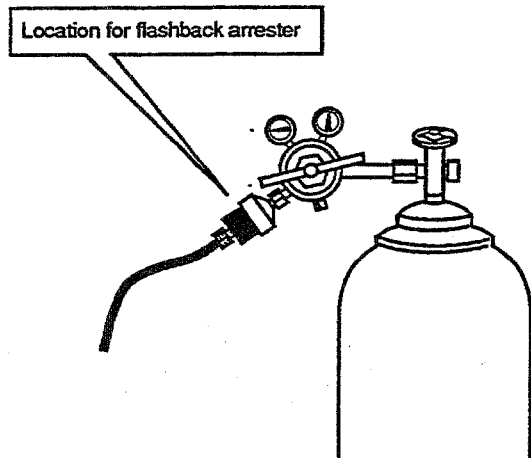


Fig. 63. Flashback arrester installed at the regulator.

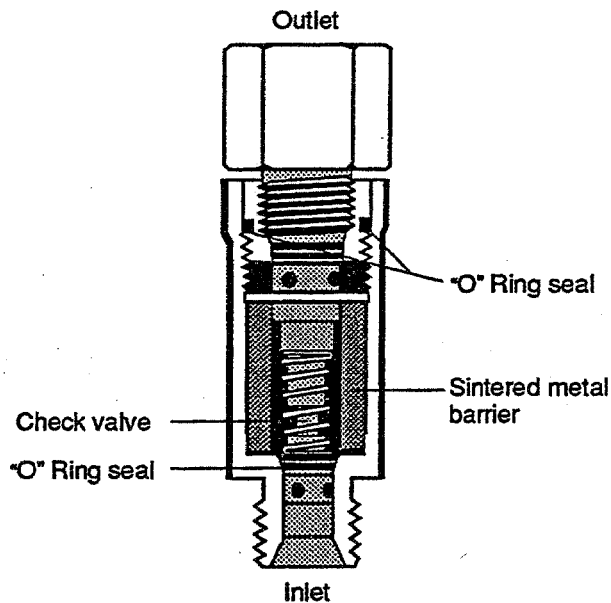


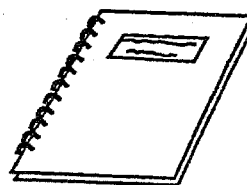
Fig. 64. Cutaway of a torch-mounted flashback arrester.

Inspect the apparatus and determine the cause of the flashback and replace any damaged components before relighting the equipment. To reduce the risk of a flashback, use a flashback arrester mounted on both regulators (Fig. 63) or on the gas supply lines at the torch (Fig. 64). Flashback arresters can restrict the flow of gas so contact the manufacturer for the proper flashback arrester for your application.

Welding in confined spaces

Welding and related operations are sometimes required to be carried out in confined spaces where there is limited access for entry or where unfavourable ventilation could result in the accumulation of gases, dust, vapour, or air unsafe to breathe. Typical confined spaces are storage tanks, pressure vessels, bins, silos, pipelines, small ship compartments, tunnels, and so forth. Special safety measures are required to reduce the risk of hazards associated with welding in such places. Local jurisdictions may have specific requirements and the employer should have written rescue procedures (Fig. 65) for confined space emergencies.

Fig. 65. There should be written safety and rescue procedures for confined space welding.



Minimizing risk of fire

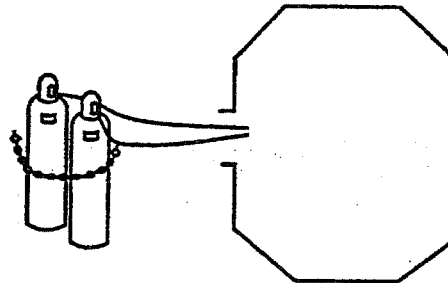
- In general, the safety practices for confined spaces are based on
- minimizing risk of fire or explosion
 - ensuring the welder has adequate breathing air
 - providing a rescue system.

These all require a degree of planning and forethought, and no welding should be carried out until all procedures are in place. Written entry permits are recommended as they provide a documented check list and ensure that authorization has been obtained.

The following practices will help to reduce the risk of fire or explosion in a confined space:

- Locate compressed gas cylinders and power sources outside the confined space. This also avoids cluttering the space and blocking escape in an emergency (Fig. 66).

Fig. 66. Locate cylinders outside a confined space.



Ensuring adequate breathing air

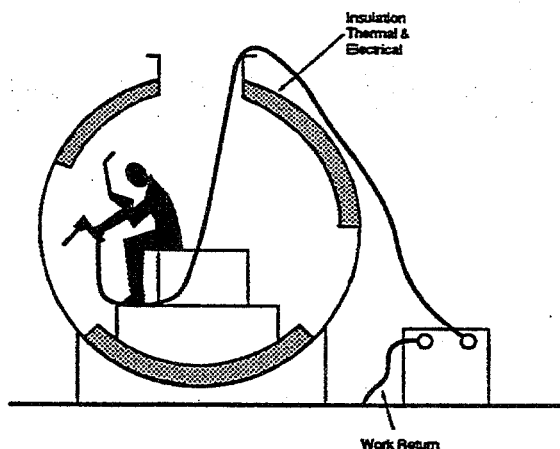
- Light up (and shut down) oxy-fuel torches outside the confined space then pass the torch in for use.
- Remove all hazardous and flammable material.
- Ventilate the area to remove gases and vapour.
- The atmosphere should be tested by a competent person to ensure it is safe. Any combustibles in the atmosphere must be below 10% of their lower explosive limit.
- Inspect all electrical cables and connections. Leak test all gas lines and connections.
- Any electric lamps should have proper protective cages to avoid accidental breakage. Hazards may also be reduced by using low voltage lamps, tools, and equipment.
- Provide adequate ventilation. In some cases personal air supplied breathing apparatus may be necessary. Remember, filter masks do not supply air and by themselves are not adequate if the atmosphere is oxygen deficient.

Heat stress

- The atmosphere should be tested by a competent person to ensure it is safe before entry. This includes testing for all likely toxic contaminants. Where there is a risk of oxygen deficiency in the air continuous monitoring and oxygen alarms should be used.
- Only use air for ventilation. Never use oxygen or any other gas or gas mixture to ventilate.

In some situations, for example in welding a thick walled pressure vessel, it can get very hot inside, particularly if the metal is being preheated. The use of insulating mats on the inside of the vessel as shown in Fig. 67 will help to reduce the heat transfer from the metal. If the mats are good electrical insulators they also reduce the risk of electric shock. Adequate ventilation will also assist in reducing the level of heat, but in certain cases it may be necessary to use heat resistant suits and personal breathing apparatus. Proper rest periods are also necessary in reducing the hazard of heat stress.

Fig. 67. Use of insulating mats to protect the welder against heat.



Note: Ventilation requirement not shown

Providing a rescue system

Before allowing welding and similar operations in a confined space the company must have a written rescue procedure. All those involved must be familiar with the procedure so that prompt action can be taken when necessary. Any effective procedure must have adequate monitoring, and welding in confined spaces should never be carried out without someone in attendance. A worker must be stationed outside the confined area to summon assistance and apply rescue procedures. The attendant worker must observe or be in constant communication with the welder inside and be able to implement the rescue plan (Fig. 68).

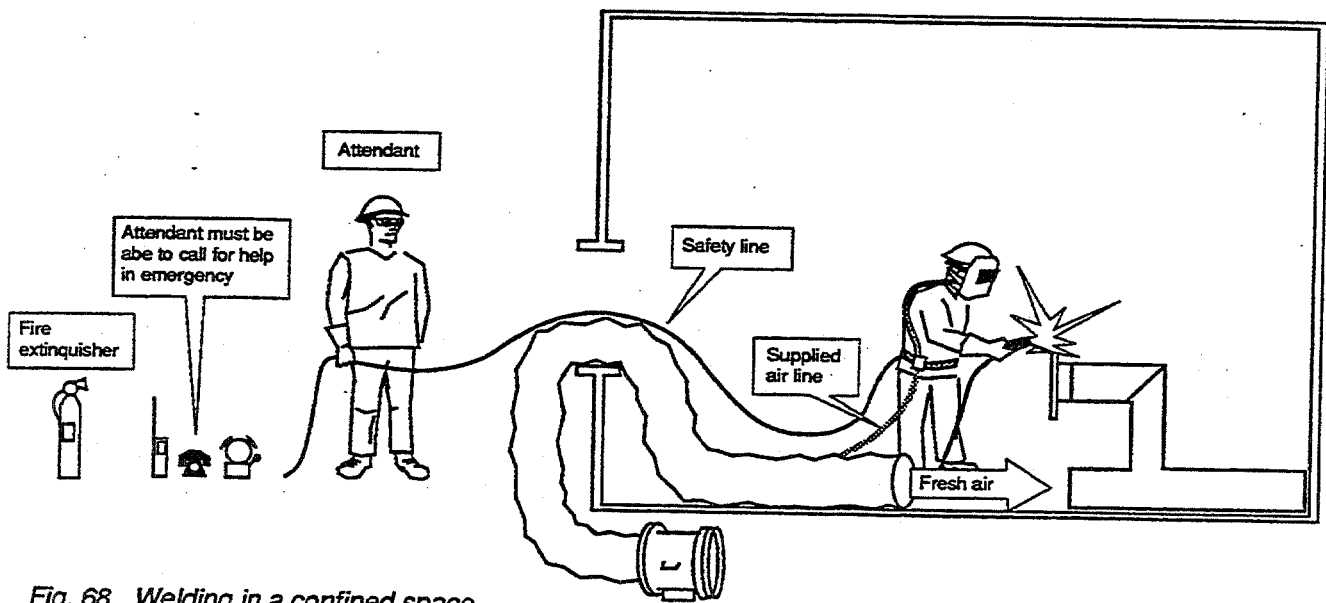


Fig. 68. Welding in a confined space.

Where the space has only a small opening for entry, the welder must use a life line secured to his safety belt or harness. The attendant outside can hold the free end of the life line so that the welder can use it to signal for help. The line must be attached to the welder in such a manner that the welder could be pulled out without jamming in the opening. In an emergency, the attendant must call for help first and should have an alarm for the purpose. He should not enter the space until another worker is present. Separate breathing apparatus should be available for rescue operations, and there should be means for quickly shutting down electrical and gas systems. Any electrical, mechanical, or gas systems not needed for the welding operation should be turned off and locked out before entering the confined space.

Welding on containers that have held hazardous materials

The residues of hazardous materials left in containers may pose serious risks of fire, explosions, or health hazards if welding or cutting is carried out on the container. Safety procedures must be carefully followed to minimize these risks. In many cases special procedures have been developed to cover the decontamination and welding of containers for specific materials. Certificates of decontamination and hot work permits may be required before any welding is allowed. Examples where special procedures are required are: vessels having contained radioactive and explosive materials, compressed gas containers, bunkers on ships, large gas and petroleum tanks, and "live" gas lines. No one should attempt to weld such containers without the proper

permissions. For the general case, where no specific procedures are available, the following points are worth noting:

- Never assume the container is empty and clean. There may still be residues which could release vapour when heated.
- Always determine what the contents of the container were. Never attempt to clean or weld until the prior contents are known. Do not weld if the contents cannot be determined.
- Apply the correct cleaning method as determined by a qualified person. The cleaning method depends on the prior contents. The main methods are: water cleaning for soluble materials (not suitable for oils and gasoline); hot chemical solution (detergents); steam cleaning; mechanical cleaning; and chemical cleaning with solvents. In the last case it is essential to remove all residues of the solvent after cleaning to avoid the formation of phosgene gas during welding.

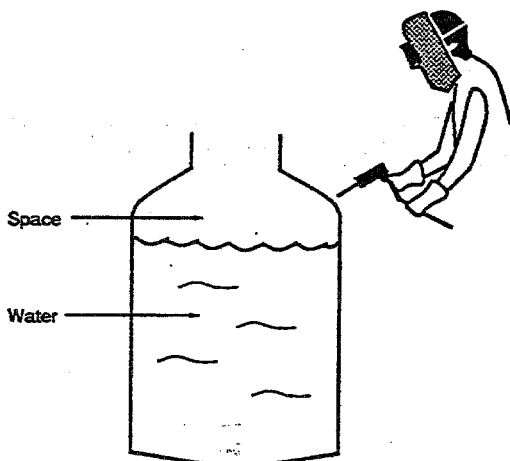


Fig. 69. Part filling a container with water before welding to reduce build-up of vapour from prior contents.

- Test the vapour concentration before and during welding operations.
- Provide for the relief of pressure in the container by appropriate venting. This applies to any container whether or not it has held dangerous materials. The expansion from the heat of welding of gas, air, or steam inside a sealed container could cause an explosion. Containers must always be vented.
- Reduce the risk of vapour build-up by filling the container with inert gas or water before welding. If water is used, keep the water below the point of welding and vent the space above (Fig. 69).

Laser welding

Laser welding involves the use of a concentrated beam of light to generate the heat for metal fusion. The light may not always be clearly visible, but the intensity creates a serious hazard of eye or skin damage. As a guide to the potential risk and the safety practices in using them, lasers are grouped into several classes:

- Class 1. These are inherently safe because of the very low power or because the design prevents any exposure.
- Class 2. Continuous wave or pulsed lasers operating in the visible range (400-700 nm) and limited to 1 mW power output.
- Class 3A. Similar to Class 2 with power output up to 5 mW. Optical equipment with filters must be used for viewing the beam.
- Class 3B. Lasers that operate over the complete range (200 nm to 1 mm) with power output up to 0.5W. Direct viewing of the beam is hazardous.
- Class 4. High powered lasers that could produce hazardous diffuse reflections. Extreme caution must be exercised and correct procedures followed. There may also be a fire hazard.

With classes 2 to 4 there is a significant hazard associated with the use of lasers and the manufacturer's recommendations and procedures should be carefully followed.

The process also involves other hazards such as heat radiation, fumes and gases which it shares with other processes and safety measures have been discussed elsewhere.

Electron beam welding

The electron beam welding process produces heat by the impingement on the metal of a beam of high velocity electrons. It is a specialized welding method involving sophisticated equipment and special safety procedures recommended by the manufacturers should be observed. A number of specific hazards encountered with electron beam welding will be briefly mentioned here.

The production of high velocity electrons requires equipment employing very high voltages, easily sufficient to cause a fatal shock. Equipment must never be operated with any covers removed or if any indicator or warning lights are not functioning correctly. High voltages can remain after the equipment is turned off and correct discharging of capacitors and grounding is required before servicing. The equipment should only be serviced by properly trained and qualified personnel.

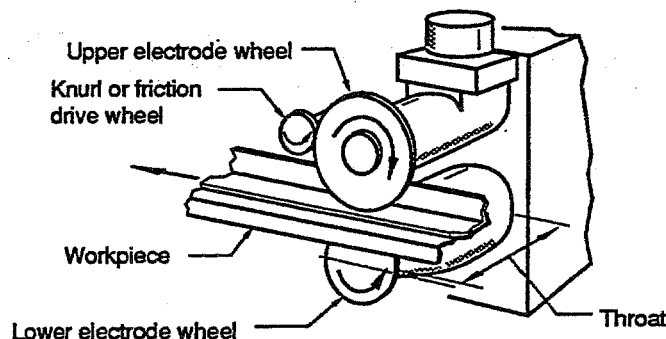
The impingement of electrons on a metal produces X-rays and these may be sufficient to cause injury. Exposure to X-rays can produce both

Resistance welding

short term injury and long term health effects. The main source of X-rays is the electron gun and the work chamber, but they may be produced in other parts of the equipment. Electron beam equipment should employ appropriate shields (of lead, for example) to minimize the exposure of the operator to X-rays. Do not defeat the purpose of any shields and ensure that they are not damaged.

The resistance welding method employs high currents that pass through the two pieces of metal causing melting at the interface. The high currents and the automatic nature of the equipment present some specific hazards. High magnetic fields may exist around resistance welding equipment which could induce currents and heating in metal objects. Operators should not wear rings, jewelry, watches or other sensitive devices while operating or near resistance welding equipment. Anyone wearing a heart pacemaker should get expert advice on whether the device would be affected by magnetic fields from resistance welding machines or any other equipment.

Fig. 70. Typical resistance welding machine for seam welding. Risk of injury to hands is a potential hazard with such equipment.



The electrical equipment should be protected with covers and doors with interlocks or interrupt switches to prevent exposure to high voltages. Do not defeat the purpose of any of these safety features and do not operate the equipment unless they function properly. There is also a risk of metal expulsion with resistance welding, and proper clothing and eye protection should be worn.

Mechanical hazards exist with resistance welding equipment, particularly the danger of injury to the hands (Fig. 70). Equipment must be designed and installed with features that minimize possible injury, and safety standards such as CSA W117.2 list possible features that equipment should have. They include:

Safety of automatic and robotic welding equipment

- design such that both the operator's hands must be used remotely from the point of operation during the machine cycle
- machine guards that prevent the operator's hands passing under the point of operation
- two handed controls
- guards that prevent accidental activation of controls, treadles, etc.
- devices that detect the presence of the operator's hands.

Since systems vary from one machine to another it is important that operators are trained in all aspects of operation and safety on the specific piece of equipment to be used. Most resistance welding machines are automatic to a certain degree, and many of the safety aspects discussed in the next section are relevant to resistance welding.

The adoption of welding robots and other automatic welding equipment in the last few years has exposed the worker to a number of new hazards which must be recognized. Overall, the use of robots can reduce occupational hazards because people are removed from the area of operation. There have, in fact, been relatively few accidents with robots, but their growing use and the increasing opportunity for workers to be working with or near robots makes an awareness of potential hazards necessary.

Several of the hazards of welding robots, such as electrical, radiation, or fume exposure, are shared with conventional welding processes and have been discussed earlier in the module. The main hazard to be discussed here is that of personal injury from a moving robot arm.

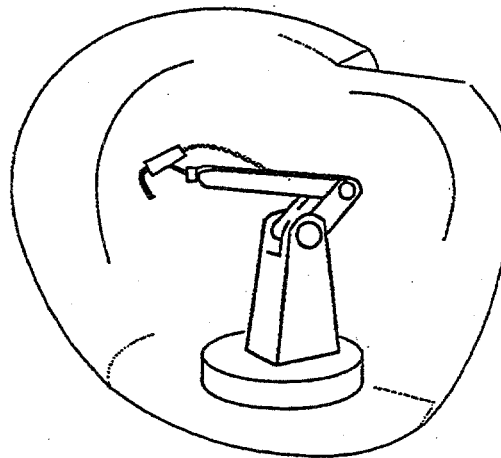


Fig. 71. Robot working envelope. This is the boundary of all regions that can be reached by the robot.

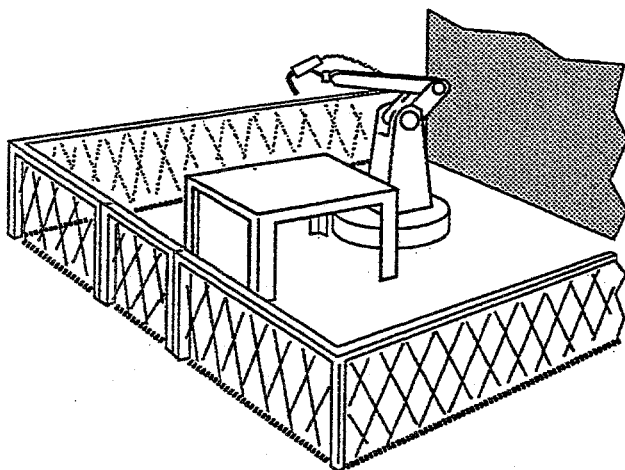


Fig. 72. Typical robot work area with restricted access.

Hazard space

The most important concept is that of the hazardous space defined by the robot's work envelope. This is the space within which a hazard exists or injury could occur. This space includes all points that could be reached by the robot arm which defines the operating zone or working envelope (Figs. 71 and 72). Here are some of the points about the operating zone and hazard space that should be noted:

- The size and shape of the operating zone depends on the type of robot. In some cases it may be advantageous to reduce the size of the zone by employing limit switches.
- The size and shape of the operating zone may be difficult to define easily.
- It is difficult to predict the path a robot will take. It usually chooses the shortest line between two programmed points and may suddenly move to another location on the workpiece.
- A person cannot usually react quickly enough to avoid being hit if within the robot trajectory for normal operating speeds. A fast reaction time for a person is 1 s and a robot can move at least at this speed, or even double it.
- For robots that must be programmed by an operator within the robot's work envelope, the programming speed is slower than normal operating speeds.

Robot safety should be a consideration in planning system layout before any installation. It should consider minimizing the hazardous space, provide suitable operator stations, and consider appropriate crossing points over production lines. Jobs that do not need to be done within the hazardous space should be kept outside this area. The safeguard system should be part of the whole design and not added later.

Safety features

To prevent unauthorized entry to the robot's working area, safety equipment such as physical barriers or light curtains are used. There are, however, occasions when the area must be entered, for example for maintenance or programming. Entry is therefore controlled by other safeguards that can disable the robot and prevent motion. These include floor mats, interlock gates, light beams, and other sensing devices (Fig. 73). There are a number of ways in which a robot may be stopped and the various types of hold functions should be understood for the specific piece of equipment being used.

A programmed hold may be part of the program where the robot will pause for a while then continue operations. Accidents have occurred where a person thought the robot was shut down whereas it was on a programmed hold and suddenly went into motion while the person was in the hazardous zone.

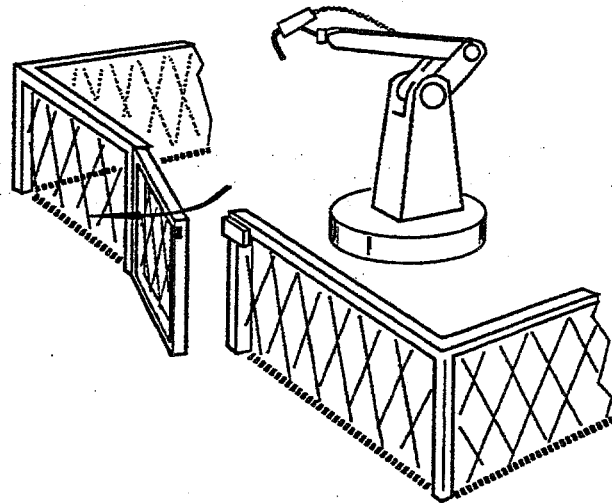


Fig. 73. Use of interlock system to disable the robot when the gate is opened.

An emergency stop cuts power to the robot's drive motors. It would be used in emergency situations such as a robot crash. Resuming the robot's programmed sequence after an emergency stop may be time consuming and the emergency stop would not, therefore, be used to interrupt the system for situations other than emergencies.

A safety interrupt, which might be used on an interlock gate, breaks power to the robot's axis system and locks the robot in position. It does not cut all power to the system (e.g., robot drive motors) or lose its position and synchronization, so restarting after a safety interrupt is easier than after an emergency stop. To lock the robot in the safety hold it must have a break system.

Reliable hold functions are necessary for safe operation of the robot. It should not, for example, suddenly move if power is restored after a power failure. Safety features are designed into a robotic system. A robot can be a potentially dangerous production tool to area operators. Proper respect for a robot's capability and proper care of the safety system will go a long way to ensure worker safety.

Summary

Creating a healthy and safe working environment is the joint responsibility of the employer and the employee. Every worker must learn safe work practices and follow safety procedures. In this module we have discussed some of the health and safety aspects of welding, identifying potential hazards and giving guidance on the generally recommended precautions. Since local conditions vary, specific procedures must be developed for each case and expert assistance may be required.

We have discussed the system of labelling to convey information on hazardous substances and described some general shop safety practices. Electrical hazards and the procedures for minimizing the risk of electric shock have been covered. Proper clothing, face shields, and eye protection are required in welding to protect the welder from burns, hot metal, and arc rays. Conditions under which fumes and gases may create a health hazard have been discussed and general guidance on appropriate ventilation methods is given. Welding and related operations may also produce high noise levels requiring the use of appropriate hearing protection devices.

Fire and explosions are major hazards when using oxy-fuel gas systems for welding, cutting, or heating. Equipment must be properly maintained and handled. Guidance is given on safety practices. Greater hazards exist when welding in confined spaces or on containers that have held hazardous materials. Situations like these require carefully planned and documented safety procedures recognizing such things as the change in air composition during welding in a confined space, the risk of explosion, and the need for a rescue system. Some of the newer, automated and robotic welding systems introduce new types of hazards to the workplace, but they may also reduce other hazards leading, perhaps, to an overall improvement in safety. Safety features are usually built in to the equipment. This module will have provided an awareness of the hazards associated with welding and related processes, and the practices, precautions, and procedures to minimize these hazards.

Additional Resources

There are many sources of information on health and safety in welding and related processes. The following provides a list of a few important references as well as addresses of agencies and organizations that may be able to provide additional information. For specific processes and equipment contact the manufacturer for safety information.

- CAN/CSA - W117.2-M94. "Safety in Welding, Cutting, and Allied Processes." Canadian Standards Association, 178 Rexdale Boulevard, Rexdale (Toronto), Ontario, Canada, M9W 1R3. Page 12 of this standard lists other CSA standards relevant to safety in welding.
- CAN/CSA-Z94.2-93. "Hearing Protectors." Canadian Standards Association, 178 Rexdale Boulevard, Rexdale (Toronto), Ontario, Canada, M9W 1R3.
- ANSI/ASC Z49.1-94. "Safety in Welding and Cutting." American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135, U.S.A.
- ANSI/AWS F4.1-92. "Recommended Safe Practices for the Preparation for Welding and Cutting of Containers That Have Held Hazardous Substances." (AWS publishes a "Safety and Health Information Packet" that includes these two standards).
- AWS F1.1. "Method for Sampling Airborne Particulates Generated by Welding and Allied Processes."

Information may also be obtained from the following organizations some of which also publish standards.

- Canadian Centre for Occupational Health and Safety (CCOHS), 250 Main Street East, Hamilton, Ontario, L8N 1H6.
- Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario, M5C 2A5.
- Industrial Accident Prevention Association, 250 Yonge Street, Suite 2800, Toronto, Ontario, M5B 2N4.

- Occupational Health and Safety Agency, 80 Bloor Street West, 6th Floor, Toronto, Ontario, M4W 3N8.
- American Conference of Governmental Industrial Hygienists (ACGIH), Kemper Woods Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.
- Compressed Gas Association (CGA), 1235 Jefferson Davis Highway, Arlington, VA 22202.
- National Electrical Manufacturers Association (NEMA), 2101 L Street, NW, Washington, DC 20037.
- National Institute for Occupational Safety and Health (NIOSH), 4676 Columbia Parkway, Cincinnati, OH 45226.

GUIDES AND EXERCISES

MODULE 1

WELDING HEALTH AND SAFETY

WELDING HEALTH AND SAFETY

MODULE 1

Guides & Exercises

To obtain maximum benefit from this module we suggest that you follow this guide and complete the exercises as indicated. It is important that you work through the text methodically, studying each section thoroughly before moving on. The exercises are designed to give you an indication of whether you have learned the material and can move on or whether you need to go back and study the section again.

Do the exercises honestly. They will not help you unless you take them seriously. If you get a question wrong go back through the text until you understand where you have gone wrong and know the correct answer.

The length of time required to complete the module will vary from student to student. Find your own pace. Do not rush. Remember you are trying to learn something, not win a race.

Some people like to underline sections when they read a text. We suggest that you use caution if you do this. What you think is important first time you read it may be different after reading it three times. We suggest you read a section three times thoroughly before highlighting anything.

The last exercise is designed to give you an indication of whether you are ready to take the WIC closed-book exams. The exercise questions are of a similar standard to the official exams. Do not take the exam until you feel you are ready and you may wish to study several Modules before taking the exams on each. The details of the examination procedures are on a separate sheet.

If you have any difficulties with this Module do not hesitate to ask for help. You may find you learn more by attending seminars which are given periodically, and you should also contact your local WIC Chapter to see if they can be of assistance. Remember, if you fail the examination you can always try again later.

After working through each guide, check your answers (starting on page 89) for accuracy. If any of your answers are wrong, re-study the guide subject matter in the text until you understand it before moving on to the next guide.

Guide 1

Read carefully pages 1 to 10 and answer the following questions:

1. True or false?
"Creating a safe working environment is strictly the responsibility of the employer."
2. WHMIS stands for—
 - a) Workers health monitoring information system
 - b) Workplace hazardous materials information system
 - c) Workers for a healthy manufacturing industry society
3. What are three ways that WHMIS information is conveyed to the workplace?
4. Which of the following is the WHMIS symbol for an oxidizing material?



a



b



c

5. If you wished to find out the hazardous ingredients of a product and their toxicological properties, where would you look?
6. Is there a Canadian Standard for Safety in welding?

Guide 2

Read carefully pages 11 to 19 and answer the following questions:

1. What is the typical three phase input voltage to welding machines in most shops?
2. True or false?
"The voltage on the secondary side of welding machines is always so low there can never be a danger of electric shocks."
3. Why is it possible to still get a shock by touching only one wire of an electric circuit?

4. If a workmate suffers an electric shock what is the first thing to do?
5. True or false?
"The cable from the workpiece back to the welding machine is correctly called 'the ground lead'."
6. Why should the workpiece always be grounded?
7. Why should you avoid welding with wet hands or standing in water?

Guide 3

Read carefully pages 20 to 27 and answer the following questions:

1. Of the two classes of radiation which is the one that can damage living cells. Give two examples.
2. Which of the following operations emits this type of radiation?
 - a) Shielded metal arc welding
 - b) Plasma arc cutting
 - c) Radiography of welds
 - d) Resistance welding
3. Is it true that you could suffer "sunburn" on exposed skin by just being near a welding arc?
4. What is the recommended shade number for a welder's helmet when using a 5/32 in. SMAW electrode at about 150 A.
5. Which of the following situations is most likely to produce the greatest amount of direct and reflected ultraviolet light?
 - a) Resistance welding two thin steel sheets
 - b) Gas metal arc welding aluminum plate
 - c) Submerged arc welding
6. Roughly how far could spatter travel when welding or cutting on a structure about 2.5 m high?
 - a) possibly up to 6 m
 - b) no more than 1 m
 - c) up to 20 m

Guide 4

Read carefully pages 28 to 50 and answer the following questions:

1. For the SMAW process which contributes more to the production of fume: the base metal or the electrode?
2. Some copper alloys contain a very toxic component. What is it?
3. Which of the following processes is likely to have the greatest fume generation rate?
 - a) SMAW
 - b) SAW
 - c) FCAW
4. Industrial hygienists often refer to allowable exposure to fumes in terms of the TLV-TWA. What do the letters TWA stand for and what do they mean?
5. True or false?

"The TLV for welding fume is 5 mg/m³. Therefore it does not matter what is in the fume as long as the concentration is below this level."
6. For a typical local exhaust system with a movable hood, how close to the arc should the hood be placed?
 - a) About 1 m (3 ft) is adequate
 - b) No further than 100 mm (4")
 - c) Typically about 200 mm (8")
7. True or false?

"Facepiece respirators with mechanical filters will remove all fumes and gases emitted in welding."

Guide 5

Read carefully pages 51 to 56 and answer the following questions:

1. Argon is heavier than/lighter than air?

Helium is heavier than/lighter than air?
2. If argon is an inert gas, why does it still matter how much gets into the air?
3. How is ozone produced around the arc?
4. Why should you never weld when there are chlorinated hydrocarbon solvents on the workpiece or in the work area?

Guide 6

Read carefully pages 56 to 59 and answer the following questions:

1. True or false?

"If there is no immediate damage or pain when exposed to a loud noise, there will be no long term effects."
2. What is the usual unit for measuring noise exposure?
 - a) J
 - b) ABd
 - c) dBA
 - d) Bells
3. For the following exposures to different noise levels during the day, determine whether the allowable exposure has been exceeded for the day using the ACGIH TLV values.

0.5 h at 100 dBA
0.5 h at 95 dBA
3 h at 90 dBA
remainder at 75 dBA
4. If a worker is standing next to two machines, each producing a noise level of 95 dBA, what noise level is the worker exposed to?
 - a) 95 dBA
 - b) 98 dBA
 - c) 190 dBA
5. For a noise level not exceeding 95 dBA, what class of hearing protector would CSA Z94.2 recommend?

Guide 7

Read carefully pages 60 to 68 and answer the following questions:

1. Which of the following fuel gases are lighter than air?
 - a) Propane
 - b) MAPP
 - c) Acetylene
 - d) Natural gas
2. Which of the common fuel gases has the widest range of mixtures with air over which it is flammable?

3. True or false?

"If the pressure adjusting screw on an oxygen regulator seems stiff, use a light grease to free it up."

4. Why should boiling water **not** be used for thawing a frozen valve on a cylinder?

5. Is it correct that reverse flow valves will always prevent a flashback?

6. Match the gases with the correct hose colour and connection thread:

Gases: oxygen, fuel gas

Threads: left hand, right hand

Usual hose colour: red, green

7. What is the maximum gauge pressure that acetylene should be used at? (kPa/psig)

8. What should you do if a flashback occurs?

Guide 8

Read carefully pages 68 to 72 and answer the following questions:

1. True or false?

"It is recommended there should be documented safety practices and procedures for welding in confined spaces including a system of written entry permits."

2. List four safety practices that will help to reduce the hazard of fire or explosion when welding in a confined space.

3. Why may a simple filter mask not provide adequate protection when welding in a confined space?

4. Give three important elements of a rescue system for welding in confined spaces.

5. Why could welding on an empty container be hazardous?

6. True or false?

"If the prior contents of a container cannot be determined, it is best to weld with a high heat to ensure residues get burnt off."

7. Give one method of minimizing vapour build-up when welding a small container that has held a volatile, flammable liquid.

Guide 9

Read carefully pages 73 to 78 and answer the following questions:

1. Which class of laser welder would create the greater hazard of eye damage?
 - a) Class 1
 - b) Class 3B
 - c) Class 3A
2. Electron beam welding may expose the operator to a potential hazard not normally present with most other welding processes. What is it?
3. Resistance welding machines usually have features designed to prevent damage to the hands. Give two examples.
4. What is meant by the term "working envelope" of a robot?
5. If a robot is in a programmed hold, is the power to the main drive motors cut?

ANSWERS

Guide 1

1. False. It is the joint responsibility of the employer and the employee.
2. (b)
3. Labels, Material Safety Data Sheets, and Training.
4. (b)
5. Material Safety Data Sheet (MSDS)
6. Yes, CSA W117.2.

Guide 2

1. 480V (US), 575V (Canada)
2. False
3. The current can pass through the body and return through the ground.
4. Turn off and disconnect the power.
5. False, it is the work lead.
6. To ensure it cannot become live and to ensure the electrode voltage cannot float above the normal OCV.
7. Water decreases the contact resistance and increases the risk of shock.

Guide 3

1. Ionizing radiation. X-rays, γ -rays.
2. (c)
3. Yes
4. 10
5. (b)
6. (a)

Guide 4

1. Electrode
2. Beryllium
3. (c)
4. Time Weighted Average. Average concentration over 8 h period.
5. False. The components, either individually or as a group, could exceed their TLV levels even though the total fume level is below 5 mg/m³.
6. (c)
7. False. Gases are not removed. Most fumes will be removed but not 100%.

Guide 5

1. Argon is heavier than air, helium is lighter.
2. Build-up of argon dilutes the oxygen in the air and could cause suffocation.
3. Action of ultraviolet light on oxygen.
4. Action of UV light on chlorinated hydrocarbons produces phosgene which is highly toxic.

Guide 6

1. False. Continued exposure to high noise levels can cause gradual loss of hearing.
2. (c)
3. $0.5/1 + 0.5/2 + 3/4 = 1.5 > 1$ therefore allowable exposure exceeded.
4. (b)
5. Class B

Guide 7

1. (c) and (d)
2. Acetylene
3. False. Never use any lubricants, oils, or grease on oxy-fuel regulators.
4. Valve or cylinder heads contain fusible plugs which could melt as low as 74°C, well below that of boiling water.
5. No. Reverse flow valves are not designed to stop flashback. A flashback arrester is required.
6. Oxygen: green: RH thread. Fuel gas: red: LH thread.
7. 103 kPa (15 psig).
8. Shut off the torch immediately, oxygen first, then fuel gas. Allow to cool. Check pressures and purge torch with oxygen for a few seconds to clear any soot before attempting to relight.

Guide 8

1. True.
2. There are seven listed on page 69.
3. It does not remove gases. It does not provide air or oxygen and will not be adequate if the atmosphere is oxygen deficient.
4. A rescue system could include the following elements:
 - must have an attendant
 - attendant must be trained in rescue operations
 - use a life line
 - attendant must have an alarm or means for calling for help
 - separate breathing apparatus for rescue operations
5. Vapour could cause explosions, residues could emit toxic gases when heated.
6. False. Do not weld if the contents cannot be determined.
7. Provide a vent. Fill with water or inert gas.

Guide 9

1. (b)
2. X - rays
3. Five examples are listed on page 75.
4. The space defined by all points that could be reached by the robot arm.
5. No.

MODULE 1

TEST

This test is designed to determine whether you are ready to attempt the formal examination.

Complete the ANSWER SHEET and compare the results with the TEST KEY. If you score less than 70% we suggest you re-study the material.

1. What does the symbol denote?



- a) Flammable material
- b) Material causing immediate and serious toxic effects
- c) Material causing other toxic effects such as long term health effects
- d) Material must not be transported
- e) Material has a low melting temperature

2. Which of the following information would not normally be found on a WHMIS supplier label?

- a) Hazardous ingredients
- b) Risk phrases
- c) Precautionary measures
- d) Product identifier
- e) WHMIS hazard symbol

3. Which is the normal maximum open circuit voltage of an AC welding machine?

- a) 25 ~ 30 V
- b) 8 V (r.m.s)
- c) 575 V
- d) 180 V (r.m.s)
- e) 80 V (r.m.s)

4. When using water cooled equipment, how could you prevent condensation on a hose running into the machine?

- a) Ensure the water pressure is high enough
- b) Check all connections for leaks
- c) Place a paper towel in the machine
- d) Provide a drip loop
- e) Run the equipment without water for a while to ensure it is warmed up

5. Which of the following types of radiation would not normally be emitted by an electric welding arc?

- a) γ -rays
- b) Infrared radiation
- c) Ultraviolet (UV) radiation
- d) UV-A (longer wavelength ultraviolet radiation)
- e) Visible light

6. What gas can be produced by the action of arc rays on the air?
- a) Nitrogen
 - b) Oxygen
 - c) Ozone
 - d) Helium
 - e) Argon
7. Why should you never weld when chlorinated hydrocarbon solvents are in the work area or on the workpiece?
- a) Ultraviolet light from the arc can react with the solvent to produce highly toxic phosgene gas.
 - b) The solvent vapours produce "metal fume" fever from which you quickly recover.
 - c) You can weld. There is no danger with any solvent.
 - d) It is alright to weld if you wear a filter mask.
 - e) Ultraviolet light and solvent vapours together cause a bad sunburn.
8. Facepiece respirators with mechanical filters will be effective in—
- a) Removing all fumes and gases in the air
 - b) Making up any deficiency in oxygen in the air
 - c) Removing only ozone
 - d) Reducing the exposure to particulates in the air
 - e) Removing all types of harmful gases
9. What is the maximum gauge pressure that acetylene should be used at?
- a) 103 kPa (15 psig)
 - a) 1030 kPa (150 psig)
 - a) 103 MPa (15 000 psig)
 - d) Twice the oxygen pressure
 - e) Any pressure
10. When welding in a confined space—
- a) a filter mask is sufficient protection
 - b) always work in pairs inside the space
 - c) keep gas cylinders inside the space so they are close to where you work
 - d) there is no need to have the atmosphere checked unless you feel dizzy
 - e) there should always be an attendant outside the space to monitor and summon help in an emergency.

**Canadian Welding Bureau
Answer Sheet - Module 1**

Complete the "Answer Sheet" and compare the results with the "Test Key". If you have a pass mark less than 70%, you are advised to re-study the material.

Please circle only ONE letter corresponding to the answer you think is most correct.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

The answer key below is provided for your use in the event that you wish to retest yourself.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e

**Canadian Welding Bureau
Test Key - Module 1**

Compare your answer sheet to this key.

QUESTION	ANSWERS				
1	a	b	c	d	e
2	a	b	c	d	e
3	a	b	c	d	e
4	a	b	c	d	e
5	a	b	c	d	e
6	a	b	c	d	e
7	a	b	c	d	e
8	a	b	c	d	e
9	a	b	c	d	e
10	a	b	c	d	e