SAFE WORK

S A F E
SPOT THE HAZARD
ASSESS THE RISK
FIND A SAFER WAY
EVERYDAY

EVERYONE'S RESPONSIBILITY

Welding Guide

March 2013

Manitoba

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Welding Guide

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March 2013

Manitoba

WELDING GUIDE

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INTRODUCTION

The intent of this guideline is to serve as a resource for employers and workers to safely perform welding activities. The guideline will provide information on

- types of welding processes
- identified hazards, including: chemical dusts, fumes and vapours, smoke characteristics, carbon monoxide, ozone and other gases, metal contents, noise, poor ergonomic working conditions, electrical hazards, arc light radiation, ultraviolet, visible and infrared light, confined space
- health effects of exposure
- current allowable thresholds and guidelines
- ventilation guidelines
- PPE requirements
- special welding situations
- checklist
- references

For specific guidance applicable to your situation, speak to your supervisor, workplace safety and health representative, safety and health committee member, or Manitoba Workplace Safety and Health.

WORKPLACE SAFETY AND HEALTH REGULATION REQUIREMENTS

The Workplace Safety and Health Act, Part 17, Part 36 and other parts of the Manitoba Workplace Safety and Health Regulation (M.R. 217/2006) require specific actions to be taken to protect workers during the welding process.

REFERENCE STANDARDS/DOCUMENTS

1. CAN/CSA Standard W117.2-06 (R2011), *Safety in Welding, Cutting and Allied Processes*
2. *Welders Health and Safety Guide* prepared by the Canadian Centre for Occupational Health and Safety
3. *Threshold Limit Values (TLVs)* and *Biological Exposure Indices (BEIs)* by the American Conference of Governmental Industrial Hygienists (ACGIH)

> ***Note:***
> ***Standards Information Sheets are available from Workplace Safety and Health.***
> They summarize general requirements of standards listed above. However, users are encouraged to obtain full copies of standards.

RISK EVALUATION

When assessing the workplace for welding hazards, it is important to conduct a complete risk evaluation. This evaluation can be done in the form of a job hazard analysis, where the work task is broken down into individual steps that are then analyzed to determine the hazards. Once the hazards have been identified, control measures and safe work procedures are developed and put in place to prevent injuries.

For more information on conducting job hazard analysis and developing safe work procedures please see Workplace Safety and Health's SAFE Work Bulletins: 249(1) and 249(2).

SAFE WORK PROCEDURES

Employers must develop, and put safe work procedures in place for welding and allied processes before beginning work on a project. (See SAFE Work Bulletin # 249(2) for more information and a sample safe work procedure.)

WELDING HAZARDS AND CONTROL MEASURES

WHAT IS WELDING?

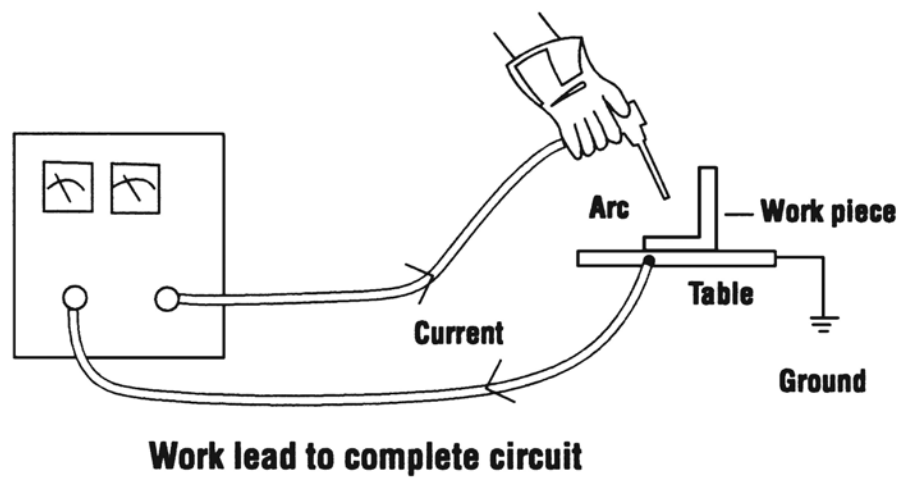
The welding process joins metals together using pressure, heat, flame and/or electric arc.

In the welding process, a filler metal and work pieces are heated using an electric arc or combustion gas. As the metal is heated a fine metal fume is formed, usually with visible smoke. For welders, inhalation is the primary route of exposure to fumes.

Ninety per cent of welding fumes come from the melting of the consumable electrode (rod) or wire. In the weld, the filler metal used is similar to the metal being welded. Some electrodes are coated and some wire consists of a metal sheath filled with a flux (flux-cored wire).

Fume composition is a mix of the base metal, flux and consumable wire or electrode used in the weld. Refer to the *Material Safety Data Sheets* (MSDS's) provided by the supplier.

Figure 1: **Welding Circuit**



A cable from the welding gun connects to the welding machine. Electric current flows through the cable and the electrode/wire, which then passes the current to the work piece being welded. The closed loop allows the current to be returned to the power supply via the work-return lead.

TYPES OF WELDING PROCESSES

There are three common types of welding processes

A. Electric arc welding
B. Combustion gas welding
C. Laser and applied processes

A. Electric Arc Welding

Electric arc welding uses an electric arc (a continuous electrical discharge) to generate temperatures of 3,000º to 30,000ºC. The electric arc is maintained at the gap between the work piece and the electrode. The arc is manipulated so that molten metal from the work piece and the electrode or wire form a common puddle, which forms the weld as it cools.

Types of Electric Arc Welding

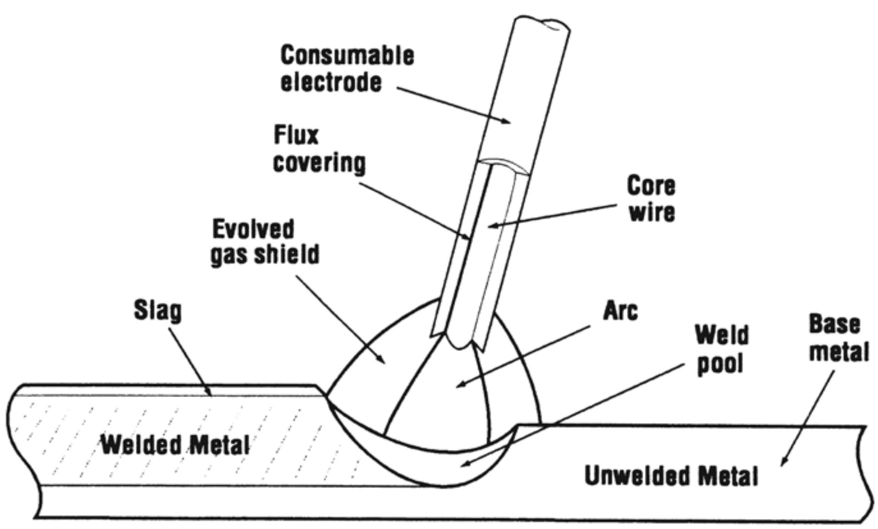
1. **Shielded Metal Arc Welding (SMAW)** *See Figure 2*

   Shielded Metal Arc Welding (SMAW) is the most common type of welding used in maintenance and repair work. SMAW is also referred to as manual, electrode or stick welding. In this welding process, an electric arc is drawn between the tip of an electrode and the metal being welded.

   The electrode has a metal core, which is covered with a flux or coating. In the consumable electrode process, the electrode is used up as the work piece is welded. The flux shields metal ions in the arc from the atmosphere and ensures arc stability. As the flux burns, it produces airborne gases and a slag blanket is formed to protect the hot weld metal from the atmosphere as it cools.

   SMAW is widely used in maintenance and repair applications on mild and stainless steel, aluminum and non-ferrous metals. SMAW has limited application in the workplace, since the welding must stop to replace the consumed electrode. SMAW is replaced in the welding industry with continuous wire processes.

Figure 2: **Shielded Metal Arc Welding (SMAW process)**

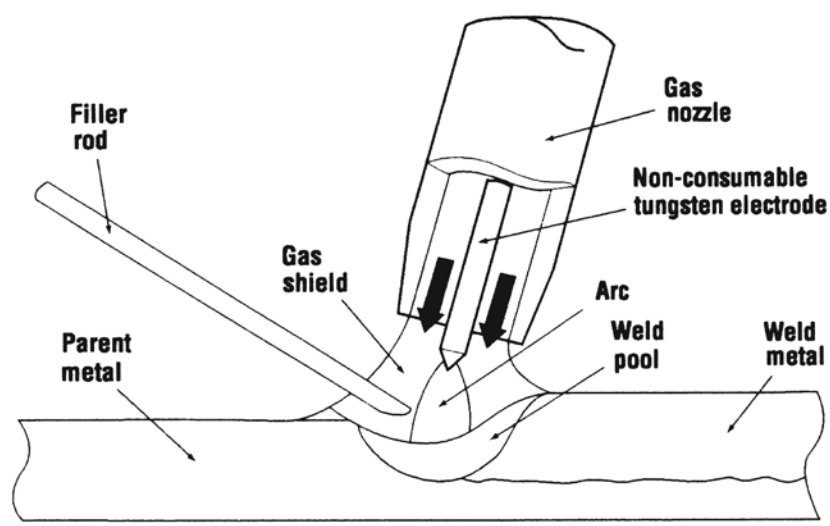


2. **Gas Tungsten Arc Welding (GTAW)** *See Figure 3*
   Gas Tungsten Arc Welding (GTAW) is also referred to as tungsten inert gas (TIG) welding. In GTAW, an electric arc is established between the work piece and the tungsten electrode. In contrast to SMAW, this is a non-consumable electrode process. The arc is protected by a flow of a shielding gas, commonly argon (also helium or a mixture of these two gases), which protects the weld zone from atmospheric gases. The arc can fuse two metals together without the use of a filler metal. A hand-held filler rod can be placed near the arc and melted to fill any gaps. GTAW is commonly used to weld aluminum. It also can be used to weld mild or stainless steel.

   Ultraviolet (UV) light from the electric arc is intense and ozone gas is produced. GTAW produces no slag and produces small amounts of fume. The tungsten electrodes contain small amounts of thorium (< four per cent), which readily converts to thorium oxide once burned. Thorium is a radioactive metal and is an inhalation and ingestion hazard.

   Because of the violent reaction of the electrical arc, the non-consumable tungsten electrode must be kept in a clean state. This normally requires that the tip (electrode) be ground with a special grinding wheel.

Figure 3: **Gas Tungsten Arc Welding (GTAW)**

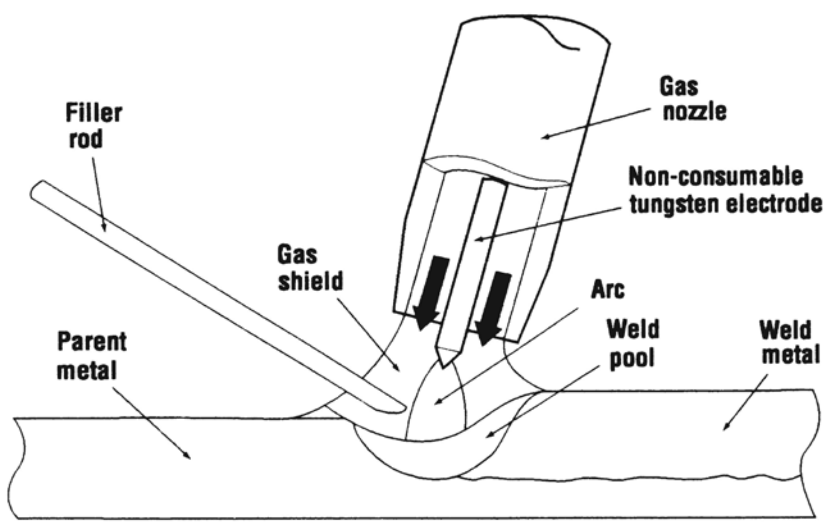


3. **Gas Metal Arc Welding (GMAW)** *See Figure 4*

The Gas Metal Arc Welding (GMAW) process is referred to as hard wire or metal inert gas (MIG). In this type of welding, a continuous solid wire is also supplied through the welding gun from the wire feeder. Shielding is provided by an inert gas, commonly argon (also helium or a mix of these two with carbon dioxide). There is no slag produced because no flux is used in this type of welding.

GMAW is used throughout the industry primarily for welding mild steel, but also copper, nickel, stainless steel, magnesium and aluminum.

Figure 4: **Gas Metal Arc Welding (GMAW)**

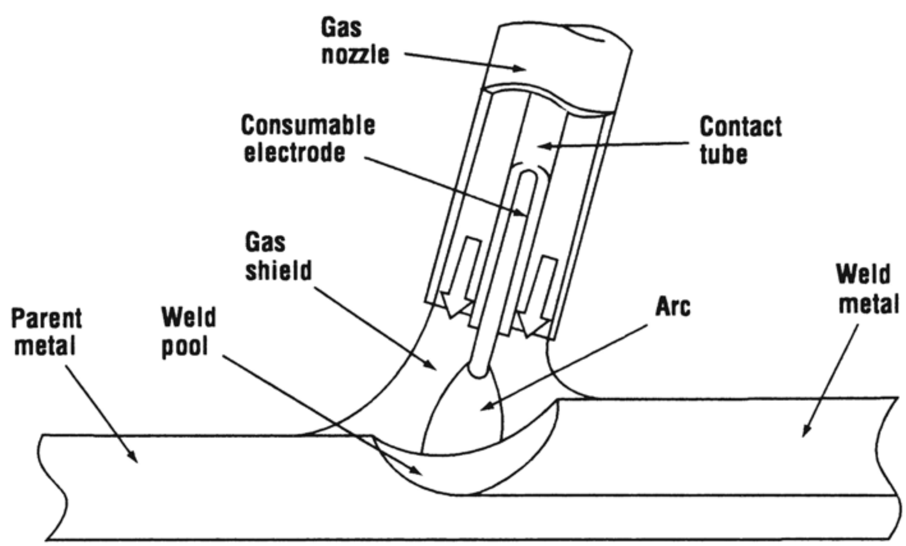


4. **Fluxed Cored Arc Welding (FCAW)** *See Figure 5*
   The Fluxed Cored Arc Welding (FCAW) process is also referred to as fluxed cored.

   In FCAW, a continuous solid wire is fed through the welding gun from a wire feeder. The wire consists of a metal sheath filled with a flux. The flux helps to establish the arc, provides additives to the weld and produces a slag.

   In gas-shielded FCAW, the shield gas (mix of carbon dioxide and inert gas) is used to protect the arc. In self-shielded FCAW, the flux burns to produce the shielding gas and slag. FCAW is used to weld mild and alloy steel and generates large amounts of fumes.

Figure 5: **Fluxed Cored Arc Welding (FCAW)**



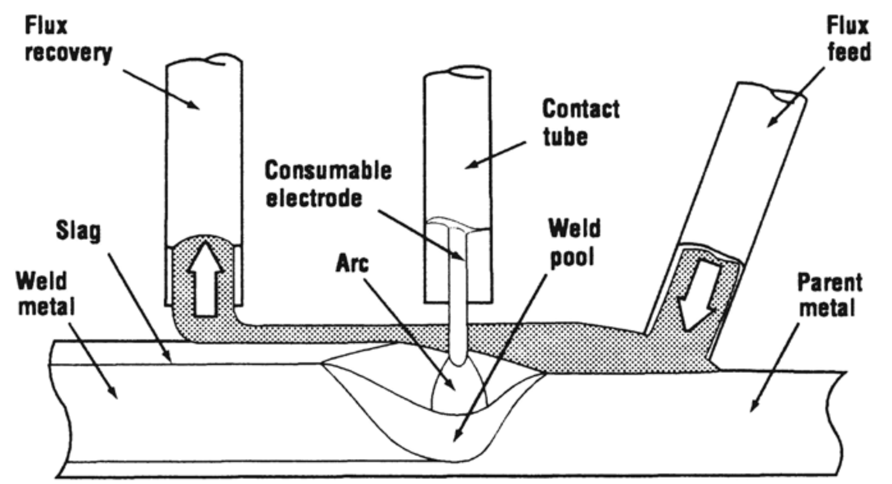
5. **Plasma Arc Welding (PAW) and Plasma Arc Cutting (PAC)**
   The plasma processes use a non-consumable tungsten electrode and a shielding gas, similar to TIG welding. The plasma torch uses a constriction cup, which forces the arc out into a narrow jet.

   When the diameter of the constriction cup is reduced, a finer arc jet is produced which can be used for cutting or gouging applications. Arc cutting is the process in which the heat of an arc between the base metal and the electrode cuts the metal. In plasma arc cutting (PAC), the metal is cut by melting an area with a constricted arc and removing the molten material with a hot high-velocity jet of ionized gas. PAC can be conducted under a water blanket on a water table, which traps noise, arc light, gases and fumes.

   During the PAC and PAW processes, the arc jet released into the air produces ozone and nitrogen oxides and high frequency noise (range 95 to 100dBA). PAW generates low amounts of fumes compared with other processes. PAC generates higher amounts of fumes, noise and ozone levels than PAW except when cutting is done under a water blanket.

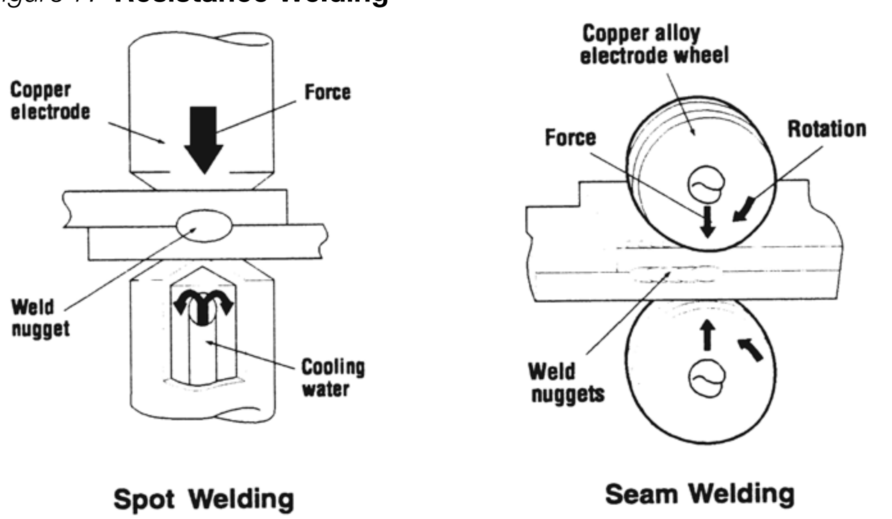
6. **Submerged Arc Welding (SAW)** *See Figure 6*
   In submerged arc welding (SAW), the arc is buried under a granular flux bed. The flux traps noise, light, gases and fumes. SAW uses a consumable electrode. The tip of the electrode and the welding zone are surrounded and shielded by the molten flux and the layer of unused flux in the granular state. No visible evidence of the passage of the current between the electrode and the work surface is evident. Fumes are generated, but in lesser quantities compared with other welding processes.

Figure 6: **Submerged Arc Welding (SAW)**



7. **Resistance Welding** *See Figure 7*
   Resistance welding is also referred to as spot, flash or seam welding. The weld is produced by pressure applied at the electrode contact points and heat from the electric current. The electrodes are commonly copper or copper-beryllium alloy. No filler metal or flux is used. Moving parts, such as tongs, tips, and linkages can injure fingers and hands.

Figure 7: **Resistance Welding**



Three Types of Electrodes for Electric Arc Welding

Ninety percent of the welding fumes from electric arc welding come from the melting of the consumable electrode. The coating and flux contributes towards the chemical composition of the fumes. There are three basic types of electrodes.

1. **Solid electrodes** produce less fumes compared with flux-cored wire or coated electrodes. Fume production is directly related to the amount of consumed electrode. Electrodes are **consumable** (composed of steel, copper, aluminum, various alloys and other metals) or **non-consumable** (primarily tungsten).

2. **Covered and coated electrodes** are the largest group of electrodes used in welding. The covering provides the flux for the weld. Major metals from the coatings include fluoride, nickel, iron, chromium, manganese, copper and molybdenum. Fluoride tends to be the largest component in the fume composition, ranging from 10 to 20 per cent.

3. **Bare rods or wire** are immersed in the flux material and fume generation is greatly reduced. Bare rods or wire are typically composed of copper alloys, steel, nickel alloys and nickel.

B. Combustion Gas Welding

Gas welding uses the heat from the combustion of oxygen and one of the following gases: acetylene, propane, hydrogen or butane. In this welding process, the filler electrode is introduced by hand. It is used for repair work and light sheet metal. The flame temperature in combustion gas welding is lower than in electric arc and is considered less hazardous.

Gases used in welding and cutting processes

- shielding gases, ex: argon, carbon dioxide, helium
- fuel gases, ex: propane, acetylene, butane
- oxygen

C. Laser and Allied Processes

Laser Welding and Cutting

Lasers use electricity to create coherent light, which is very different from ordinary non-coherent light, such as that from a light bulb. Coherent light can be tightly focused, as opposed to diffused or scattered ordinary light. This coherent light beam can be focused to cut or weld metals.

Thermal Spraying

Thermal spraying is a group of processes that deposit molten metallic or non-metallic surfacing materials onto a prepared substrate. All thermal spraying processes introduce a feedstock (usually a powder or wire) into a heating device (combustion or electrical).

Brazing, robotics and other allied processes can be found in the Special Welding Situation section of this guideline.

WELDING HAZARDS

Airborne hazards include fumes and gases.

Airborne Hazards – Fumes

Fumes are very fine solid particulates formed when a metal is heated above its boiling point. Fumes are created by condensation from the metal vapour state. Welding fume particles are generally less than 1 micron (u) in diameter **(one millionth of a meter – 1u)**. Welding fume particles penetrate into the alveoli region of the lung. All welding processes produce fumes, but the quantity varies widely depending on the process.

Note: Fumes may be present during welding whether a smoke plume is visible or not. Welding smoke is an example of visible fumes.

The health hazard of fumes depends on

- amount of fume produced
- presence of specific metals and gases

Fumes are generated by

- vaporization of elements and oxides from the arc area (near electrode tip)
- rapid condensation of the vapours to form solid particles

Major sources of fumes

- electrode metal
- flux material
- coatings, residues, oils, rust inhibitors, solvent-based paints, primers on the base metal

Consumable electrode process: Here the electrode is consumed in the weld. Fumes originate from the electrode, electrode coating or fluxes. The base metal being welded contributes a small portion.

Non-consumable electrode process: Here, fewer fumes are generated compared with the consumable electrode process. Fumes are primarily generated from the base metal being welded and the filler rod.

Some welding processes generate more welding fumes than others.

Highest levels:	flux core arc welding (FCAW) shielded metal arc welding (SMAW) gas metal arc welding (MIG)
Lowest levels:	gas tungsten arc welding (TIG)

Note: A lower fume concentration may result in higher concentrations of ozone and nitrogen oxide gases.

Fume generation rate can be altered by

a. **Voltage** – As the voltage increases, more fumes are generated.

b. **Arc length** – As the arc length increases, more fumes are generated.

c. **Current** – As the current increases, more fumes are generated. The exception is GMAW of aluminum where higher currents generate less airborne fumes.

d. **Electrode diameter** – A smaller diameter electrode results in more fumes.

e. **Electrode polarity** – 30 per cent more fumes are generated by welding DC positive, compared with DC negative or AC.

f. **Shielding gas** – The composition of the shielding gas can significantly affect the fumes generated. An argon and carbon dioxide mix reduces fume generation up to 25 per cent, compared with using only carbon dioxide.

g. **Composition of the base metal, fluxes and fillers (refer to MSDSs)** – A system has been developed by the American Welding Society to classify all consumable welding electrodes and rods. Every manufactured welding rod and electrode is referenced back to an MSDS. All welders are encouraged to refer to the information contained in the MSDS.

h. **Effectiveness of the existing ventilation system (general dilution vs. local)**

i. **Welder's work practices and years of experience** – When the distance between the work piece and electrode tip is increased, more fumes are generated (more vaporized metal is exposed to the environment).

j. **Wire feed speed –** As the feed speed increases, more metal is used and fume generation increases.

k. **Humidity** – In humid environments, the amount of fume generated increases due to absorption by fluxes.

l. **Position of weld** – A flat horizontal weld produces fewer fumes, compared with an overhead or vertical weld.

Airborne Hazards – Gases

The following gases are produced from the

- burning of shielding gases and fluxes
- interaction of ultraviolet light or high temperatures with atmospheric gases
- shielding gas

a. **Ozone (O_3)** – is produced during the ionization of oxygen (O_2) by the ultraviolet light (UV) from arc welding. **$UV + O_2 = O_3$**

   Hazard: Ozone is irritating to the eyes and mucous membrane and can cause pulmonary edema and chronic respiratory disease.

b. **Carbon Monoxide (CO)** – created from the effects of ultraviolet on carbon dioxide (CO_2) in the shielding gas. **$UV + CO_2 = CO$**

   Carbon monoxide is a chemical asphyxiant. Exposure to carbon monoxide reduces the body's capacity to carry oxygen, by reducing or altering the haemoglobin found in blood. This can result in a condition known as anemic hypoxia, characterised by severe headaches, blue discoloration of the skin, nausea, shortness of breath and fatigue.

Carbon monoxide is an odourless and colorless gas. Acute symptoms of carbon monoxide poisoning include dizziness, headache and mental confusion.

Hazard: The airborne concentration of carbon monoxide generated from the welding process was determined to be < 5 ppm (measured at source) as per a Manitoba Workplace Safety and Health (WSH) welding proactive study, conducted in 1998-99, the results of which were compiled to inform this guideline.

Note: A poorly adjusted flame will result in higher amounts of carbon monoxide.

c. **Carbon Dioxide (CO_2)** – from the burning of fluxes. Carbon dioxide is classified as a simple asphyxiant. It displaces oxygen, reducing the amount of oxygen available in the air. Oxygen depletion may cause dizziness, disorientation, inattention, unconsciousness or even death if the level of oxygen drops too low. The minimum acceptable oxygen content in the air is 19.5 per cent.

d. **Nitrogen Oxides (NO, NO_2)** – formed from the heating of atmospheric oxygen and nitrogen (in the presence of ultraviolet light). The oxide usually consists of nitrogen dioxide (NO_2) and nitric oxide (NO). NO_2 is the dominant oxide present in the fume. NO_2 is irritating to the eyes, nose and throat at low concentrations (10-20 ppm) and at higher concentrations results in pulmonary edema.

e. **Hydrogen Chloride (HCl) and Phosgene ($COCl_2$)** – produced by the reaction between ultraviolet light and vapours from chlorinated hydrocarbon de-greasing solvents. Both of these gases irritate and can damage the respiratory system.

Particulates (Dusts and Sparks)

There are sampling methods for assessing the airborne concentration of welding fumes and gases. The simplest and least expensive method is the gravimetric (weight) method. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends an exposure limit of **3 mg/m^3 for respirable dust and 10 mg/m^3 for inhalable dust** TLV-TWA (threshold limit value-time weighted average) for welding fumes.

The gravimetric method determines the total particulate weight of all aerosols including metals in the smoke generated from the welding process. NIOSH Method # 0500 is used.

For specific concentration of fumes and gases the following may be used

- commercial air sampling personal pumps with approved NIOSH method
- direct reading instrumentation or monitor

Chemical Composition of Welding Fumes and Gases

Welding fumes are a complex mixture of metallic oxides, fluorides and silicates. A summary of the common gases and metals most frequently encountered during welding processes in Manitoba workplaces are outlined below, followed by the health effects of exposure to them.

Type of Welding	Metal	Gases
Shielded Metal Arc Welding (SMAW) a. Mild steel welding (MIG) b. Stainless steel	a. iron oxide and manganese b. nickel, chromium and manganese	a. ozone and nitrogen oxides b. fluorides
Gas Metal Arc Welding (G)	nickel, chromium and manganese	ozone and nitrogen oxides
Gas Tungsten Arc Welding (GTAW)	aluminum oxide	ozone and nitrogen oxides
Submerged Arc Welding (SAW)	metal fumes*	fluorides
Plasma Arc Welding (PAW)	metal fumes*	ozone and nitrogen oxides
Plasma Arc Cutting (PAC)	metal fumes*	high levels of ozone and nitrogen oxides

*Depends on composition of work piece being welded

Primary Health Effects of Exposure to Fumes

Lung Irritation/Injury/Cancer

- Lung, nose and throat irritation, bronchitis, emphysema and asthma.
- Welders suffer a greater incident of bronchitis, compared with the general population.
- 40 per cent more lung cancer diagnoses reported among welders, compared with the general population.

Metal Fume Fever

- This occurs after exposure to high concentrations of magnesium (Mg), copper (Cu) and zinc (Zn).
- This acute condition occurs when a freshly formed fume is inhaled.
- Symptoms develop eight to 12 hours after exposure and tend to subside after 24 to 48 hours.
- Symptoms include: fever, headache, cough, chest pains, chills, muscle aches and metallic taste.
- Zinc is the major component of the galvanized coatings used on steel and is the most frequently used metal that can cause metal fume fever.

Other Identified Health Effects from Metal Exposure

- **Iron Oxides** – Siderosis (benign lung condition).
- **Manganese** – Chronic exposure results in central nervous system problems similar to Parkinson's disease.
- **Cadmium** – Affects the respiratory system (chest pain and difficulty breathing). Long-term exposure can cause kidney damage – Biological Exposure Index (BEI) 5ug/g creatinine.
- **Chromium** – Associated with skin ulceration, perforated nasal septum and an increased risk of lung cancer.
- **Fluorides** – Acute effects: eye, nose and throat irritation, chronic effects: pulmonary edema.
- **Lead** – Blood lead level: 30 ug/100 ml (ACGIH BEI), no safe level of exposure to lead. chronic effects: anemia, fatigue, abdominal pain and kidney damage.
- **Nickel** – Acute effects: eyes, nose, throat and skin irritation, chronic effects: increased risk of nasal and lung cancer.

Noise Hazards

Sources of Noise

Noise originating from the metal fabrication processes can pose a hazard to workers (ex: metal to metal impacts, materials handling, metal working, grinding/drilling).

Noise levels in Manitoba welding workplaces determined from the 1998-1999 WSH welding proactive study were found to be at least 80 dBA in shops that were continuously welding and in the smaller shops that were spot welding (> 80 dBA requires the implementation of a hearing conservation program). Most welding shops were > 85dBA, requiring mandatory hearing protection as per Part 12 of the Manitoba Regulation 217/2006. High noise levels (levels > 85dBA) pose a significant hazard. Chronic exposure without hearing protection will lead to noise induced hearing loss.

Methods of Noise Control

- administrative controls: relocate welders away from noisy areas to reduce exposure to excessive levels
- engineering controls: replace noisy operations with quieter equipment, quieter processes or quieter materials
- reduce the driving force in mechanical equipment: decrease speed, maintain dynamic balance, provide vibration isolation and increase the duration of impact while reducing the force
- reduce the response of vibrating surface
- increase sound absorption
- use of equipment noise enclosures
- use of personnel noise enclosures
- use of shield(s) or barrier(s)

Radiation Hazards

Welding and cutting can produce four types of radiation

- intense visible (VIS) light
- ultraviolet (UV) radiation
- infrared (IR) radiation
- laser

Welding arcs emit intense ultraviolet (UV) radiation. UV radiation in the welding arc will tan and burn the skin, similar to UV radiation from sunlight. Long-term exposure to UV radiation can cause skin cancer.

UV radiation to the eye injures the cornea and mucous membrane and is referred to as welder's flash, arc eye or arc flash. The medical term for this condition is photokeratitis and photoconjunctivitis.

Welder's Flash

The cornea of the eye becomes inflamed when exposed to ultraviolet (UV) light. Symptoms develop four to six hours after exposure and tend to subside after 24 hours.

Symptoms include

- sensation of sand in the eyes
- ranging from a feeling of pressure in the eyes to intense pain
- tearing and reddening of the eye membranes
- photophobia: inability to look at a light source

UV exposure levels

Highest levels:	plasma arc welding (PAW) gas metal arc welding (MIG) shielded metal arc welding (SMAW)
Lowest levels:	gas tungsten arc welding (TIG)

Visible and infrared light are also emitted and are a hazard both to the welder, and non-welders in the area. Hazards associated with these two forms of radiation are considered to be less dangerous to the eye.

Ergonomic Hazards

Preventing Musculoskeletal Injuries

This job puts physical demands on the welder's wrist, elbows, arms, shoulders and neck, due to the awkward postures and forceful exertions required. Musculoskeletal injuries (MSI) are common among welders, with female welders often at additional risk due to poor equipment design. The following recommendations can reduce the incident of MSI among welders.

Maintain good posture

- Improve workbench design (seated or standing).
- Use positioning aids to accommodate work posture (examples provided in Figure 8).
- Keep spine straight and elbows close to the body.
- When awkward postures are unavoidable, take regular, short breaks to move the affected body parts.

Minimize force required

- Choose handles that fit the size of your hand.
- Choose a tool with an appropriate weight. The smokeless gun (see Figure 15) which has a fume extraction nozzle that covers the welding gun to capture fumes is heavier. This places additional strain on the wrist, elbow and shoulder, especially for female welders.
- Be careful when manipulating work pieces. Use jigs or cranes when they are available.

Avoid repetition of inappropriate movements

- Use your hands to lower the welding mask instead of using your neck. This nodding motion puts a great deal of stress on the neck and upper back.

Note: The welder's head should be as far from the welding plume as possible. It's common for welders to work very closely to the piece being welded.

Figure 8: **Workbench and Lifts**

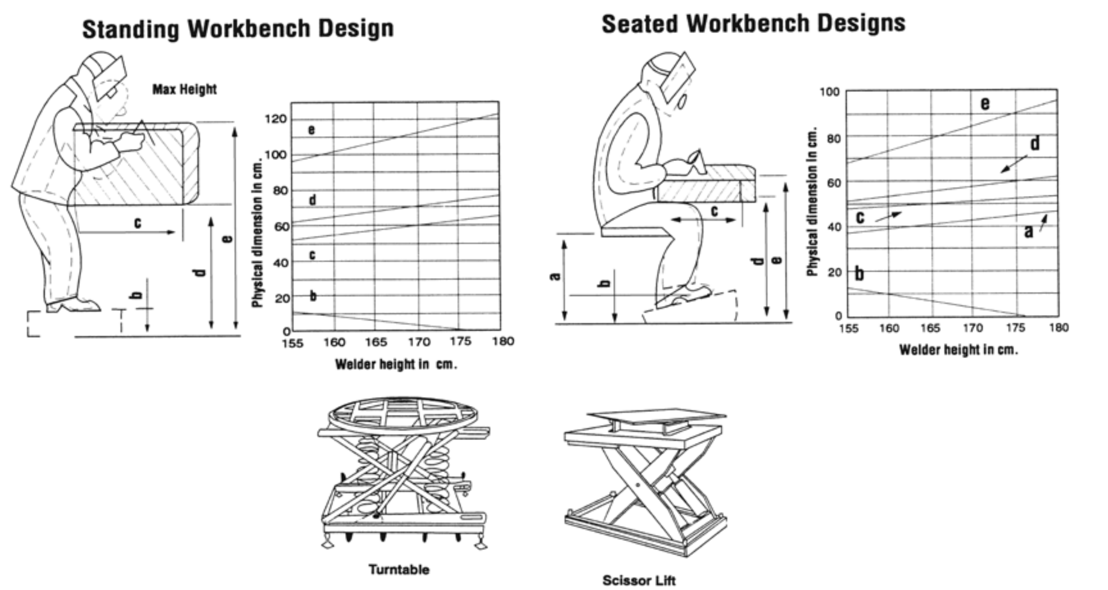
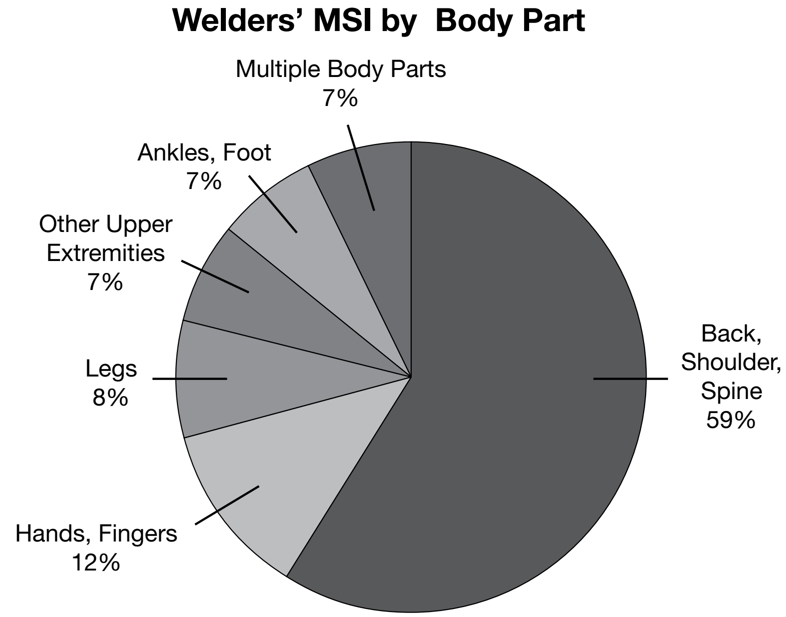
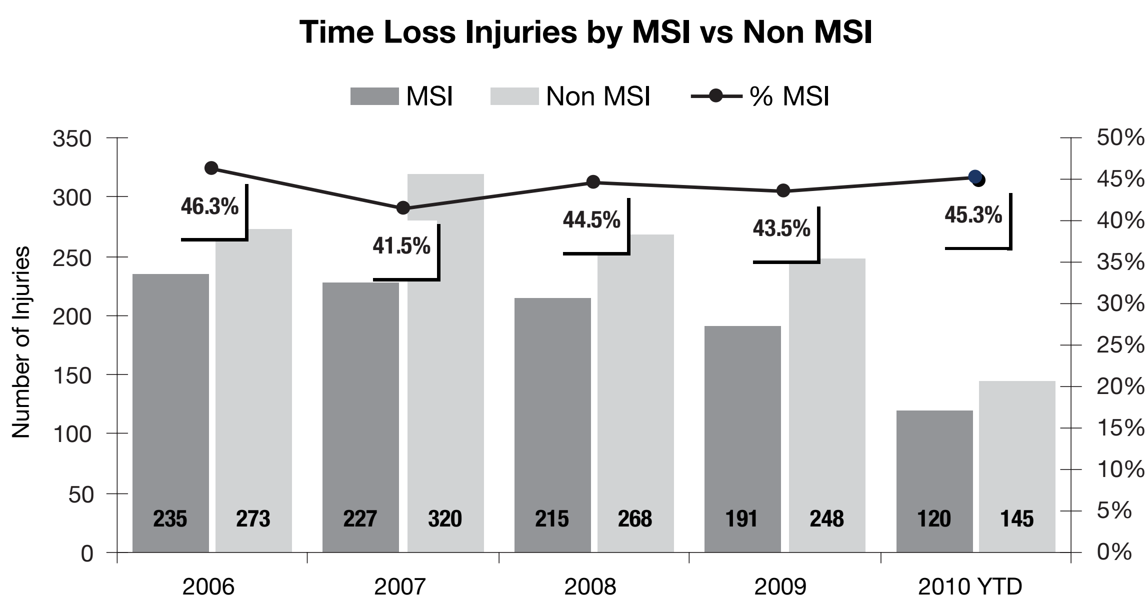


Figure 9: **Musculoskeletal Injuries (MSI)**





Electrical Hazards

In arc welding, an electric arc supplies the energy required to bond work pieces together. The electricity is generated from welding machines, which are designed to use either alternating current (AC) or direct current (DC). DC machines may be powered by a rotating generator or by a transformer/rectifier. AC machines are powered by transformers using line voltage.

Electrical current can pass through a conductive material into your body, causing a shock. Electric shock from welding and cutting equipment can result in death or severe burns. Serious injury can also occur if the welder falls as a result of the shock.

Safety precautions are required when welding is performed
- in damp locations or while wearing wet clothing
- on metal scaffolds, floors, gratings, or other metal structures
- in cramped positions
- when there is a high risk of contact with the work piece or ground.
- when using incorrectly installed, or improperly grounded equipment

Electricity used in welding is available as
- single phase, 120 V or 240 V
- three phase, 575 V
- the voltage drops to 15 to 30 V once the arc is established and the current is flowing

Typical welding currents are between 150 Amperes (A) and 500 A for manual welding, and higher for semi-automated and robotic welding.

The most common electrical hazard is electrical shock. Spasms, burns, muscle paralysis or death can result depending on the amount of current flowing through the body.

Ensure that the welding machine is grounded to the electrical panel input into the building and ground the work piece separately.

Continuous welding wires are on a spool (wire which is advanced by a wire feeder) and the current is conducted through the electrode. The wire spool is live while the wire is being fed.

Arc welding, which requires high electrical currents, is also a source of
- **magnetic fields** – the strength of the magnetic field increases as the electrical current increases
- **strong magnetic fields** – may affect pacemakers

The long-term effects of magnetic fields are less well-understood.

Welders should all be trained on electrical safety procedures. Equipment inspection should be conducted daily/regularly as required.

Burn Hazards

Burns in the welding process are caused by two sources
- **thermal:** skin burns from hot metal, spattering slag and handling hot tools or electrodes
- **erythemia:** skin burns primarily by ultraviolet light

Fire and Explosion Hazards

- Oxyfuel processes involve the use of oxygen and fuel gases.
- Some fuel gases (ex: acetylene) are lighter than air and rise to the ceiling.
- Other fuel gases (ex: butane and propane) are heavier than air and settle on the floor.
- Flammable mixtures of fuel gases can ignite and cause a fire.
- Any oxygen leak can enrich the atmosphere, making a fire/explosion difficult to extinguish.

Before welding or cutting begins, precautions must be taken to prevent a fire or explosion. If possible, the object to be welded or cut should be moved to a location free of fire hazards. If the object cannot be moved, all fire hazards should be moved at least fifteen meters (fifty feet) away from the welding area.

Adequate ventilation in the workplace is required to prevent the displacement or enrichment of oxygen and the accumulation of other flammable gases.

Other Hazards

Tripping and Falling

Welding, cutting and associated processes take place in a wide variety of locations and under many conditions. As such, there are many causes for tripping or falling, including

- poor housekeeping of materials, equipment, hoses, and tools
- scattered parts and pieces, either leftover or waiting for use
- failure to use safety belts and harnesses, or incorrect use of them when working above floor level
- incorrect use or installation of safety equipment such as ladders, guardrails, scaffolds and nets
- failure to wear proper personal protective equipment such as skid-resistant soles on shoes
- horseplay or unsafe actions, such as tossing tools or bumping someone in a precarious position
- restricted vision caused by safety gear such as welding helmets and safety goggles

Cuts and Lacerations

Welding and cutting are seldom done in isolation. Other equipment and tools are normally used and kept nearby. The use of, or the proximity to, mechanical equipment can present hazards. Knowledge of the proper use of power tools, such as grinders, chippers, drills and various hand tools, is also important to welder safety. Follow these recommendations to avoid common mechanical hazards.

- Do the job faster and safer by using the right tool for the job and ensure that tool is the right size.
- Keep a firm grip on tools to prevent them from slipping away.
- Do not overload or force a tool beyond its capabilities.
- Check for damage before reusing a tool that was jammed or otherwise overstressed.
- When using tools that involve weights and spring tension, be certain that all pressures are applied and released safely.
- Follow lockout procedures for equipment and tools which specify such a procedure.
- Inspect tools before use. Never use a tool that is in poor or faulty condition.
- Store hand tools in a safe place. Many accidents are caused by tools falling off ladders, shelves, or scaffolds being moved. Each tool should have a designated place in the tool box or electrician’s pouch.

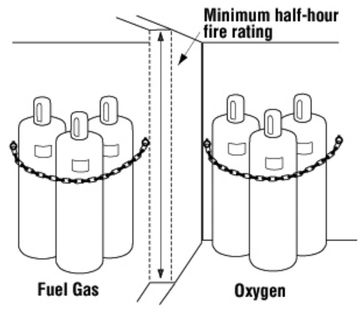
For more information of the safe operation and guarding of mechanical equipment, refer to the manufacturer’s safe operating procedures.

Grinding Wheels

- Follow grinding wheel speed limitations according to manufacturer's instructions.
- Do not grind on the side of a wheel not designed for such service.
- When starting a new wheel, stand to the side until it reaches speed and correct any abnormalities noted.
- Ensure guards are in place and properly used.
- Wear proper eye and hand protection.
- Use a face shield, safety glasses and goggles as required.
- Avoid wearing loose items such as rings, necklaces, bracelets, long hair, loose clothing, neckties, scarves, earrings and beards.

Cylinders/Tanks

- Ensure valve caps are in place and secured tightly.
- When cylinders are hoisted, they should be secured on a cradle, sling board or pallet.
- Move cylinders by tilting and rolling them on their bottom edges. They should not be intentionally dropped, struck or permitted to strike each other violently.
- Secure cylinders in a vertical position when they are transported by powered vehicles.
- Do not use valve caps to lift cylinders from one vertical position to another.
- Close valves when cylinders are moved or not in use.
- Ensure compressed gas cylinders are in an upright position at all times.
- Separate stored cylinders containing oxidizing materials, from fuel-gas cylinders or combustible materials – especially oil or grease. Distance required: a minimum of six meters (20 feet), or with a non-combustible barrier that is at least 1.5 meters high (five feet) and with a fire resistance rating of at least one half hour.



- Inside of buildings, store cylinders in a well protected, well ventilated, dry location, at least 6.1 metres (20 feet) from highly combustible materials such as oil.
- Store cylinders away from elevators, stairs, or gangways. Locate assigned store places where cylinders will not be knocked over or damaged by passing or falling objects, or subject to tampering.
- Use a suitable cylinder truck, chain or other steadying device to keep cylinders from being knocked over while in use.
- Keep cylinders far enough away from actual welding or cutting operations so that sparks, hot slag or flame will not reach them. Provide fire-resistant shields when this is impractical.
- Place cylinders where they cannot become part of an electric circuit. Do not strike an electrode against a cylinder to create an arc.
- Place fuel gas cylinders with valve end up whenever they are in use.
- Do not take cylinders containing oxygen or acetylene or other fuel gas into confined spaces.
- Do not use fuel gas from cylinders through torches or other devices which are equipped with shutoff valves without reducing the pressure through a suitable regulator attached to the cylinder valve or manifold.
- Do not crack the valve before connecting the regulator to the cylinder. The valve should be opened slightly and closed immediately. It is intended to clear the valve of dust or dirt that might enter the regulator. The person cracking the valve should stand to one side of the outlet, not in front of

it. And do not crack the valve where the gas would reach welding work, sparks, flame, or other possible sources of ignition.

- Always open the cylinder valve slowly to prevent damage to the regulator. For quick closing, valves on fuel gas cylinders should not be opened more than one turn. When a special wrench is required, it should be left in position on the stem of the valve while the cylinder is in use so that the fuel gas flow can be shut off quickly in case of an emergency. In the case of manifolded or coupled cylinders, at least one such wrench should always be available for immediate use. Do not store items on cylinders that may interfere with the quick closing of the valve.
- The cylinder valve should always be closed and the gas released from the regulator before a regulator is removed from a cylinder valve.
- Close the valve and tighten the gland nut if there is a leak around the valve stem. If this does not stop the leak, do not use the cylinder. It should be properly tagged and removed from the work area. If a regulator attached to a cylinder valve will effectively stop a leak through the valve seat, the cylinder need not be removed from the work area.
- Remove the cylinder from the work area if a leak develops at a fuse or other safety device.
- Do not store compressed gas cylinders near elevators, stairs, aisles or emergency exits.

BASIC WELDING CONTROL MEASURES

Substitute Welding Wires to Reduce Hazards

Substitution implies the use of welding electrodes with a less hazardous composition, but without altering welding or metallurgical characteristics. Some manufacturers are introducing a new **low smoke welding wire**, which they claim meets the requirements for a given electrode class and generates less fume and smoke compared with the conventional consumable rods. Another example of substitution in welding is the use of **low manganese welding wire**. Manganese is a known carcinogen, found in welding rods and wire.

Ensure Proper Ventilation to Reduce Contaminant Levels

Ventilation recommendations

- Hood designs should be chosen based on their level of effectiveness. Enclosing hoods are the most effective in controlling welding contaminants. Dilution – or general – ventilation is the least effective ventilation technique, but was the most commonly encountered in Manitoba welding shops.
- Integrate the planning for the ventilation systems with materials handling.
- Place welding curtains or other barriers to prevent cross-drafts.
- Avoid recirculating filtered air from the welding hoods back into occupied spaces. Most filtering devices do not adequately remove gases.
- Face velocity for enclosing hoods ranges from 100-130 fpm – higher face velocity may be required where cross-drafts exist.
- Capture velocities for non-enclosing hoods range from 100-170 fpm.

General Ventilation Can Address Low Concentrations of Contaminants

In general ventilation, large amounts of air are introduced into a workplace by mechanical intervention (ex: installation of exhaust fans). General ventilation dilutes the contaminant in the workplace, but does not remove it. This type of ventilation is commonly installed when the contaminants are not considered to be toxic and contaminants are generated at a uniform rate. MIG welding of mild steel produces iron oxide fumes, which are not considered as toxic as other welding by-products.

The Industrial Ventilation Manual, A Manual of Recommended Practice recommends the following requirements for installations when local exhaust ventilation systems cannot be applied.

Rod Diameter	CFM/Welder
5/32	1000
3/16	1500
1/4	3500
3/8	4500

OR

a. For open areas where welding fumes can rise away from the breathing zone:
CFM required = 800 X lb/hour rod used

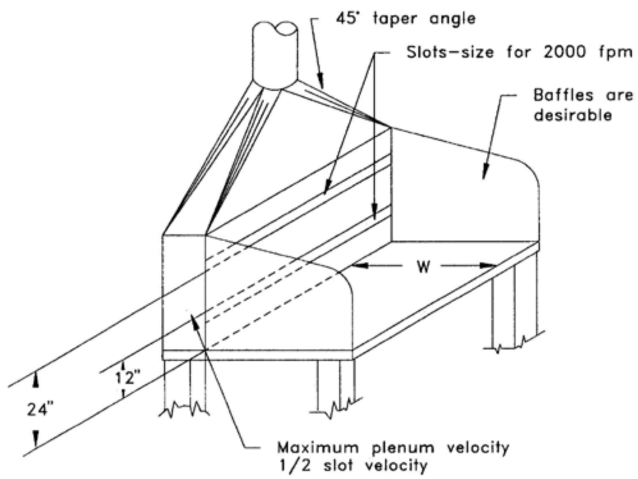
b. For enclosed areas or positions where fumes do not readily escape the breathing zone:
CFM required = 1600 X lb/hour rod used

Local Exhaust Ventilation Systems Capture Higher Concentrations of Contaminants
This is the preferred method of ventilation since welding processes tend to generate high concentrations of fumes and gases in localized areas. In contrast to general ventilation, local exhaust ventilation captures contaminants at their source and removes them from the workplace.

Seven types of local exhaust welding ventilation systems are shown here (installed as recommended from *The Industrial Ventilation Manual, A Manual of Recommended Practice*).

1. **Ventilation bench hood** *See Figure 10*
   - Q = 350 cfm/ft of hood length
   - Hood length = required working space
   - Minimum duct velocity = 2000 fpm

Figure 10: **Welding Ventilation Bench Hood**



Q = 350 cfm/ft of hood length
Hood length = required working space
W = 24" maximum, if W>24" see chapter 3
Minimum duct velocity = 2000 fpm
$h_e = 1.78\ VP_s + 0.25\ VP_d$

General ventilation, where local exhaust can not be used:

Rod, diam.	Cfm/welder
5/32	1000
3/16	1500
1/4	3500
3/8	4500

or

A. For open areas, where welding fume can rise away from the breathing zone: cfm required = 800 x lb/hour rod used

B. For enclosed areas or positions where fume does not readily escape breathing zone: cfm required = 1600 x lb/hour rod used

For toxic materials higher airflows are necessary and operator may require respiratory protection equipment.

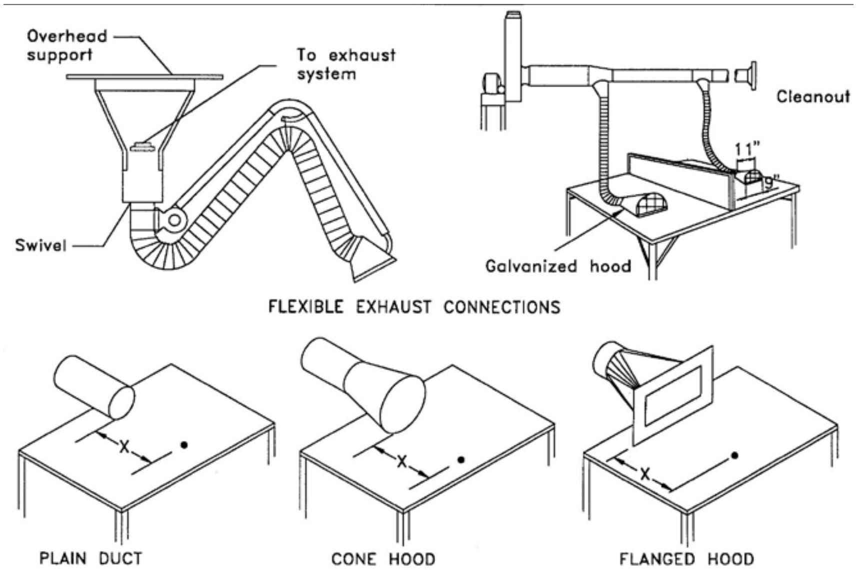
Other types of hoods
Local exhaust: See VS-90-02
Booth: For design see VS-90-30
Q = 100 cfm/ft^2 of face opening
MIG welding may require precise air flow control

2. **Movable exhaust hoods** – several hood types are recommended *See Figure 11*
   a. flexible exhaust connections with swivel attachments and/or galvanized hood
   b. with plain, cone or flanged hood
      - face velocity = 1500 fpm
      - minimum duct velocity = 3000 fpm

Notes:

- Locate work as close as possible to hood.
- Hoods perform best when located to the side of the work.
- Ventilation rates may be inadequate for toxic materials.
- Capture velocities above 100 – 200 fpm may disturb shield gas.

Figure 11: **Welding Ventilation Movable Exhaust Hoods**



RATE OF EXHAUST

X, inches	Plain duct cfm	Flange or cone, cfm
Up to 6	335	250
6–9	755	560
9–12	1335	1000

Face velocity = 1500 fpm
Minimum duct velocity = 3000 fpm
Plain duct entry loss = 0.93 VP_d
Flange or cone entry loss = 0.25 VP_d

Notes:
1. Locate work as close as possible to hood.
2. Hoods perform best when located to the side of the work.
3. Ventilation rates may be inadequate for toxic materials.
4. Velocities above 100–200 fpm may disturb shield gas.

GENERAL VENTILATION, where local exhaust cannot be used :

Rod, diam.	cfm/welder
5/32	1000
3/16	1500
1/4	3500
3/8	4500

OR

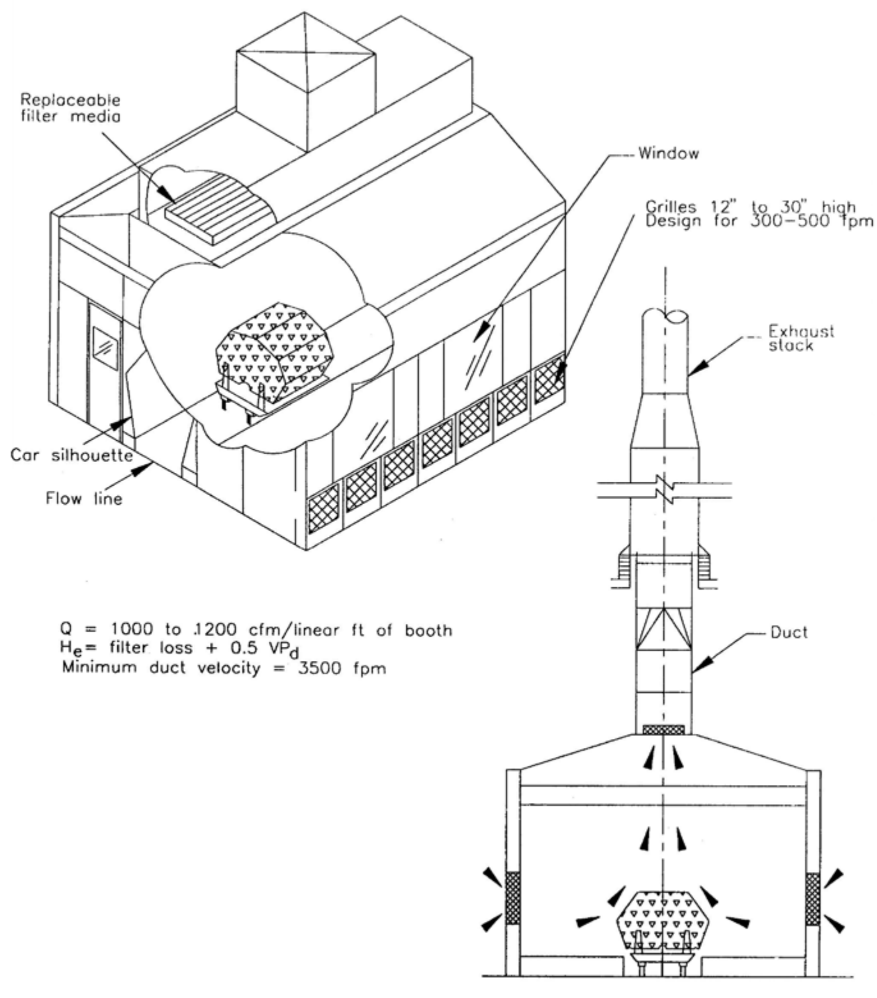
A. For open areas, where welding fume can rise away from the breathing zone: cfm required = 800 x lb/hour rod used
B. For enclosed areas or positions where fume does not readily escape breathing zone: cfm required = 1600 x lb/hour rod used

For toxic materials higher airflows are necessary and operator should use respiratory protection equipment.

Other types of hoods
Bench, see VS-90-01
Booth, for design see VS-90-30
Q = 100 cfm/ft^2 of face opening

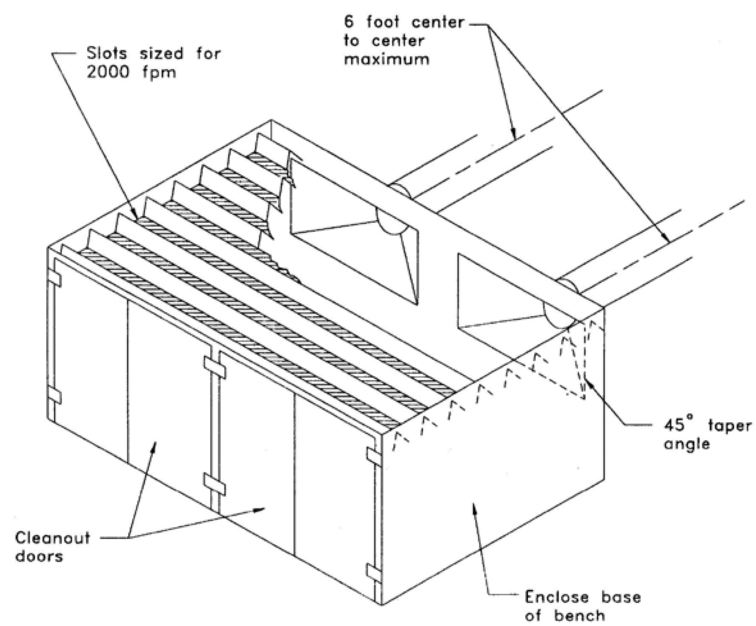
3. **Production line welding booth** *See Figure 12*
   - Q = 1000 – 1200 cfm/linear ft of booth
   - minimum duct velocity = 3500 fpm

Figure 12: **Production Line Welding Booth**



4. **Torch cutting ventilation** *See Figure 13*
- enclosed bench with slot design
- Q = 150 cfm/ft^2 of gross bench area
- minimum duct velocity = 4000 fpm
- slot sized for 2000 fpm

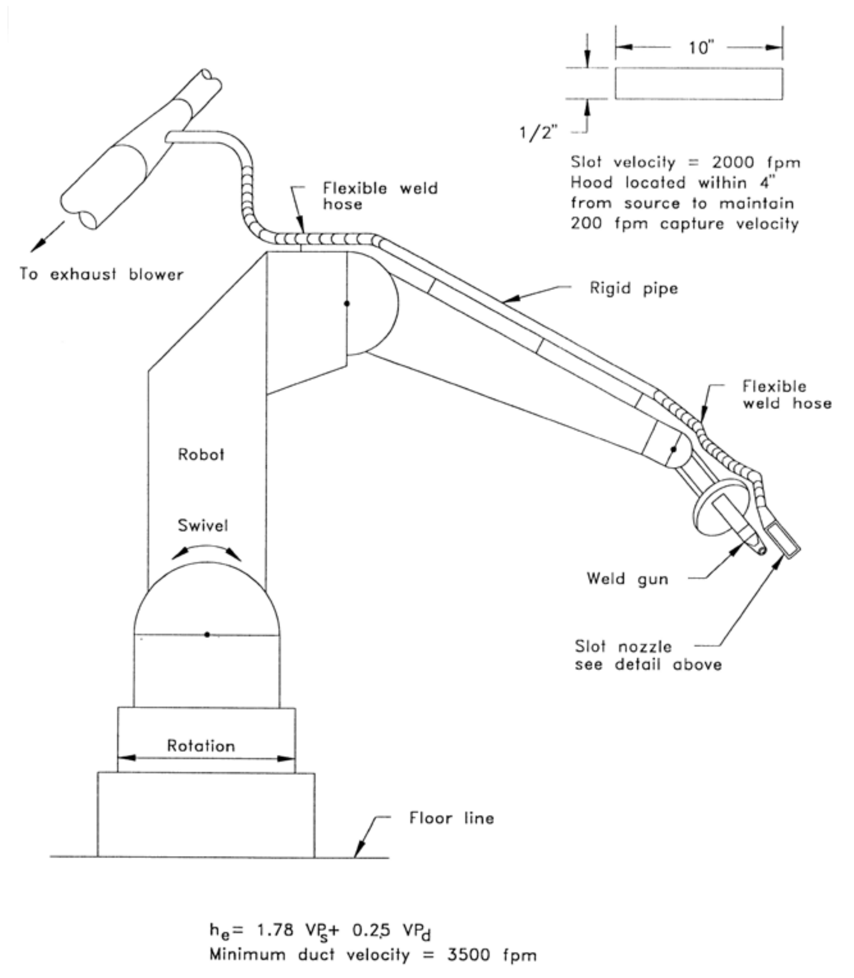
Figure 13: **Torch Cutting Ventilation**



Q = 150 cfm/ft^2 of gross bench area
Minimum duct velocity = 4000 fpm
$h_e = 1.78\ VP_s + 0.25\ VP_d$

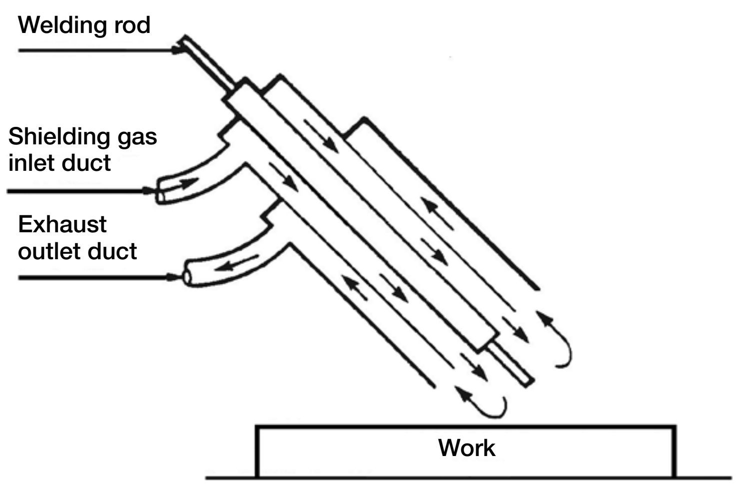
5. **Robotic welding application** *See Figure 14*
robot swivel arm with a flexible weld hose
   - slot velocity = 2000 fpm
   - hood located within four inches of source to maintain 200 fpm capture velocity
   - minimum duct velocity = 3500 fpm

Figure 14: **Robotic Application**



6. **Welding gun with fume extraction nozzle (smoke-less gun)** *See Figure 15*
   - These are welding guns with a fume extraction nozzle attached.
   - Contaminants are removed very close to the source of generation and are drawn into an extraction system.
   - Recommended air flow rates are 30 – 50 cfm/welder (as per manufacturers' guidelines).
   - The problem is the added weight to the welding gun – usually requires selecting a light weight gun and hose.

Figure 15: **Welding Gun Mounted on Exhaust Hood**

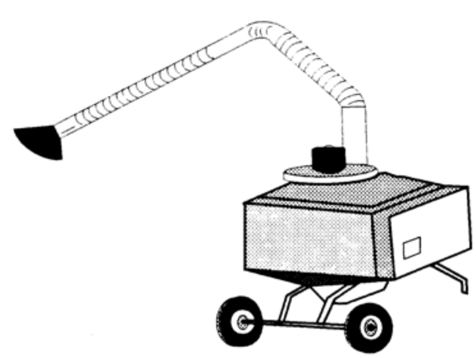


Exhaust flow requirements must be determined for each welding operation and welding gun configuration by experimental testing with air contaminant sampling and analysis.

7. **Portable fume extractor** *See Figure 16*
   A portable fume extractor unit is most useful on large work pieces, which cannot be moved or can only be moved with great difficulty. An extractor consists of a movable capture hood, duct, air cleaner, fan and motor. The system consists of a series of filters
   - coarse and finer filter (particulates)
   - charcoal filter (gases)

   The portable fume extraction system is designed to stop the recirculation of air when the filtering system fails. Manitoba welders complained that these units are heavy and awkward to move around the work piece being welded.

Figure 16: **Portable Fume Extractor**



AVOID THE USE OF CANOPY HOODS
A canopy hood located over a welding table is not suitable for capturing welding contaminants. Canopy hoods would, however, provide some relief from heat and humidity. This type of hood design draws the

contaminants through the breathing zone of the welder and, in most instances, is located too high above the process to provide any means of exhaust. *See Figure 17*.

Adapt Specific Engineering Controls to Reduce Hazards

Ozone is difficult to control since it is formed at a distance from the welding arc. Local exhaust ventilation tends to be ineffective in controlling ozone exposure.

A stainless steel shroud, which acts as a barrier to the ultraviolet radiation, is one method to capture ozone. By layering the stainless steel mesh, the transmission of radiation and ozone concentration is reduced. Another method is the use of a ventilation enclosure.

Check for Coatings on the Metal to be Welded

To minimize fumes, remove coatings, paints, degreasers and rust inhibitors on the metal work piece to be welded. This will also improve weld quality. Examples of coatings and associated hazards

- metal working fluids, oils and rust inhibitors
- zinc on galvanized steel vaporizes to produce zinc oxide fumes
- cadmium plating
- vapours from paints and solvents
- lead oxide and chromate primer paints
- some plastic coatings can produce polymer fume fever
- polyurethane coatings can produce hydrogen cyanide, formaldehyde and toluene diisocyanate
- epoxy coatings can produce hydrogen cyanide and carbon monoxide
- vinyl paints can produce hydrogen chloride
- phosphate rust inhibiting paints can release phosphine

Note: Welders are advised to apply stripping products to remove coatings. Do not grind coatings as the grinding dust will pose an additional health problem. However, caution should be used since stripping products can pose chemical health risks on their own and can leave a surface residue, which can become airborne when welding heat is applied.

Follow Safe Electrical Practices to Reduce Hazards

Control Measures

Use proper precautionary measures and recommended safe practices at all times. Reduce the risk of injuries, fatalities and electrical accidents by following these instructions.

- Train all personnel involved in welding operations to observe safe electrical work practices according to CSA W117.2-06 (R2011), *Safety in Welding, Cutting and Allied Processes*.
- Read all instructions, labels and installation manuals before installing, operating, or servicing the equipment.
- Properly install and ground the equipment in accordance with the instruction manual and federal, provincial and local codes.
- Frequently inspect input power cord for damage. Replace cord immediately if damaged.
- Do not work alone where there are electrically hazardous conditions.
- Do not wrap cables carrying electric current around any part of your body.
- Turn off all equipment when not in use. Disconnect the power to equipment that will be left

unattended or out of service. Disconnect the input power or stop the engine before installing or servicing the equipment. Lock the input disconnect switch in the open (off) position, or remove the fuses, so that power cannot be turned on accidentally. Follow lockout/tagout procedures.
- Use only well maintained equipment. Frequently inspect welding equipment and repair or replace all damaged parts before further use.
- Keep all covers and panels securely in place.

Follow Safety Precautions for Engine-powered Welders

- Always operate in an open, well-ventilated area or vent the engine exhaust directly outdoors.
- Never fuel the engine while it is running or in the presence of an open flame.
- Wipe up spilled fuel immediately and wait for fumes to disperse before starting the engine.
- Stop the engine before performing any maintenance or trouble shooting. The ignition system should be disabled to prevent the accidental start of the engine.
- Keep all guards and shields in place.
- Be sure the welder is properly installed and grounded.
- Never weld without adequate ventilation.
- Take proper precautions to prevent fires.
- Protect your entire body with fire retardant clothing, shoes and gloves. Wear eye protection at all times.
- Weld only in a fire safe area.
- Never do any welding, cutting, or hot work on used drums, barrels, tanks or other containers.
- Mark metal as **HOT** with a soapstone.
- Keep hands, hair and clothing away from moving parts.

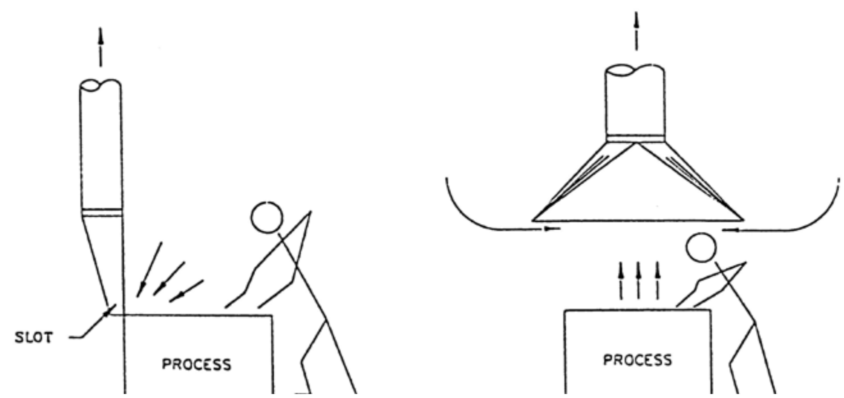
Proper grounding and bonding of portable and vehicle mounted welding machines that also supply 115 or 230 volts AC auxiliary power is an ongoing topic among welders. Generators are grounded to prevent the build up of voltages that may result in undue hazards to people or equipment. When no voltage difference exists between the grounded generator frame and earth, no electric current can flow. Therefore, the shock hazard is reduced. Since it is the flow of electric current through the human body that is hazardous, proper grounding is one of the best ways to prevent unintended electric shock. If the auxiliary power circuit has a fault condition (such as a short caused by bare wires) and there is no safety ground connection to protect the user, the result can be an electric shock. Grounding helps prevent a fire or explosion when fuelling by reducing the chances of a static electricity spark moving from the fuel nozzle to the tank.

Under the following conditions it is not required to ground the frame of the welder, as the frame itself acts as the ground.
- The welder only supplies power to the items that are plugged into the receptacles mounted on the welder.
- All non current carrying parts of the welder and the receptacles mounted on the welder are bonded to the welder frame.

The frame of the welder acts as a grounding electrode (ground rod or plate) if the above noted conditions are met. If the above noted conditions are not met or it is the recommendation of the manufacturer of the welder, then the welder frame must be grounded by an approved grounding method.

Fuel Gas and Oxygen Manifolds

Figure 17: **Direction of Air Flow**



Fuel gas and oxygen manifolds should bear the name of the substance they contain, either painted on the manifold or on a sign permanently attached to it. These manifolds should be placed in safe, well ventilated, accessible locations and not be located within enclosed spaces.

Manifold hose connections, including both ends of the supply hose that lead to the manifold, should be such that the hose cannot be interchanged between fuel gas and oxygen manifold and supply header connections. Adapters should not be used to permit the interchange of the hose. Hose connections should be kept free of grease and oil. When not in use, manifold and header hose connections should be capped. It is recommended that a periodic inspection be performed on all manifolds for damage and leaks.

Hose

- Oxygen and fuel gas hoses should not be interchangeable. All hoses in use, carrying any gas or substance which may ignite or enter into combustion or be in any way harmful to employees, should be inspected at the beginning of each working shift.
- Defective hose should be removed from service.
- Hose coupling should be of the type that cannot be unlocked or disconnected by a straight pull without rotary motion.

Note: Oxygen hoses are red with right-hand thread connection. Fuel gas hoses are red with left-hand thread connections and the nut is grooved to indicate the left-hand thread.

Torches

- Clogged torch tip openings should be cleaned with suitable cleaning wires, drills or other devices designed for this purpose.
- Torches should be inspected at the beginning of each working shift for leaking shutoff valves, hose couplings and tip connection.
- Torches should only be lighted by friction lighters or other approved devices.

Note: Improper use of the oxyfuel gas torch can lead to several safety problems including backfire, sustained backfire and flashback.

Backfire occurs when the flame returns into the tip followed by flame out due to insufficient gas flow at the tip. A backfire is accompanied by popping sounds. Check for inadequate pressure, leaking hose, blocked tip, etc. before resuming work.

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. Follow the manufacturer's instructions. Let the torch cool. Check the hoses, cylinders and regulators for damage. Replace or repair any damaged components.

Flashback occurs when the flame travels back through the torch to the cylinders due to overheating of the torch head or insufficient gas pressure.

Flashback Arresters are required versus reverse flow check valves because they can stop a flashback and also stop a flow reversal. They may be mounted on the torch or on the regulator.

Refer to the manufacturer's instructions about where to mount the arrestor, replacement frequency, testing and suitability in specific applications.

Note: Flashback arresters are mandatory as per Part 17.8 Manitoba Regulation 217/2006.

Flashback Arrester

Regulators and Gauges

- Acetylene and propane regulators have the same fitting. Never mount a propane regulator onto an acetylene cylinder because the operating pressure of the acetylene regulator must never exceed 103 kilo Pascal (kPa) or 15 pounds per square inch (PSI). The propane regulator can be set, and is used, above 15 PSI.
- Regulators removed from cylinders must always be stored with protective caps on the fittings.

Personal Protective Equipment for Welders

Respiratory Protection

Respiratory protection is the least desirable method of fume and gas exposure control. It should only be used in emergency situations or as a temporary measure until permanent control measures are installed or when other controls are not practicable. Appropriate respiratory protection should be employed as per the current CSA standard Z94.4 – 02 (R2011), *Selection, Care and Use of Respirators*.

Respiratory protection depends on the selection of the right type of respirator. Other important considerations include proper use by the welder, fit testing, storage and maintenance/repair of the respirator.

There are two basic types of respirators

- air-purifying respirators
- air-supplying respirators

Air-purifying Respirators
For situations involving exposure to moderate amounts of non-toxic welding fumes, air-purifying respirator masks provide adequate protection. **They do not offer any protection if the atmosphere is low in oxygen or contains hazardous gases.**

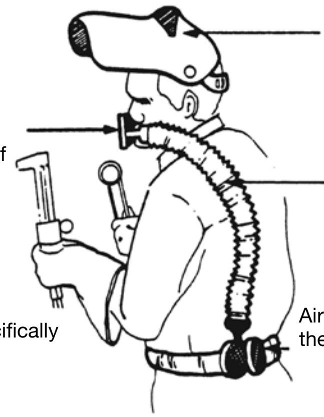
Disposable, single-use dust masks give limited protection from welding fumes and are not generally recommended, particularly when the fume has toxic components. A multi-use respirator consists of a face-piece with replaceable filter cartridges that remove particulate matter such as fumes and dust. The mask may be a half or full-face piece. To be effective it requires a good seal around the rim. Beards and moustaches do not allow a proper seal.

Air-supplying Respirators
Air-supplying, NIOSH-approved respirators are the preferred system since they supply you with clean air. These respirators provide breathing air from a remote source. For extreme conditions, various types of self-contained breathing apparatus (SCBA) are available.

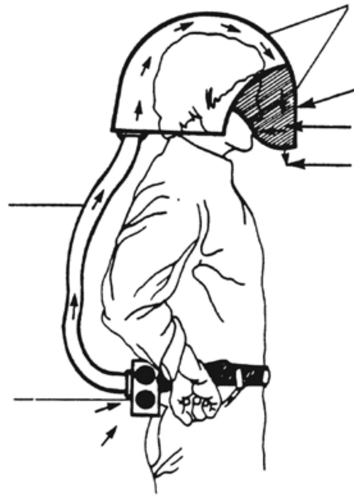
- **Disposable single-use, NIOSH-approved air purifying fume/dust respirator**
  – disposable respirators to protect against metal fumes and dust
- **Air-purifying, belt-mounted cartridge respirator**
  – the face piece fits over the nose and mouth and does not interfere with the functioning of the welding helmet
  – a flexible hose draws air through the belt-mounted cartridges
- **Powered air purifying respirator**
  – a compact fan unit, powered by a rechargeable battery pack, draws contaminated air through a series of filters for aerosol protection only (not for capturing gases)
  – the filtered air is carried to the helmet by a flexible hose
  – the face/head seal maintains positive pressure inside the helmet
  – the filtered air enters the welding helmet at the top of the helmet
  – exhaled air exits through the bottom of the welding helmet
- **Supplied air respirator**
  – protects against metal fumes/dust/gases
  – operating principle similar to powered air purifying respirator
  – clean air is provided from a compressed air source (air line) and flows into the half mask underneath the helmet
  – the length of hose line determines the welder's movement
  – this type of respirator should be used in situations where maximum protection is required (ex: confined entry or enclosed spaces with little or no ventilation)

Figure 18: **Examples of Respiratory Protection for Welding**

Single-use air purifying respirator (dust/fume mask)



Air purifying, belt-mounted respirator



Powered-air purifying respirator

1. A fan powered by a battery pack draws contaminated air through filter cartridges
2. Filtered air is carried to the helmet through a flexible hose
3. Face/head seal maintains positive pressure inside the helmet
4. Filtered air is brought over the face for improved comfort, user breathes normally
5. Exhaled air exits through cutout in bottom of faceshield

System is completely portable to allow maximum movement by the worker.

Supplied-air respirator

- Operating principle similar to powered air purifying respirator
- Clean air is provided from a compressed air source (air line) and flows into the helmet
- Worker movement limited by length of hose connected to air line

Table 1: **Minimum Respiratory Protection Recommendations for Welding Processes**

		Shop Welding		**Field Welding**	
		Ventilation Good: Exhaust vent is used to capture fumes and gases	**Ventilation Poor: Vent cannot be used due to physical or process restrictions**	**Ventilation Good:* Open area spark enclosure, or inside vessel with excellent air movement**	**Ventilation Poor:** Spark enclosure or inside vessel with poor air movement**
Shielded Metal Arc Welding	Carbon Steel	Not required	Not required	Not required, except for galvanized	Fume mask required
	Other Alloys	Not required	Fume mask required	Not required, except for galvanized	Fume mask required
Arc Cutting or Gouging		Arc cutting in shop not recommended: see field welding requirements		Fume mask required except for open plant areas	Air supplied respirator required, helpers to wear fume mask (minimum)
Oxy-acetylene Torch Cutting		Not required	Not required except for galvanized steel		Air supplied respirator required
Plasma Arc Cutting		Air supplied respirator required for all plasma arc cutting			
Gas Metal Arc Welding		Not required	Air supplied respirator required	Not required	Air supplied respirator required
Gas Tungsten Arc Welding		Not required	Air supplied respirator required	Not required	Air supplied respirator required

*General criteria to be met
Spark Enclosures: At least two open sides; no fume accumulation; no more than one welder
Inside Vessels: Directional air flow moving fume away from welder: no more than one welder; no major structural or scaffolding barriers to air flow

**Examples
Spark enclosure with all sides enclosed
Vessel with welders working at different elevations
Visible accumulation of fume
Short circuiting of air flow by open manways

Eye Safety

Welder's Helmet

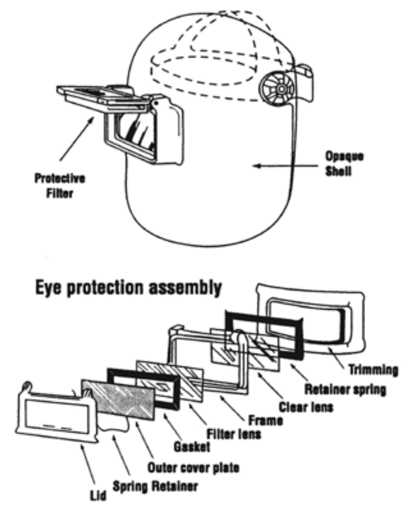
The helmet is made of a material that is an electrical and thermal insulator, non-combustible and opaque to visible, ultraviolet and infrared light.

Eyes are protected from ultraviolet radiation by a filter shade mounted on the welder's helmet. The shell of the helmet is hinged so that it can be raised and then lowered during welding. Most welders were observed jerking their necks back to raise the helmet, rather than manually raising it. This jerking motion can cause neck strain.

Eye protection is provided by an assembly of the following
- outer cover plate (polycarbonate plastic)
- filter lens (glass with a filter to reduce the amount of light)
- clear retainer lens (plastic)
- gasket (heat insulating material)

Safety eyewear should always be worn under the welding helmet to protect against flying debris when the helmet is raised to inspect work and when engaged in other welding activities, ex: grinding, hammering.

Figure 19: **Welders Helmet**



Personal Protective Clothing

Protective clothing is required to protect the skin from burns (sparks, spatter and radiation). All clothing should be laundered regularly to prevent oil and grease build up. Ideally, protective clothing should be chemically treated to reduce combustibility. In some Manitoba welding shops, welders were not provided with any protective clothing over their street clothes. These welders wore their street clothes in the workplace, which were then laundered at their homes.

Personal protective equipment/clothing should include
- leather aprons to protect from sparks
- a fire-resistant skull cap under the welding helmet
- safety footwear as per the current CSA Standard Z195, *Protective Footwear*
- certified industrial safety eyewear with side shields as per the current CSA Standard Z94.3, *Eye and Face Protection* to be worn under the welding helmet
- hearing protection such as ear plugs and/or muffs. Refer to CSA Standard Z94.2, *Hearing Protectors*.

Do This
- Keep clothing clean and free of oil, greases and combustible contaminants.
- Wear long-sleeved shirts with buttoned cuffs and a collar to protect the neck. Dark colors prevent light reflection.
- Tape shirt pockets closed to avoid collecting sparks or hot metal or keep them covered with flaps.
- Pant legs must not have cuffs and must cover the tops of one’s boots. Cuffs can collect sparks.
- Repair all frayed edges, tears or holes in clothing.
- Wear high top boots fully laced to prevent sparks from entering the boots.
- Use fire resistant boot protectors or spats strapped around the pant legs and boot tops to prevent sparks from bouncing into the top of the boot.
- Remove all ignition sources such as matches and butane lighters from pockets. Hot welding sparks may light the matches or ignite leaking lighter fuel.
- Wear gauntlet-type cuff leather gloves or protective sleeves of similar material, to protect wrists and forearms. Leather is a good electrical insulator if kept dry.

Do Not

- Wear contact lenses. Any foreign particles in the eye may cause excessive irritation.
- Wear clothing made from synthetic or synthetic blends. The synthetic fabrics can burn vigorously, melt and cause serious skin burns.

Protect Adjacent Workers

Non-welders near a welding operation can suffer welder's flash by inadvertently looking directly at an arc struck or by being exposed to reflected light.

1. **Wear eye protection** if you are within **30 meters (100 feet)** of an unshielded welding area.
    - Use polycarbonate plastic lenses to absorb the UVB and C and most of the UVA light.
    - Wear tinted polycarbonate safety glasses with tinted side shields if you are standing near a welding operation. Use a # 3 or # 5 shade if you are not looking directly at the arc.
    - Use the same shade as the welder, when looking directly at the arc.
    - Refer to Tables 2 and 3.
2. **Use non-reflective screens, partitions or curtains** to shield welding activities and minimize the risk of exposing others to arc light.
3. **Use spark or spatter shields** to help prevent the escape of hot material from the welding area into nearby locations.
4. It was observed in Manitoba welding shops that welders may not put on their helmets if the welding job is short. This unnecessarily exposes their eyes to the arc struck.

Table 2: **Shade Numbers for Cutting (from CSA W117.2)**

Process	Plate Thickness (in mm)	Minimum Shade #	Suggested Shade #
Light	< 25	3	4
Medium	25 – 150	4	5
Heavy	> 150	5	6

* In the United States use ANSVAWS Standard F2.2 for selecting filter lens shade.

Table 3: **Shade Numbers for Arc Processes (from CSA W117.2)**

Process	Electrode Diameter (in mm)	Current (Amperes)	Minimum Shade #	Suggested Shade #
SMAW	< 2.5	< 60	7	–
	2.5 – 4	60 – 160	8	10
	4 – 6.4	160 – 250	10	12
	> 6.4	250 – 550	11	14
GMAW and FCAW		< 60	7	–
		60 – 160	10	11
		160 – 250	10	12
		250 – 500	10	14
Air Carbon Arc Cutting				
light		< 500	10	12
heavy		500 – 1000	11	14

* In the United States use ANSVAWS Standard F2.2 for selecting filter lens shade.

SPECIAL WELDING SITUATIONS

HAZARDS AND SAFETY PRECAUTIONS

Confined Space

Any welding operation in a confined space is potentially lethal due to oxygen deficiency, flammable gas/vapour build-up and airborne chemical concentrations exceeding the current acceptable guidelines. Confined spaces require continuous ventilation and monitoring. Refer to *Code of Practice for Confined Space*, a publication produced by Manitoba Family Services and Labour, Workplace Safety and Health.

Common Hazards

- shielding gases given off during the welding which can displace oxygen
- flammable gas or vapour build-up (ex: carbon monoxide)
- electrical hazards
- heat stress
- arc light reflections

In confined entry situations

- portable self-contained ventilation systems are required, which include a gas absorbing system and particulate filters
- confined space gas detector to monitor exposure to combustible and other hazardous gases

Brazing and Soldering

Oxyfuel gas equipment used for cutting and heating has been largely replaced by electric arc welding processes. In the oxyfuel process, oxygen gas is combined with a fuel gas to produce a flammable gas mixture, which is ignited to produce an intense burning.

- **Brazing** joins metals by heating them above 450ºC with a filler metal.
  – Brazing joins metals of different composition.
  – Heating during brazing can be by induction heating, torch or brazing furnace.
  – Brazing fumes may contain fluorine, chlorine and boron.
- **Soldering** is similar to brazing but requires much lower temperatures (below 450ºC).

Robots

Welding robots and other automatic welding equipment have become common in the industry. A robot's movements may be hazardous to workers because of

- contact with the robots
- entrapment between the robot arm and other structures
- legitimate work activity of the robot
- unexpected movement of the robot

The risk of injury is greatest inside the robot working envelope. This space includes all points that could be reached by the robot arm. Welders should know how to

- teach (program) the robot
- maintain the robot
- clear a jam

A good source of information on robot safety is CSA Z434-03 *Industrial Robots and Robot Systems – General Safety Requirements*.

Welding or Cutting Containers

Before welding or cutting

- Identify the previous contents of the container and their toxic and flammable hazards.
- Consult the Material Safety Data Sheet (MSDS) and WHMIS labels.
- Test for the presence of combustible materials.
- Clean the container thoroughly by steaming or washing with water.

During the actual welding or cutting, the following precautions must be taken.

- Fill the container with water to within a few inches of the point where the welding or cutting is to be done.
- Vent the space above the water to allow the heated air to escape.
- Test the vented gases for combustible or toxic components. If you detect any, stop welding or cutting.
- Avoid explosion from expansion of trapped gases.

Precautions: Do not weld near unvented pockets such as lap patches or seams, reinforcing pads or jacketed containers.

Hot Work Permit

Work involving ignition sources in the vicinity of flammable materials is referred to as hot work. Welding and cutting are examples of hot work. Fires are often the result of quick jobs done in areas not intended for welding or cutting. If no precautions are taken, a spark or hot material can start a fire within minutes.

Follow these precautions when cutting or welding near combustible materials.

- Ensure that all equipment is in good operating order before starting work.
- Inspect the work area thoroughly before starting. Look for combustible materials in structures (partitions, walls, ceilings).
- Sweep clean any combustible materials on the floor around the work zone. Combustible floors must be kept wet with water or covered with fire resistant blankets or damp sand.
- Use water only if electrical circuits have been de-energized to prevent electrical shock.
- Move all combustible materials away from the work area.
- Cover combustibles with fire resistant blankets or shields if such materials cannot be moved.
- Protect gas lines and equipments from falling sparks, hot materials and objects.
- Cover cracks between floorboards, along baseboards and walls and under door openings with a fire resistant material. Close doors and windows.

- Cover wall or ceiling surfaces with a fire resistant and heat insulating material to prevent ignition and accumulation of heat.
- Inspect the area following work to ensure that wall surfaces, studs, wires or dirt have not heated up.
- Vacuum combustible debris from inside ventilation or other services duct openings to prevent ignition.
- Prevent sparks from entering into the duct work. Cover duct openings with a fire resistant barrier and inspect the ducts after work has concluded.
- Post a trained fire watcher within the work area during welding and for at least 30 minutes after work has stopped.

Laser Welding

A laser is a device which produces an intense, coherent, directional beam of light. The term laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers can be designed to deliver a large amount of energy to a very small area. In welding and cutting operations, this energy can heat metals quickly to very high temperatures. Much of the radiation that strikes the work piece is reflected into the environment, creating hazards. Some laser light used in laser welding equipment is invisible, so the hazard may not be readily apparent.

Typical lasers use electricity to create coherent light, which is very different from ordinary non-coherent light, such as that from a light bulb. Coherent light can be tightly focused, as opposed to diffuse or scattered ordinary light. This coherent light beam can be focused to cut or weld metals. Laser light can be different colors of the visible light spectrum, or can be invisible when the light is ultraviolet or infrared.

Lasers used for welding and cutting may be infrared, and therefore the beam may be invisible. It is very difficult to take precautions against things you cannot see. It is even more difficult to convince others to take precautions against hazards they cannot see and may not understand.

Potential Hazards of Laser Welding

- **Radiation** – both visible and invisible light radiation is produced when welding or cutting. Due to the interaction with the work piece, high levels of both hazardous blue light and ultraviolet radiation (secondary radiation) are produced. This light radiation is often reflected from the work piece into the work area. Radiation from these processes can seriously burn eyes and skin quickly and permanently. These hazards are addressed in the American National Standards Institute Z136.1 standard, *Safe Use of Lasers*.
- **Fire** – Since the laser system produces a very small spot with very high energy, the hazard of fire is present if the beam hits flammable material. Keep flammables away from the welding or cutting area. Be sure to cover and protect anything flammable in the area, since reflected radiation could start fires in unexpected places. Protect the work area.
- **Fumes and mists** – Lasers easily vaporize metals. In doing so, fumes and mists are created. Often, fumes and mists cannot be seen, yet they can pose a serious respiratory hazard. Always use adequate ventilation.
- **Mechanical** – The optical device on the robotic arm or other beam manipulator can malfunction and send the laser beam in unintended directions. It is essential that the work cell be shielded in conformance with standards for the laser type and class.

- **Electric shock** – Since lasers require a large amount of electrical power to accomplish specific tasks, electrical hazards are present. Conventional hazards associated with any electrical industrial power source are present. These require standard and common electrical safe practices as found in ANSI Z49.1, *Safety in Welding and Cutting,* and in AWS, *Standard for American Welding Society Certified Welders*.

  There are the unique electrical hazards common to lasers in general and the hazard of the individual application. Usually, the best source of safety information is provided in the instruction manual from the manufacturer of the laser system. Always read, understand and follow the manufacturer's recommended safety procedures.
- **Eye and skin damage** – Laser system eye and skin hazards are addressed in the ANSI Z136.1 standard. In many situations, special laser eye protective devices are required. According to the ANSI Z136.1 standard, this eyewear must be labelled with both the optical density (protective factor) and wavelength(s) for which the protection is afforded. The protective eyewear must be compatible with the manufacturer's specifications for the laser system in use, to ensure that the eyewear is suitable. In addition to the primary hazard of the laser beam, there may be a considerable eye hazard from high levels of secondary radiation. The ANSI Z136.1 standard requires that eyes be protected from this secondary radiation in addition to the primary laser beam. A precaution must be added here – standard safety glasses alone do not provide protection. Any laser eyewear, plain or prescription, must be labelled with the wavelength(s) of protection and the optical density at that wavelength(s). In some laser systems, ultraviolet light may be leaked into the workplace. Eyewear should provide primary beam protection, secondary radiation protection and ultraviolet protection.

Safety Considerations for Laser Welding

All laser welding and cutting installations are required to have a laser safety officer (LSO). The LSO is responsible for personnel protection, laser cell class conformance, and enforcement of all laser safety regulations. Be certain to follow recommendations from the laser system manufacturer. In addition, provide certified laser protective eyewear, clothing and shields where required.

WELDING SAFETY CHECKLIST

Welding Processes

Determine what type of welding is being done and the frequency throughout the work shift.

Type of welding ______________________________

____

Frequency ______________________________

____

Work shifts ______________________________

Total number of welders ______________________________

Number of female welders ______________________________

Experience of welders ______________________________

Average age of welders ______________________________

- ❑ Are current MSDS's available?
- ❑ Do welders understand the hazards?
- ❑ If you see a smoky haze in the welding area, check that the existing ventilation system in the welding area is operating properly and airflow rates are not obstructed. A smoky haze in the workplace is suggestive that the ventilation system is not working properly or that no ventilation system exists.

Note: Fumes may be present during welding whether a visible smoke plume is present or not.

What type of ventilation exists in the welding area(s)?

- ❑ Local
- ❑ General

- ❑ Are welding curtains or other barriers available?

Health Effects

Are welders experiencing any health effects that may be related to the welding process?

- ❑ Welder's flash?
- ❑ Eye, nose and/or throat irritation?
- ❑ Do they suffer from any respiratory problems, ex: bronchitis/asthma/emphysema?
- ❑ When was their last chest X-ray?
- ❑ Other complaints ______________________________

  ____

Safe Work Practices

- ❑ Are welders wearing their helmet when welding?
- ❑ Are welders keeping their head out of the plume?
- ❑ Are welders positioning their work to take advantage of existing ventilation to direct the plume away from the breathing zone?

Personal Protective Equipment

Do welders have the required personal protective equipment (PPE)?

- ❑ welding helmet
- ❑ safety eyewear
- ❑ protective clothing, ex: coveralls and/or leather apron/jacket
- ❑ safety footwear
- ❑ no frayed or loose clothing
- ❑ clean clothing
- ❑ protective gloves
- ❑ respiratory protection
- ❑ hearing protection

- ❑ Is appropriate PPE readily available to welders?
- ❑ Is the PPE certified for its intended use by the appropriate standards authority, ex: ANSI, NIOSH, CSA?
- ❑ Does the PPE fit properly?
- ❑ Is the PPE maintained/stored properly?
- ❑ Is there a written PPE policy for specific jobs?
- ❑ Are welders using the PPE as prescribed?
- ❑ Do any welders wear respiratory protection?
- ❑ Is there a respiratory protection program?
- ❑ Do welders understand the limitations of the PPE?

Training Program Elements

- ❑ Workplace survey
- ❑ Selection
- ❑ Fitting and wearing
- ❑ Maintenance
- ❑ Training support
- ❑ Auditing the program

Air Monitoring

Has there been any monitoring of welding fumes in this workplace? ________

What areas were monitored? ________

Who did the air monitoring? ________

What year was it done? ________

Have any welding processes changed since the last monitoring? ________

Has production changed since the last monitoring? ________

What method of air monitoring was used? ________

Was proper analytical air monitoring conducted? ________

NIOSH Method # ________

Ergonomics

- ❑ Have ergonomic factors in the workplace been assessed?
- ❑ Do any of the welders have complaints about back, wrist, shoulder pain, etc.?
- ❑ Is an ergonomic assessment requested/required?

Noise Levels

- ❑ What are the noise levels in the workplace? ________
- ❑ Have noise levels been monitored in this workplace?

  Areas monitored: ________
- ❑ Is there a hearing conservation program in the workplace?
- ❑ Is hearing protection made available to the welders?
- ❑ Are welders wearing hearing protection?
- ❑ Do control measures exist to reduce noise levels?

  Control measures: ________

Safety Training

- ❑ Are welders trained in electrical safety?
- ❑ Are welders trained in fire safety?
- ❑ Do welders receive emergency training?
- ❑ Is all equipment installed in accordance with the CSA Standard C22.1, Canadian Electrical Code Part I – Safety Standard for Electrical Installations?
- ❑ Is all equipment installed by a qualified authority in accordance with the manufacturer's instructions?
- ❑ Are welding machines grounded?
- ❑ Is the work piece grounded to an electrical ground by locating the work on grounded metal floor, plate or other satisfactory ground?
- ❑ Are repairs made only by qualified personnel?
- ❑ Compressed gases should be used from cylinders only with an appropriate regulator attached to the cylinder valve. If the cylinder is attached directly to a manifold, the manifold should be designed to withstand full cylinder pressure.
- ❑ Is there any evidence of gas leakage?
- ❑ Is there any evidence of valve leakage?
- ❑ Flashback arresters should be fitted to all oxyacetylene equipment. Oxyacetylene equipment should not be left near hot equipment or metals, which could lead to burns.

Other Training

- ❑ Have welders received workplace training on safe work practices and safety in welding and cutting? (ex: ANSI Z49.1-2005, Safety in Welding and Cutting)
- ❑ Is there a workplace training program for those newly recruited into the industry? (ex. recent college graduates)
- ❑ Or does the company only hire experienced welders?

Welding Health and Safety Program

- ❑ Is there a welding health and safety program in the workplace?

Program Elements

- ❑ individual responsibility
- ❑ joint occupational health and safety committee
- ❑ health and safety rules
- ❑ correct work procedures
- ❑ employee orientation
- ❑ training
- ❑ workplace inspections
- ❑ reporting and investigating accidents
- ❑ emergency procedures
- ❑ medical and first aid
- ❑ health and safety promotion

- ❑ Does the program include hazard identification?

- ❑ Are there regular workplace inspections to ensure safe working procedures?
- ❑ Is there regular air monitoring for common contaminants?
- ❑ Are there regular assessments of the ventilation system(s)?
- ❑ Has there been a review of time loss injuries?
- ❑ Are there regular reviews of the training program?
- ❑ Is the health and safety program periodically evaluated to ensure that welders are being adequately protected?
- ❑ Are training manuals available to welders or supervisors?

Health and Safety Committee

- ❑ Is there a health and safety committee in this workplace? Or a worker representative?
- ❑ Is the health and safety committee involved in the welding health and safety program(s)?
- ❑ Last committee meeting? ______________________________

Hygiene

- ❑ Are welders provided with adequate hand washing facilities?
- ❑ Are welders washing their hands before eating food and smoking?
- ❑ Are welders given protective clothing (ex: coveralls) and does the company launder these items?
- ❑ Is the lunchroom separated from the shop floor?
- ❑ Are there proper locker facilities?

Housekeeping

Ensure working areas are free from debris, wastes are removed, areas are free from tripping hazards and walkways are clear of welding cables, air hoses, electrical cords, tools and equipment.

- ❑ Is good housekeeping maintained in the workplace?
- ❑ Is the work area cleaned up at the end of each shift?
- ❑ Is the work kept free of flammable debris, ex: rags and solvents?

Other Comments ______________________________

____

____

____

____

____

____

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