FAB1010

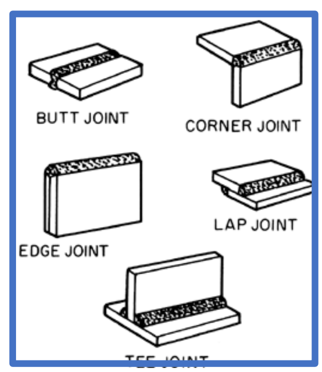
Welding Fundamentals

Before you begin, here is what you need to complete for full marks in this credit:

1) Welding Safety – Questions 1 – 14. - 15%
2) SMAW welding – Questions 15 – 30 - 15%

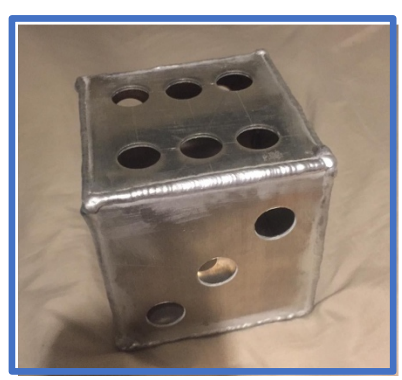
3) Copper Rose - 10%

4) Welded Flat Practice Pad - 10%



4. Welded Joints. - 25%

5. Welded Dice. - 25%



Welder

Welding Safety

Welding Safety

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Rationale

Why is it important for you to learn this skill?

You are exposed to a massive number of hazards on the work site. Some of the most harmful hazards are invisible fumes and gases. You should be familiar with the government legislation that provides the regulations to protect you from exposure to harmful substances in the workplace. You must follow these regulations to provide reasonable assurance that you will not be injured or poisoned.

Outcome

When you have completed this module, you will be able to:

Apply safe work practices according to Occupational Health and Safety Act (OHS) legislation.

Objectives

1. Identify hazards for welding and cutting operations.
2. Identify the use of personal protective equipment for welding and cutting operations.
3. Explain the hazards involved with welding fumes and gases.
4. Identify welding fume ventilation methods.
5. Explain the effects of electricity and precautions used to prevent injury.
6. Describe the procedure for welding or cutting in confined spaces or potentially dangerous enclosures.
7. Interpret sections of the *Occupational Health and Safety Act, General Safety Regulations.*

Introduction

This module teaches you how to locate and interpret sections of the *Occupational Health and Safety Act* (OHS) and how to apply safe working practices on the job site. This module also contains procedures to follow when you have to weld or cut in a confined space that has the potential to become a dangerous environment.

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Objective One

When you have completed this objective, you will be able to:

Identify hazards for welding and cutting operations.

Welding Safety

Safety and recognizing workplace hazards are a matter of concern to everyone associated with the welding trade. You are ultimately responsible for the safety of everyone working in your shop. When using welding and cutting equipment, be aware of the following potential hazards:

- flames,
- sparks,
- slag,
- harmful rays,
- fumes and
- fire hazards.

Be proactive and take the necessary steps to use safety equipment and avoid potentially hazardous situations. If you spot a co-worker engaged in an unsafe practice, approach that person and make your concerns known. Many accidents can be avoided.

Radiant Energy Hazards

Some of the most serious arc welding hazards are harmful light rays emitted from the arc and the oxyfuel flame. You must guard your body against these harmful light rays by wearing proper personal protective equipment. This equipment also helps protect you from grinding sparks, flying slag and weld spatter.

You must also put up screens and warning signs when arc welding, cutting or grinding at work sites in the vicinity of the general public. Do not use any high gloss or shiny surfaces for screens because reflected rays can also be dangerous.

Both visible and invisible light rays are given off by the oxyfuel torch and the electric arc. This radiant energy can be divided into three types:

1. visible light,
2. ultraviolet rays and
3. infrared rays.

Visible Light Rays

Visible light rays are those that you can see. They may come from the source or they may be reflected off shiny surfaces. Intense rays of this light can cause eye strain or in extreme cases temporary or permanent blindness.

Ultraviolet Rays

Ultraviolet rays are invisible. They cause burns to exposed skin and blistering of the eyeball. These are more common with electric arc welding than with other methods. *Arc flash* (sometimes called *welding flash* or *arc eye*) is the term for eyes burned by ultraviolet rays. When you experience arc flash, your eyeballs are covered with small water blisters causing extreme pain when you open your eyes or when you blink.

Symptoms of arc flash are profuse watering of the eyes and a feeling of sand in the eyes usually hours after the actual flash has occurred.

DANGER
See an eye specialist as soon as possible after an arc flash to ensure that the pain is not being caused by a foreign object lodged in your eyes.

There are medications available to treat arc flash, but most are local anaesthetics, so further damage can be done to your eye since the pain is deadened and you may not know if there is a foreign object in your eye.

Skin exposure to the intense ultraviolet rays of the arc is comparable to direct exposure to the sun. The ultraviolet ray intensity of the arc is approximately ten times that of the sun. Exposed skin can be burned in one-tenth the time required for a sunburn of the same degree to occur.

The GMAW process uses a gas shield and not a slag cover to shield the molten puddle, so the ultraviolet radiation intensity is substantially greater than that of *shielded metal arc welding* (SMAW) also called *stick welding*.

DANGER
Overexposure to ultraviolet radiation can lead to skin cancer. Never arc weld with short sleeves and make sure your shirt or jacket is buttoned up at your neck.

Infrared Rays

Infrared rays are also invisible. They penetrate deeply and can cause temperature increases and burns to exposed skin. These rays may also penetrate the interior of the eye and can cause retina damage. Over a long period of time, infrared rays can cause cataracts.

X-Rays and Gamma Rays

X-rays and *gamma rays* are produced from non-destructive testing of welds. Exposure may result in cancer or damage to body tissues. Distance is the best protection, so stay away from the equipment or cordoned-off areas.

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Temperature Hazards

Temperature extremes are caused by the SMAW process, welded materials, work environment and weather conditions.

- Excessive heat in the welding environment causes fainting, heat stress, dehydration and exhaustion.
- Extreme cold causes frostbite, hypothermia and fatigue.
- Both temperature extremes can reduce resistance to disease and result in death.

Temperature extremes encountered by welders may include the following.

- Temperatures of the welding arc may reach 3316°C (6000°F).
- Temperatures of the plasma arc may reach 33 538°C (55 000°F).
- Melting temperatures of metals range from 260°C (500°F) to more than 2760°C (5000°F).
- Furnace and refinery stacks can operate at 1093°C (2000°F) or more.
- Gases used in the welding process may be stored at temperatures as low as -268°C (-452°F).

Burns

Burns are graded on the severity of the burn. Figure 1 illustrates the three degrees of burns. As a general rule, burns that result in injury from contact with hot metal, flames, hot slag or sparks fall into two basic types: surface or minor burns and major burns.

- With *surface* or *minor burns* (*first degree burns*), only the outer layers of the skin are damaged. The burned area may be red in colour and may blister.
- *Major burns* (*second* or *third degree burns*) are deep burns with all layers of the skin destroyed and underlying fat and muscle damaged to varying depths.

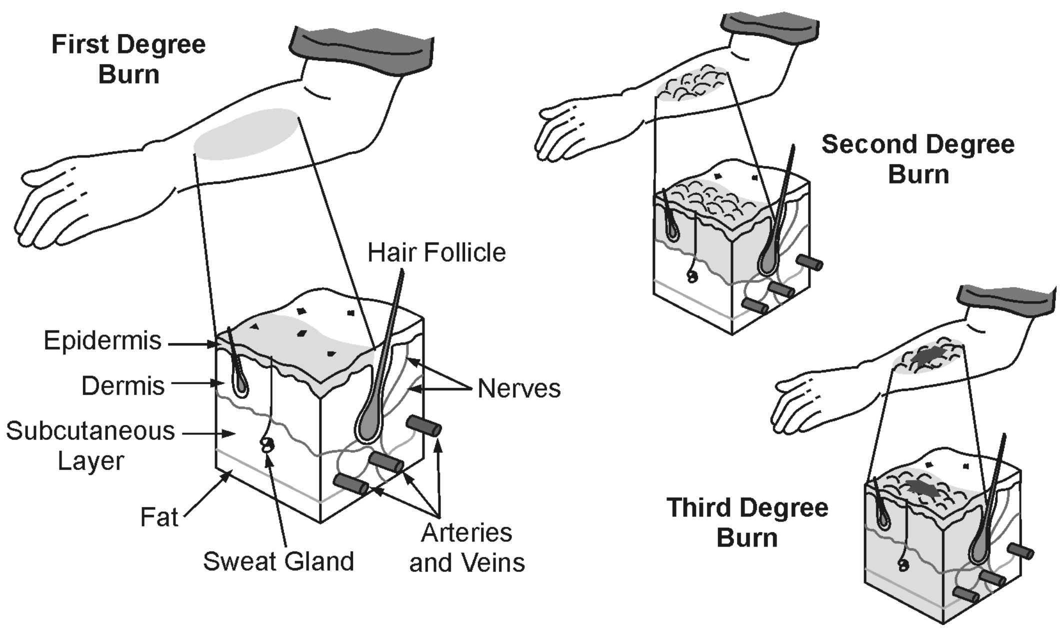

Figure 1 - First, second and third degree burns.

When you receive a burn, follow these steps for treatment.

1. Remove jewellery and loosen tight clothing before swelling starts.
2. Immediately cool the burned area by immersing the burned part in cool, still water until the pain is relieved.
3. If immersing the burned area is not possible, gently pour cool water over the burned area or apply a clean cloth soaked in cool water. Cooling a burn reduces the temperature of the burned area and prevents further tissue damage. It also reduces swelling and blistering and relieves pain.
4. Cut clothing away from burned areas carefully, but do not attempt to remove cloth that adheres to the burn. Cut around it.
5. When the pain has lessened, cover the burned area loosely with a clean, sterile material.
6. Secure the dressing, ensuring that the tape does not touch the burned area.
7. Immediately obtain professional medical assistance.

Deep burns are often caused by metal at temperatures lower than red-hot. Before you realize the metal is hot, the burn has penetrated beyond your skin and into the flesh. In other cases, the metal or slag may be trapped against the skin by improper or worn gloves, worn clothing or open-top boots. This type of burn takes longer to heal and care should be taken to prevent infection.

In and around welding shops, all metal surfaces should be treated as a possible source of burns. Use caution. Before picking up anything around a welding area, tap it gently with your fingertips so that you are sure it is safe to handle.

Remember that in a welding shop everything is hot until proven otherwise. Whenever you set a hot object aside where others are apt to be burned, mark it **hot** with chalk or soapstone. You can prevent many burns by doing this. Safety conscious welders always consider others and take every precaution to protect others as well as themselves.

If your clothing catches fire, remember to *stop, drop and roll* (SDR).

- **Stop** moving; do not run.
- **Drop** to the ground.
- **Roll** several times to put the flames out.

Frostbite and Hypothermia

Frostbite is injury to skin caused by exposure to extremely cold temperatures. If you are working outside in sub-zero temperatures and your fingers and toes start to hurt and feel numb, you are likely starting to get frostbite even though you may have put on warm clothing.

- With mild frostbite, there is redness and discomfort, but once you have warmed back up your skin returns to normal in a few hours.
- With more severe frostbite, you may get swelling and burning pain when you warm up and your skin may blister and fall off.
- The most severe cases of frostbite can result in gangrene and possible amputation.

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The immediate treatment of frostbite is as follows.

1. Cover the affected area with other body surfaces or warm clothing.
2. Do not rub or massage the area.
3. Avoid applying dry heat to the area.
4. Immerse the affected part in warm (not hot) water until the frozen tissue thaws.
5. If you have moderate to severe frostbite, immediately seek medical attention.

Hypothermia is usually caused by prolonged exposure to cold. The body adjusts to the cold by diverting blood away from your body extremities such as toes, fingers and ears and sending more blood to the heart and liver. Blood vessels in the extremities shut off and the risk of frostbite and eventually hypothermia increases. Symptoms of hypothermia include uncontrollable shivering, dizziness and light-headedness. If no treatment is rendered, hypothermia can result in slow pulse, memory loss and eventually unconsciousness and death.

To treat hypothermia, the body temperature must be raised slowly. Give the victim warm liquids without caffeine and make sure the victim gets medical attention as soon as possible.

Noise Hazards

Noise is defined as unwanted sound and is one of the most common workplace hazards. Noise produced by a welding or cutting process or in the welding environment may cause:

- tiredness,
- irritability,
- headaches,
- a rise in blood pressure,
- a loss of concentration,
- a drop in productivity,
- accidents,
- hearing problems and
- deafness.

The harmful effects are not always immediate, but permanent damage can and usually does result. Hazardous noise conditions that are considered major contributors to hearing loss are:

- work site overall noise level,
- frequency distribution of the noise,
- duration of the noise exposure during the work day,
- time distribution of the noise exposure and
- susceptibility of the individual to noise-induced hearing loss.

Some welding and cutting operations, such as air arc gouging, pneumatic chipping and grinding, produce very high noise levels. Earmuffs and earplugs help to protect against hearing loss and keep sparks and slag from entering your ears.

The following warning signs should alert you to high noise levels and remind you to wear hearing protection:

- you have to raise your voice to a person who is a metre or less away from you or
- you develop a ringing or buzzing sound in your ears.

Noise Intensity and Exposure Limits

The intensity of noise or sound is measured in units called *decibels* (dBA). Table 1 lists some dBA levels from different sources.

Cause	Noise Level (dBA)
Jet plane	140
Gunshot blast	140
Riveting a steel tank	130
Air arc cutting	120
Sandblasting	112
Drilling rig motors	90-100
Punch press	100
Pneumatic drill	100
Boiler shop	100
Hydraulic press	100
Average factory	80-90
Noisy restaurant	80
Conversational speech	65
Quiet office	40
Soft whisper	30

Table 1 - Noise levels.

Table 2 lists the maximum number of hours permitted at different levels of dBA according to Alberta Occupational Health and Safety regulations.

Sound Level (dBA)	Maximum Permitted Duration (hours per day)
82	16 hrs
83	12 hrs and 41 mins
84	10 hrs and 4 mins
85	8 hrs
88	4 hrs
91	2 hrs
94	1 hr
97	30 mins
100	15 mins
103	8 mins
106	4 mins
109	2 mins
112	56 seconds
115 and greater	0
Note: Exposure levels and exposure durations to be prorated if not specified.	

Table 2 - Occupational exposure limits to noise.

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If you work in an average factory, you need hearing protection. The maximum permitted sound level for an eight-hour day is 85 dBA; hearing protection should be worn if the sound level is above 85 dBA. Most of the time, someone in your shop or work site will be grinding, gouging or drilling, so you should wear hearing protection at all times.

Objective Two

When you have completed this objective, you will be able to:

Identify the use of personal protective equipment for welding and cutting operations.

Head Protection

You should wear a beanie or cap to protect your head and hair. Wear a welder's cap with a peak to protect exposed ears and neck from welding radiation, sparks and spatter. You may also be required to wear a hard hat depending on your specific job situation.

Eye Protection

Depending on the specific application, eye protection is very important around welding and cutting so that you have protection from radiant energy, sparks, slag and other debris. Eye protection for welding and cutting operations can include:

- safety glasses,
- a full-face visor or clear plastic goggles,
- welding goggles and/or
- a welding helmet.

Safety Glasses

You should always wear safety glasses in a welding environment to protect against arc flash, sparks and flying particles. The glasses should have side shields and be shatter resistant. They may be tinted depending on the specific environment and the level of protection needed. If tinted, safety glasses usually have a #1 or #2 shade and should be worn when you have to work near others who are using an arc welding process.

Prescription safety glasses are available. Many styles have side shields that can be clipped on when you work in the shop. Safety glasses should fit under all face protection equipment.

Clear Goggles

Tight-fitting, high-impact *clear goggles* can be worn over safety glasses to provide extra protection for your eyes from flying debris caused by grinding, chipping or splashing liquids.

Full-Face Visors

Your entire face can be protected by a *full-face visor* which should be used with safety glasses when grinding or chipping. The visor should fit over your safety glasses. If you are wearing clear safety glasses and a CSA Z94.3-certified face shield for oxy-fuel welding or cutting, it should have a #4 or #5 shade or higher depending on the job.

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Figure 2 shows a welder wearing safety glasses under a full-face visor.

Figure 2 - Safety glasses and full-face visor.

Welding Goggles

Welding goggles are worn when oxy-fuel welding or cutting. They filter out the harmful light rays and prevent slag and sparks from entering the eyes. Filter plates are available in various shades depending on the intensity of the light radiation in the welding or cutting environment. Usually a shade #4 or #5 is adequate for light cutting and gas welding. You may want to use a darker shade for heavier cutting and welding.

As a general rule, if after cutting or welding for a few minutes, you see light spots when you lift your goggles or helmet, your lens is probably too light. If you see dark spots, your lens is likely too dark. Everyone's eyes have different sensitivity to light, so the best shade filter plate to use is up to you.

NOTE
When choosing a shade filter, ensure that you can see clearly to watch for correct metal flow and placement.

Figure 3 shows a common style of goggles.

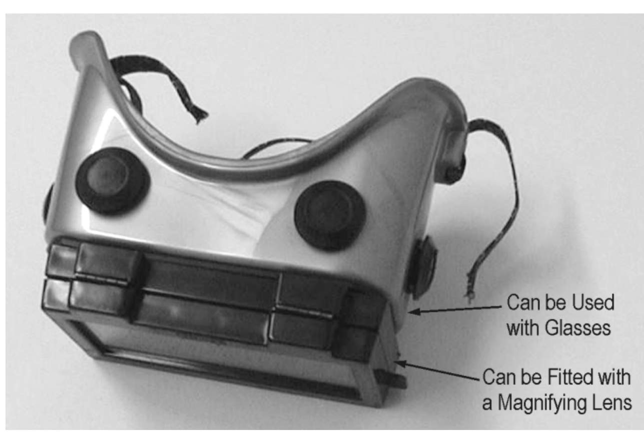

Figure 3 - Oxyfuel welding and cutting goggles.

Welding Helmets and Filter Plates

A suitable welding helmet must be worn when welding or grinding to protect your eyes and facial area from harmful rays and flying particles. The helmet shell protects your face from light, heat, spatter and slag. Helmets are available with flip fronts, fixed fronts or photoelectric filter systems. The flip front or photoelectric type is best for general welding operations because it provides continuous protection while you inspect the weld and chip the slag with your helmet in front of your face. If a hard hat is required, a welding helmet can be attached to your hard hat with a special swivel attachment. Figure 4 illustrates a welding helmet and hard hat combination.

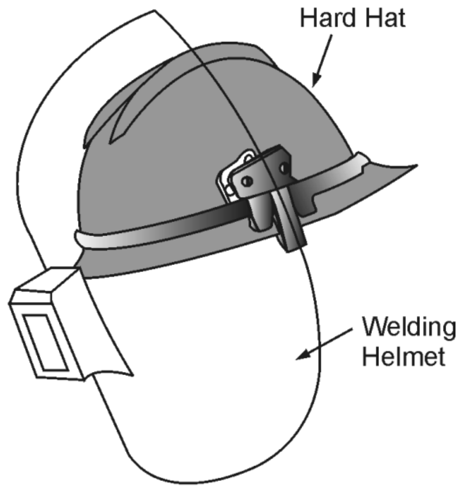

Figure 4 - Arc welding helmets.

Special *filter plates* (sometimes called *filter lenses*) for welding operations are available in various shades ranging from #1 (lightest) to #14. The filter plate absorbs most of the harmful ultraviolet and infrared rays and a large amount of visible light. The dark glass is only a filter and does not correct vision problems.

The shade for your particular welding process has a considerable effect on your comfort and vision. Select a shade that eliminates glare, but allows you to see the work distinctly. No single shade of filter plate suits all types of welding and cutting operations.

The type of filter plate used for most welding and cutting is a hardened blue/green glass. The *American Welding Society* (AWS) and the *Canadian Standards Association* (CSA) have guidelines for filter plates for most welding and cutting operations. The shade number you select can be determined by using the recommendations as a guideline or starting point.

NOTES

Table 3 shows the recommended shade for various welding processes.

Shade #	Welding Processes
9	Low amperage SMAW, GTAW, PAC.
10	Low to medium amperage SMAW, GTAW, PAC.
11	Medium amperage SMAW, GMAW, GTAW, PAC.
12	Medium to high amperage SMAW, GMAW, GTAW, PAC, CAC-A.
14	High amperage SMAW, GMAW, GTAW, PAC, CAC-A.

Table 3 - Filter plate recommendations for arc welding and cutting.

Whether you have a helmet with a flip front or a fixed front, you should place a clear plastic plate in the helmet next to your face. Figure 5 illustrates the parts of a welding helmet associated with changing out clear or filter lens.

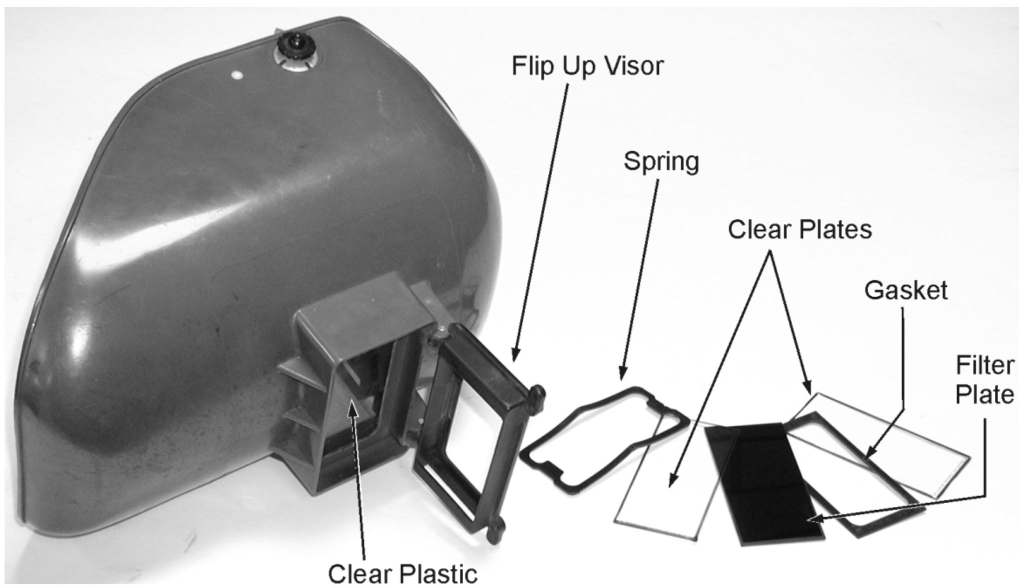

Figure 5 - Welding lenses.

The plastic plate protects your face when you are chipping slag or inspecting welds. Mount the coloured plate between two pieces of clear glass or plastic in the helmet visor to protect the filter plate from weld spatter. Place a gasket between the outer clear glass or plastic and the filter plate. This gasket provides an air space between the two plates which helps prevent heat cracking of the filter plate and separates the plates so that moisture build-up does not cloud your vision. Some helmet flip fronts may only have room for the outside clear plate, the gasket and the filter plate.

CAUTION
Never use glass next to your face because it can shatter and cause serious damage to your eyes.

Photoelectric Welding Helmets

If you have a CSA-approved *photoelectric* welding helmet, it may be used in combination with your safety glasses for welding and cutting. Be aware that your side vision will be restricted, which may be somewhat hazardous depending on your situation. Figure 6 shows an assortment of photoelectric welding helmets available for purchase from welding equipment and safety manufacturers. Most welding helmets are designed to meet *CSA Standard Z94.1 – Industrial Protective Headwear*.

Many photoelectric welding helmets have a control for adjusting the shade number. Some also have a sensitivity control that affects how much light the filter in the helmet absorbs before it automatically turns dark. Different welding processes require different settings. It is up to you to adjust your helmet for the best all-around protection.

Figure 6 - Photoelectric welding helmets.

Protective Clothing

White-hot sparks and slag are a normal part of welding. Slag gathers heat from the arc and molten metal and may be propelled toward the welder by exploding off the weld bead or during chipping. Flying sparks and slag endanger exposed parts of the body and can cause burns and eye injuries. Be aware that an accumulation of hot slag or excessive heat on concrete floors can cause the concrete surface to explode, creating a personal injury hazard. The welder is protected from the sparks and slag by wearing:

- a leather half-jacket (called *cape sleeves*),
- welders' gauntlet gloves and
- 100% cotton coveralls.

Figure 7 shows the flying sparks and slag that a welder needs to be protected from.

Figure 7 - Protection from sparks and slag.

The best clothing materials for welding and cutting are leather, wool and denim (cotton) because they repel sparks and slag.

- Leather offers the best protection against sparks and molten slag and is a very durable material, but full leather clothing may lead to overheating in warm weather.
- The same protective quality can be achieved by wearing leather aprons, capes or sleeves that allow body heat to escape.
- Wool is less flammable than cotton and more desirable for cold temperatures.
- Denim, a tightly woven form of cotton, is a very popular type of clothing worn for most indoor and outdoor welding operations. Make sure it is 100% cotton.
- Welders often wear heavy-weave cotton work wear with leather sleeves for added protection.

DANGER
Denim burns slowly if exposed to extreme sparks or slag, especially if any of the material has become frayed. Keep your work clothing clean and in good condition.

Certain specialized man-made materials, such as *Nomex*, are designed to provide a short-term barrier against flash fires, but may not perform well in a welding environment. Always check to make sure the material is recommended for welding and cutting operations. Some other recommendations related to clothing also exist.

- Wear a cap or beanie to protect your hair, but do not use hair spray.
- Shirt or coat pockets should have flaps, sleeves should be rolled down and collars should be buttoned up.
- Do not keep matches or disposable lighters in the pockets of your clothing.
- Pant legs should cover the top of your footwear and not have cuffs.

DANGER
Avoid wearing synthetics such as polyester and nylon because they tend to melt where sparks land. This allows those sparks to penetrate to your skin. Some synthetics flare rapidly and engulf the wearer in flames or the material can melt into the flesh.

Welding Gloves

Welders' leather gauntlet gloves provide the best protection because they cover up your wrists. They should have inside seams to prevent the seam stitching from burning. Most leather is *chrome-tanned*, meaning chromium salts are used in the tanning process and this makes the leather tougher and more resistant to abrasion.

Welding gloves are usually *dry-tanned* (no oil). They can be purchased with a lined back for extra heat protection or as a thinner, tighter-fitting glove if you don't need the extra heat protection (such as for TIG welding). Aluminized gloves have an aluminized fabric sewn on the back of the gloves and are designed to insulate your hands from intense heat. Leather exposed to extreme heat even for a short time shrinks, stiffens up and becomes useless because it has lost its flexibility. Rubber gloves protect against chemicals and electrical shock. Do not expose rubber gloves to heat, flame or weld spatter.

Footwear

High-top leather steel-toed safety boots that are fully laced and worn under your trousers offer the best foot protection against hot sparks and slag. Footwear should have electrically non-conductive soles. Most safety boots are designed to meet *CSA Standard Z195-M92 – Protective Footwear*. In wet conditions, rubber boots and dry socks provide the best protection from electrical shock hazard. Rubber boots also prevent chemicals from coming in contact with your feet.

Hearing Protection

Most welding shop environments, plant maintenance and construction job sites operate at noise levels in which hearing protection should be used or is compulsory. It is recommended that you use one of the types of hearing protection in Figure 8.

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Figure 8 - Earplugs and earmuffs.

Respiratory Protection

When conventional general ventilation systems are not adequate for protection of health and life, masks and respirators become necessary. They should be selected with care and expert advice may be necessary.

Face Piece

Face pieces require a close seal to the face. This is especially important with negative pressure respirators (also known as *demand respirators*) where suction develops inside the face piece as the wearer inhales which in turn draws breathing air in through the filtered face piece or face piece inlet. Contaminated air could be breathed in if you use a poorly fitting respirator. Sideburns, beards, moustaches, clothing, eyeglasses and earpieces can all interfere with a close fit and may allow contaminants to be inhaled as well. A fit test is required to ensure contaminated air is not going to leak into the face piece.

Make sure you choose a respirator that is designed for the work you are doing. Not all respirators and masks are alike. Some are designed to remove specific vapours or gases only. Some remove particles, but not vapours and gases.

If there is more than one user, wash and disinfect breathing devices before transferring them between users.

Respirators

Respirators have specific tasks that they have been designed for. It is important that welders know the limitations and the proper application of each type of respirator.

NOTES

Objective Three

When you have completed this objective, you will be able to:

Explain the hazards involved with welding fumes and gases.

Fumes and Gases

Fumes and gases are silent and often unseen dangers. *Fumes* are small, condensed particles of metal or other substance that vaporize during welding and cutting operations. These particles are often smaller than $^{1}/_{50}{}^{th}$ of the width of a human hair. They may or may not be visible, depending upon their size and concentration. These small particles stay suspended in the vapour or the gas and may enter your body with the air you breathe. Welding smoke is an example of a fume.

A *gas* is one of the fundamental states of matter, with freely moving particles that mix readily with air and tend to expand out of an open container or expand because of the use of the gas in a particular welding process. Gases such as argon, helium or carbon dioxide are non-toxic, but inhalation of large quantities of these gases can cause suffocation.

DANGER
Gases created during welding, such as ozone, carbon monoxide or nitrogen dioxide, are extremely toxic (poisonous). In high enough concentrations, these gases can be fatal.

DANGER
Some harmful gases cause cancer and are called *carcinogens*.

Metal fume fever produces flu-like symptoms from inhaling fumes of certain metal oxides. Zinc oxides from welding galvanized steel or from braze welding (copper and zinc) are major causes of metal fume fever. Although exposure to fumes and gases is unavoidable, it should be kept to a minimum. You should know where fumes and gases come from, their effects on your body and how you can reduce or eliminate the risk of injury (body positioning, PPE usage and ventilation methods).

Fumes and gases are created from three sources:

1. the melting of base metals and fillers,
2. base metal coverings such as coatings, residues and plating or
3. fluxes.

NOTES

Fumes from Metals

Table 4 lists metals and other materials that produce fumes, some possible sources and the results of inhaling the fumes.

Metal	Source	Result of Inhalation
Aluminum	– Component of some alloys. – Base metal of applications.	– Irritation of respiratory system.
Beryllium	– Hardening alloy.	– Coughing, shortness of breath. – A carcinogen (cancer causing). – Severe poisoning can be fatal.
Cadmium	– Some silver brazing alloys. – Cadmium plated material.	– Tight chest, coughing, headache. – Vapours are poisonous and carcinogenic. – Can cause kidney damage and emphysema. – Cadmium poisoning can be fatal.
Chromium	– Most stainless steels. – Used as a plating material.	– Risk of lung cancer. – Some forms are carcinogens.
Cobalt	– Hardening alloy (red hardness).	– Irritation of respiratory system.
Copper	– Alloys in brass, bronze and monel.	– Irritation of respiratory system and eyes. – Can cause metal fume fever.
Iron	– Major element in carbon steels.	– Immediate symptoms include irritation of nose and lungs, usually non-permanent. – Effects tend to disappear over time, once exposure is reduced or stopped unless your lungs have already been damaged.
Lead	– Alloy in solder, brass and bronze.	– Toxic vapours affect the nervous and digestive systems and kidneys. – Lead poisoning can be fatal.
Manganese	– Alloy in high tensile steels.	– Toxic vapours affect the nervous system. – Can cause metal fume fever.
Nickel	– Alloy in stainless steels, inconel, monel and hastelloy.	– Irritation of the respiratory system. – Can cause metal fume fever. – Fumes can cause cancer.
Zinc	– Galvanized metal alloy in brasses.	– Irritation of the respiratory system. – Major cause of metal fume fever.

Table 4 - Results of metal fume inhalation.

NOTES

Fumes from Base Metal Coatings and Welding Fluxes

Table 5 lists some harmful substances produced from base metal coatings, residues, plating and fluxes and a description of the health hazards caused by the inhalation of the gas these substances produce.

Coating	Harmful Substance	Result of Inhalation
Rust inhibitors	Phosphine gas formed by reaction with welding radiation.	– Irritation of eyes and respiratory system. – Can damage kidneys and other organs.
Chlorinated-Hydrocarbon degreasers	Phosgene gas and hydrochloric acid produced by ultraviolet light acting upon the vapours.	– Irritation of eyes and the respiratory system. – Poisonous, may be fatal.
Paint	– Iron oxide. – Zinc. – Mercury or lead.	– Irritation of the nose and lungs. – Can cause metal fume fever. – lead poisoning could be fatal.
Plastics	Ethylene dichloride gas, used in manufacturing plastics.	Poisonous, may be fatal.
Fluoride	Common electrode coating.	– Irritation of eyes, nose and throat. – Long term effect is fluid in the lungs.
Borates	Used in soldering flux.	Irritation of the skin, eyes and respiratory system.

Table 5 - Harmful base metal coatings, residues, plating and fluxes.

NOTE
Consult your MSDS for specific procedures when welding or cutting on materials which can produce poisonous fumes.

Welding Gases and Gases Produced by Welding

As gases enter your body with the air you breathe, different gases affect you in different ways. A healthy body can rid itself of some gases without lasting effects. The health effects of gases used in welding and gases created when welding are listed in Table 6.

Gas	Source	Result Of Inhalation
Shielding Gases		
Argon Helium Carbon dioxide	Used during welding processes (GMAW, GTAW).	– These gases are non-toxic. – Inhaling concentrated amounts can lead to suffocation.
Gases Produced by Welding		
Carbon monoxide	Formed in the arc as CO_2 is reduced to CO by heat.	– Absorbs readily in the bloodstream and decreases blood's oxygen-carrying ability. – High concentrations can cause death.
Ozone	Formed as oxygen reacts with ultraviolet light from welding.	– Low concentrations cause headaches and irritation of the nose and throat. – Death or permanent lung damage can result from prolonged exposure.
Nitrogen dioxide	Rapid cooling of air.	– Coughing, bronchial irritation, chest pain and fluid in the lungs. – Death can occur in 24 hours in severe cases.

Table 6 - Results from inhaling gases.

Occupational Exposure Limits

Occupational exposure limits (OELs) are the maximum concentrations of a hazardous substance that a healthy person can be exposed to without suffering adverse health effects. There may be increased risks for persons with health problems such as asthma or allergies or for those who smoke. The values of the OEL that are used are limits based on:

- a normal eight hour working day,
- a fifteen minute short-term exposure and
- a ceiling that must never be exceeded.

Normally, gases and fumes created by welding on clean carbon steels do not cause immediate health problems. However, over the years, if you breathe in gases and fumes that exceed the OELs, you will probably suffer health problems.

DANGER
You must protect yourself by knowing what you are working on and what harmful substances may be produced. Ensure that you use the correct ventilation based on the welding job you are doing.

NOTES

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Objective Four

When you have completed this objective, you will be able to:

Identify welding fume ventilation methods.

Ventilation Methods

Welders need to be able to assess their work environment and choose the method of ventilation that is most suitable for the task that they have been assigned.

The Plume

A safe practice is to place your head so the smoke coming from the welding plume is not in your breathing zone. Although this does not remove the fumes, it reduces the exposure to them if you are not welding in a confined space. Figure 14 shows a welder who has incorrectly positioned himself with the welding plume rising around his head.

Figure 14 - Head in the welding plume increases exposure.

Figure 15 illustrates the same welder positioned correctly so that the welding plume rises up and away from his head.

Figure 15 - Keep your head out of the plume.

Natural General Ventilation

An unlimited fresh air supply should eliminate any potential fume hazards unless particularly toxic materials are involved. One important line of defence against fumes and gases is to weld outside where fumes and gases are not confined. Figure 16 shows a welder positioned so that the welding smoke is drifting out the open door.

Figure 16 - Natural general ventilation.

Mechanical General Ventilation

Mechanical general ventilation occurs when air is pumped into the shop, passes through the environment and is vented outdoors through ductwork, doors and windows. Simple mechanical ventilation may consist of portable fans near the source of the welding station to remove fumes and smoke.

As a guide, a minimum of fifty-seven cubic metres (two thousand cubic feet) of air per minute per welder has to be moved in the room. If the visible fume clears in about thirty seconds, ventilation is probably adequate. In most welding shops, the ventilation system should give four complete changes of air per hour.

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Figure 17 is an illustration of a mechanical general ventilation system where the air is drawn in from the top of the building and exhausted out through a wall vent.

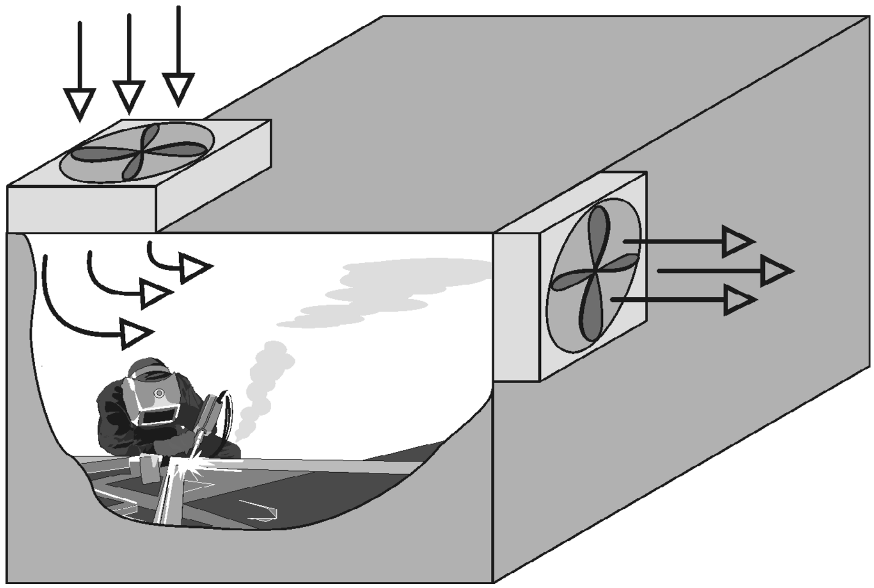

Figure 17 - Mechanical general ventilation.

Local Ventilation

Exhaust fans capture fumes at their source and exhausts them outdoors. Also known as *source extraction*, local ventilation systems can have either fixed or flexible ducting systems. A flexible ducting system allows you to place the extraction hood in the most effective position to remove fumes. In either case, the plume should not rise up into your breathing space.

Figure 18 illustrates a local ventilation system that captures the fumes and vents them outdoors.

Figure 18 - Local ventilation system.

NOTES

Objective Five

When you have completed this objective, you will be able to:

Explain the effects of electricity and precautions used to prevent injury.

Electric Shock Hazards

Electrocution accounts for approximately fifty industrial accidents in Canada and one thousand in North America per year. As a welder, you must take every precaution to protect yourself and others from electrical shock. The voltages used for manual arc welding are relatively low and do not usually cause electrical shock. Conditions such as high temperatures, high humidity, sweaty clothing and working in wet conditions greatly increase the possibility of electric shock. Some of the factors affecting the severity of electric shock are listed in Table 7.

Factor	Effect on Severity
Current type	When voltages are equal, alternating current is more dangerous than direct current. AC can cause spasms that tighten your grip. DC may throw you away from the circuit, but DC is still harmful.
Voltage	Circuits of 200V - 250V can be deadly because these voltages do not have the power to throw the victim clear of the circuit.
Amperage	A current of only 15mA - 20mA AC can stop you from releasing your grip. This may cause death, especially at low frequency.
Frequency	Low frequency is more dangerous than high frequency. For example, 50Hz - 80Hz can be fatal because the victim stays locked to the circuit, whereas 30 000Hz - 50 000Hz can throw the victim clear.
Resistance	Body chemistry and the amount of moisture on the body cause body resistance to vary from 500 ohms - 50 000 ohms. Low body resistance allows increased current to flow through the body. High body resistance reduces the severity of electric shock.
Contact duration	Electrical current flowing through the body for one to three seconds can be fatal.
Path of current through the body	The path that the current takes through the body can determine the extent of damage. For example, current passing through the heart is more dangerous than current flowing between the fingers of one hand.

Table 7 - Factors affecting the severity of electric shock.

Avoiding Electric Shock

To avoid electrical shock, follow the guidelines listed in Table 8 as they pertain to safety equipment and welding accessories.

Equipment	Precautions
Ground fault circuit interrupter (GFCI)	Electrical shock is experienced when current finds a path through the body to the ground. The GFCI senses that current flow and breaks the circuit in about $^1/_{40}$ of a second while the flow is still at a low level (example 5 mA). GFCIs are available to protect people or equipment. GFCIs that protect people open the circuit at a lower level of current flow.
Clothing	Damp skin and sweaty or wet clothing can decrease the body's resistance. Dry clothing is the first line of defence. Wear rubber gloves under gauntlets if your hands are sweating. In wet conditions, wear rubber boots with dry liners and dry socks. Avoid boots with nailed soles and gloves with rivets.
Electrode holders	Never allow their metal parts to touch your skin or wet clothing. Never hold them under your arm so that you can have both hands free. Never cool them in water.
Cables	Never loop cables around your body. Use only approved connectors to join lengths of cable. Never use cables that have damaged insulation without repairing them first.
Power sources	Power sources must be connected by a qualified electrician to ensure they are properly grounded. Leave them outside of a confined space. Have a readily accessible means of disconnecting the power. When changing or repairing any power source, lock out the power feeding it.
Lights and tools	Use low voltage electric lighting. Insulate electrical tools with heavy-duty leads. Use pneumatic tools wherever possible.

Table 8 - Guidelines for avoiding electric shock.

Rescue Procedures for Electric Shock Victims

Electrical shock can cause cardiac arrest, *ventricular fibrillation* (uncoordinated heart activity), damage to the nervous system or dangerously high body temperatures. Violent convulsions can cause broken bones and torn tissues. If you suspect someone has been subjected to electrical shock, be aware of the following before attempting a rescue.

- Alert the proper authorities about the location and type of accident.
- Act quickly. One second can make the difference between life and death, but do not become another victim.
- Do not touch a victim who is still in contact with the conductor. Switch off the electrical supply or pull the plug.
- Use adequate insulation if the conductor must be moved. Wear dry, rubber gloves and use a dry cloth or dry timber. Considerable force may be needed.
- Be careful that victims who are at heights do not fall when they are released.
- Remember that in a confined space, the walls or floor may conduct electricity.

NOTES

Objective Six

When you have completed this objective, you will be able to:

Describe the procedure for welding or cutting in confined spaces or potentially dangerous enclosures.

Welding or Cutting Near Flammables

High temperature flames and electric arcs are essential parts of the welding process. Welding shops are built with this in mind. However, outside the shop, conditions are often different. Flammable materials are found in containers, vessels, pipes, walls, other rooms or even on other floors of a building. These concealed flammables may exist as solids, liquids, gases, dusts and powders. All flammables have the potential to cause major damage and injury or death.

Because welders and welding businesses are legally responsible for preventable damage they cause, they must carry liability insurance. However, if an insurance policy is overused, it may be cancelled. A welding company without liability insurance might have difficulty obtaining work. For this reason and for the safety of others, you must check the surrounding area for fire and explosion hazards before starting to weld.

Welding sparks can travel through cracks or ducts and sparks can land on flammable substances, gases or energized electrical equipment. These hazards can exist anywhere, so you must be alert to the effects that your work may cause.

Preventing Fires or Explosions

Many safety concerns must be addressed to prevent fires or explosions.

- Obtain a safe work permit or a hot-work permit if your job requires one.
- Use a gas detector (commonly referred to as a *sniffer*) to determine if dangerous gases are present prior to and during the welding operation. Check with your employer for specific procedures.
- Welding must not be done in an explosive atmosphere. Dangerous atmospheres are created by air mixing with flammable gases, vapours, liquids or dust.
- Oxygen-rich air is also dangerous. Excess oxygen causes some substances that are usually non-combustible to burn actively.
- Become familiar with the available fire extinguishers. Know where they are, how they work and what type of fire they are designed to extinguish.
- Move combustibles to a safe place or shield them from the welding process with fireproof blankets or barriers. Wet combustible floors or cover them with a protective material such as metal or wet sand.
- Shield fire protection sprinklers and smoke detectors if you are welding within one metre (39") of them.
- Know what is contained in nearby pipes and vessels in case explosive substances are or have been in them.
- Use a fire watch person, if necessary, to ensure complete protection. This person looks for fires as the welder works and for an additional sixty minutes after the job is finished.

NOTES

Working In or On Containers

You must also be aware of the dangers while working on containers that have held or are coated with a combustible material.

DANGER
Extreme danger exists when cleaning, purging, cutting or welding on containers. Toxic and/or explosive gases can be produced no matter how long the container has been empty.

You should be aware of potential hazards when working in or on containers.

- Identify the substance that was held in the container so that you can guard against fire, explosion and toxic gases. If the contents are unknown, treat the container as if it had held a combustible substance, no matter how long it has been empty.
- Know what materials coat, plate or have been spilled on the container. Containers that have held non-volatile materials can be as dangerous as containers that held volatile petroleum products.
- Non-volatile substances such as plastic, oil, paint, varnish or resin can burn, explode or produce toxic vapours when they are heated by welding or cutting. Remember that containers that have held safe substances may be coated, inside or outside, with potentially dangerous materials.
- Understand that containers or buildings such as grain elevators, coal storage bins or woodworking shops may be filled with dust. Concentrations of dust are flammable when they fill the atmosphere of a building or a storage bin. In a split second, a sheet of flame can sweep through the air and fill the building with fire.
- Watch for pipes that contain flammable gases or liquids and are within one metre (39") of welding or cutting operations. Be sure to shield or insulate these pipes from heat and accidental arc strikes.
- Use extreme caution when working on boxed-in sections made from pipe or tubing or enclosed automotive and heavy equipment frames. These enclosures may have years of accumulated oil and grease and can form an explosive mixture from the heat of welding or cutting.
- Use a gas detector to determine if these enclosed spaces contain flammable gases. Check the internal atmosphere frequently as the hot work progresses.
- Remove internal components such as pipes and baffles before cleaning or take extra care to clean them thoroughly.
- Monitor the air in the confined space at all levels because some gases rise and some collect in low areas.

REVIEW QUESTIONS

Complete the following questions on the bubble sheet provided.

1. Permanent eye damage in the form of cataracts or retinal damage may result from over exposure to which harmful light ray?
   a) visible
   b) infrared
   c) ultraviolet
   d) reflected
2. Which type of radiant energy can cause welding flash?
   a) visible light
   b) infrared light
   c) ultraviolet light
   d) gamma rays
3. What must be done where the general public is exposed to harmful welding rays?
   a) Put up proper screens and warning signs.
   b) Let people look out for themselves.
   c) Weld only when no one is around.
   d) Avoid the use of a long arc length.
4. What should you do immediately if you receive a major contact burn?
   a) Rub the affected area with antibiotic cream.
   b) Seek professional medical attention.
   c) Cool the burned area by immersing in cool, still water.
   d) Place the burned area under a fast-running warm water tap.
5. One of the most common workshop hazards is:
   a) heavy weights.
   b) high noise levels.
   c) other workers.
   d) poisonous gases.
6. Hearing protection should be worn when the noise level is above:
   a) 65 decibels.
   b) 85 decibels.
   c) 115 decibels.
   d) 135 decibels.
7. What type of eye protection is recommended for grinding operations?
   a) full-face visor
   b) safety glasses with side shields
   c) welding goggles
   d) photoelectric welding helmet

8. What shade of filter plate is recommended for medium amperage GMAW operations?
   a) 9
   b) 10
   c) 11
   d) 12 or over
9. Which type of material offers the best protection against sparks and molten slag?
   a) leather
   b) wool
   c) nylon
   d) cotton
10. What gloves are recommended for oxyfuel cutting?
   a) hard twist cotton
   b) silicon-treated nylon
   c) dry-tanned leather gauntlet style
   d) oil-treated cowhide with external cotton stitching
11. Which metal, when heated or welded, can produce metal fume fever if the fumes are inhaled?
   a) aluminum
   b) zinc
   c) chromium
   d) cobalt
12. The first line of defence against welding fumes and gases is:
   a) a supplied air respirator.
   b) source extraction equipment.
   c) to complete all welding during the first half of your work shift.
   d) to weld outside.
13. A tool rest on a fixed grinder must be:
   a) adjusted when the grinder is in motion.
   b) set to a minimum 6 mm (1/4") from the wheel.
   c) positioned for grinding on the side of the wheel.
   d) set to a maximum of 3 mm (1/8") from the face of the wheel.

Shielded Metal Arc Welding (SMAW) - Part A

Shielded Metal Arc Welding (SMAW) - Part A

NOTES

Rationale

Why is it important for you to learn this skill?

The *shielded metal arc welding* (SMAW) (manual arc welding) process is commonly used in many phases of equipment repair. You must know the safety requirements, machine set-up and adjustments, electrode selection and puddle control techniques in order to make these necessary repairs. This module provides the information required to perform these welding operations.

Outcome

When you have completed this module you will be able to:

Perform welding operations using arc welding equipment.

Objectives

1. Define basic electricity terms related to arc welding.
2. Describe selected machine types, welding currents and polarities.
3. Describe care and maintenance procedures of arc welding equipment.
4. Demonstrate equipment set-up and adjustments.
5. Describe the electrode designation system.
6. Select electrodes for specific applications.

Introduction

This module will cover safe operation and adjustment of arc welding machines. The module is designed to introduce you to puddle control techniques and to develop your hand skills at performing beads and fillet welds on mild steel using the SMAW process. This module presents information necessary to select the correct electrode for the application at hand.

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Objective One

When you have completed this objective you will be able to:

Define basic electricity terms related to arc welding.

Definitions

In order for you to gain an understanding of basic electricity and welding power sources, you must first understand some basic terms associated with this subject matter. The following terms are used throughout the trade and you should become familiar with these terms in order to communicate with others in the trade.

Term	Definition
alternating current (AC)	*Alternating current* (AC) is current that flows in one direction during any half cycle, then reverses and flows in the opposite direction during the next half cycle. The rate at which this alternating occurs is measured as cycles per second, with 60-cycle AC being the most common in North America.
amperage	*Amperage* is also known as *heat setting.* Amperage is the current flow through the welding cables while welding. A welding machine is manufactured to have a maximum amperage output (for example, 200 amps, 250 amps or 300 amps). The operator can select the welding amperage, within the limits of the machine, to suit the requirements of the job at hand. This is the electrical property that causes the electrode, the parent metal, or both, to be melted. Amperage in arc welding is responsible for the following. • *Metal deposition rate* (also known as *burn-off rate*). If the amperage is increased, there is a proportionate increase in the metal deposition rate of the electrode. A decrease in amperage results in a decrease of the metal deposition rate. • *Penetration*: Increasing the amperage causes the arc to penetrate or burn deeper into the parent metal and lowering the amperage causes a decrease in penetration.
arc	In welding, an *arc* is created when there is enough amperage and voltage available at the electrode tip to overcome the natural resistance to the flow of electricity. This resistance is usually caused by the air gap between the electrode and the work. The heat of the arc melts the base plate and the electrode.

Term	Definition
arc blow	*Arc* blow is a condition encountered when welding with direct current that causes the arc to flare uncontrollably from side to side. Puddle control is very difficult and the subsequent weld quality is very poor. *Arc blow* is caused by magnetic fields being set up around the work. This is due to current travelling in the same direction for a prolonged period of time. Arc blow is not a problem when welding with AC because the reversals in the direction of current flow prevent the accumulation of magnetic fields being set up around the work. If it is not possible for you to change to an AC power source, arc blow can be minimized or eliminated by: • changing the position of the ground clamp, • using a different electrode angle or electrode inclination, • welding toward a heavy tack or existing weld, • welding in the opposite direction, • positioning the object being welded on so it is in contact with the earth, • using a lower current setting and/or • wrapping the ground cable around the pipe a few times, as in pipe line welding. If that is not successful, wrap it in the opposite direction.
arc voltage	*Arc voltage* is the voltage output of the machine while welding is being done. It is the force that maintains the current flow across the arc between the electrode and the workpiece. Higher arc volts improve arc stability and also increase the amount of heat in the arc, thus causing the puddle to be more fluid. There is not an adjustment to the arc volts on most manual arc welding machines. The operator can influence the arc voltage by varying the length of the arc.

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Term	Definition
buzz box	The term *buzz box* is often used to describe an AC transformer type welding machine because of the typical buzzing sound made when welding with them. Figure 1 illustrates an inexpensive AC transformer type welding machine. Settings tend to be rather coarse; typically ten to twenty amps per step. Each step or tap is connected to a fixed position on the secondary coil in the machine.

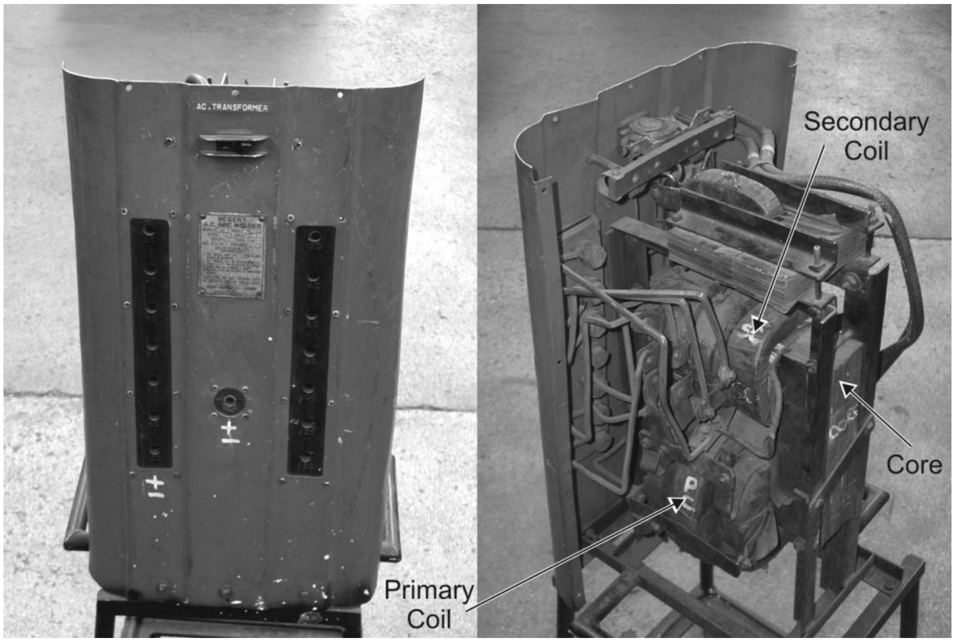

Figure 1 - AC transformer welder with step controls (taps).

circuit	Any system of conductors that is designed to complete the path of an electric current is called a *circuit*. Current flows in the conductor when voltage is applied to it.
core	The *core* is the magnetic link between the primary and the secondary coils of a welding transformer. The core can be moved into, or out of, the coil as a method of current control. This type of current control is called *movable shunt*. A movable shunt means that the core can be moved into different positions thus, influencing the magnetic link between the primary and secondary coils. The shunt is usually moved mechanically by an external hand crank that controls its movement on a slide assembly. This allows for any setting between minimum and maximum of the machine's output potential.

Term	Definition
coil	A *coil* is usually made of insulated copper wire and is designed to have a certain number of turns of wire. The coil can be moved over or away from the core as a method of adjusting the welding current. Figure 2 illustrates an AC transformer type welding machine with a fixed primary coil, a fixed secondary coil and a movable shunt.

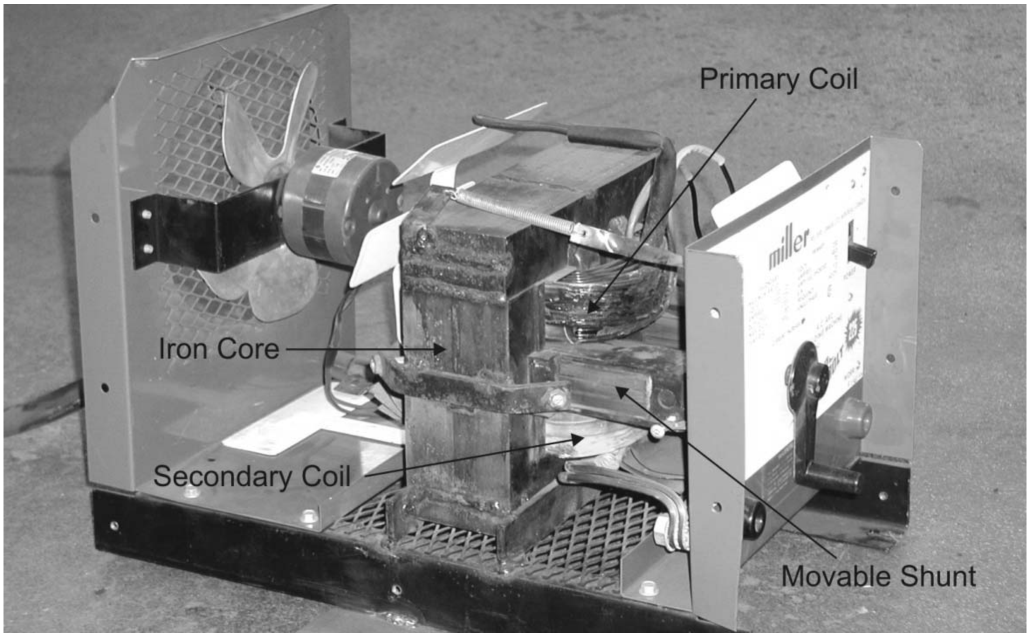

Figure 2 - Coils and movable shunt in an AC welding machine.

conductor	A conductor is a material or substance that is capable of transmitting electricity. Most metals are good conductors because they offer little resistance to current flow.
constant current (CC*)*	*Constant* current (CC) is a term denoting a welding machine suitable for SMAW and GTAW. These machines typically produce a relatively high open circuit voltage to assist in establishing a welding arc. These machines produce a steep or drooping volt-amp curve.
constant voltage (CV)	*Constant voltage* is also known as constant potential A term denoting a welding machine suitable for GMAW, FCAW and SAW. These machines produce a relatively stable voltage regardless of the amperage output of the machine. These machines produce an almost flat volt-amp curve.

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Term	Definition
cycle	A *cycle* is one complete rotation of the sine wave pattern as illustrated in Figure 3. The sine wave begins at zero, climbs to its maximum positive value, then drops back through zero and becomes negative. It reaches its maximum negative value, then proceeds to zero again. This movement is one full cycle of AC current. With 60-cycle AC, the current changes direction 120 times per second.

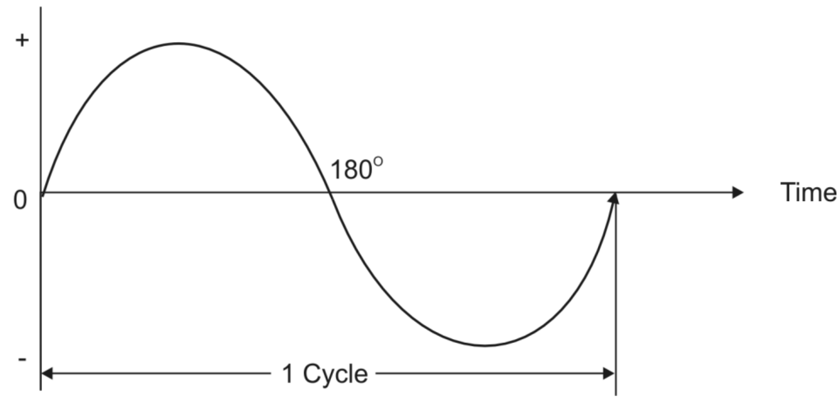

Figure 3 - One cycle of alternating current (sine wave).

Term	Definition
direct current (DC)	*Direct current* (DC) is electric current that flows in one direction only and has either a positive or negative value. There is no change of current flow direction as there is with AC. The electron theory states that current flows from negative to positive.
duty cycle	All welding machines are rated by the *National Electrical Manufacturers Association* (NEMA). The rating is based on maximum output over a ten-minute time period. This rating is expressed as a percentage of the time that the machine can run at maximum rated output current before it must be allowed to cool down. For example, a machine rated at 300 amps with a 60% duty cycle can operate at maximum rated amperage for six minutes out of ten without causing damage by overheating. Also, if the machine was required to run continuously, it could safely run at 60% of 300 amps, or 180 amps maximum. (This is a rule of thumb calculation for estimating other than rated output). Exceeding duty cycle ratings can damage or ruin a welding power source.
flux core arc welding (FCAW)	*Flux core arc welding* uses GMAW equipment and process, but uses flux core wire rather than solid core wire. Shielding gas can be externally applied and/or obtained within the hollow electrode core. FCAW is used extensively in the fabrication industry for welding of carbon and alloy steels, stainless steels and hard surfacing applications.
generator	A *generator* is a machine used to create electricity of sufficient volume for welding. A shaft, with an electrical conductor, is rotated perpendicular to a magnetic field. Generators produce

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Term	Definition
	either AC or DC depending on their internal configuration.
gas metal arc welding (GMAW)	*Gas metal arc welding*, (Figure 4), commonly referred to as MIG (metal inert gas) welding, is an arc welding process that fuses metal by heating it with an electric arc established between a continuously fed filler metal (consumable solid wire) electrode and the workpiece. Appropriate settings made by the operator maintain a constant burn-off rate of the wire electrode. Depending upon the power source and wire drive system used, the arc length is maintained automatically. Atmospheric contamination is prevented by using an externally applied shielding gas

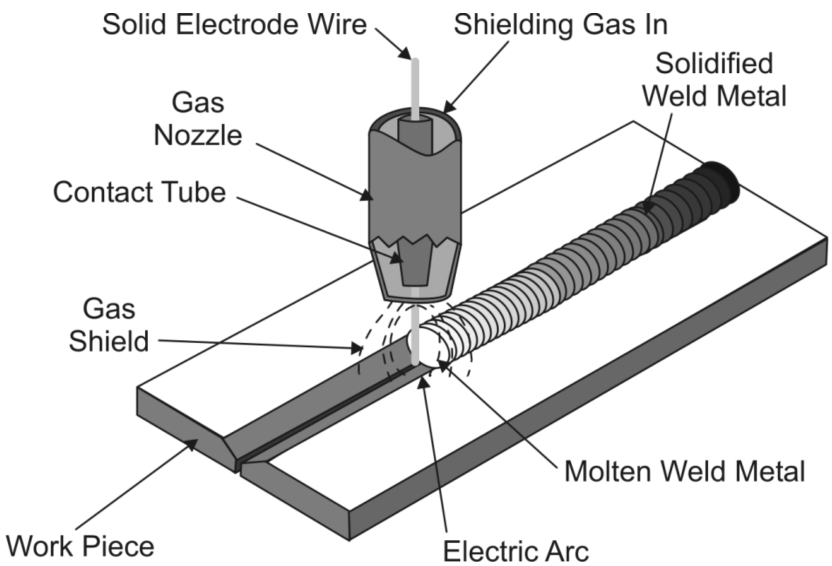

Figure 4 - Gas metal arc welding process.

Term	Definition
gas tungsten arc welding (GTAW)	*Gas tungsten arc welding*, (commonly referred to as TIG - tungsten inert gas) is a process in which fusion welding is accomplished by the heat of an electric arc drawn between a non-consumable tungsten electrode and the workpiece. The electrode, arc, weld puddle and the adjacent heated area of the workpiece are protected from atmospheric contamination by an externally applied gaseous shield. Filler rod is added manually. GTAW is easily adapted for welding a wide variety of ferrous and non-ferrous metals with high quality control.
inverter	An *inverter* is a device that changes DC to AC. In welding machines, inverters are also used to increase the frequency of AC.
metal inert gas (MIG)	See GMAW.
open circuit voltage (OCV)	When a welding machine is turned on, but no current is flowing in the circuit, *open circuit voltage* is the potential force available to initiate the current flow when the arc is struck. Open circuit voltage is built into the machine and is not adjustable by the operator. 80 OCV is the maximum available for safety reasons.

NOTES

Term	Definition
	A machine with high OCV will have superior operator appeal. The arc is easier to strike and the arc voltage will be higher, creating better arc stability.
rectifier	A *rectifier* is a device that changes AC to DC by allowing current to flow in one direction only.
resistance	*Resistance* is the property of an electrical conductor to oppose the flow of current, causing electrical energy to be turned into heat. Resistance is measured in ohms and is calculated by dividing voltage by amperage (Ohms = V/A). The air gap (arc length) offers resistance to current flow. It is this resistance to the flow of current across the arc that creates the heat needed for welding.
reverse polarity (DCRP)	*Direct current reverse polarity, direct current electrode positive*. In a SMAW DC welding circuit, reverse polarity occurs when the electrode cable is connected to the positive terminal of the welding machine. For more details, see the sections on *Machine Types* and *Welding Currents* in Objective Two.
shielded metal arc welding (SMAW)	*Shielded metal arc welding* is a manual arc welding process that fuses metal using the heat from an electric arc established between a consumable *stick* electrode and the workpiece. Appropriate settings made by the operator maintain a constant burn-off rate of the electrode. The operator controls the molten puddle and ultimately the finished weld by manually manipulating the arc length, the electrode angle relative to the workpiece and the rate of travel. The electrodes are supplied with a coating that breaks down during the welding process to produce a protective gaseous shield around the molten puddle and also a slag cover to protect the cooling weld.
straight polarity (DCSP)	*Direct current straight polarity, direct current electrode negative*. In a SMAW DC welding circuit, straight polarity occurs when the electrode cable is connected to the negative terminal of the welding machine. For more details, see the sections on *Machine Types* and *Welding Currents* in Objective Two.
voltage	*Voltage* is the electrical pressure or force that causes current to flow in a conductor or to cross the arc gap. Voltage in arc welding is responsible for the following: • *Starting the arc:* With constant current welding machines, open circuit voltage needs to be quite high (80 volts) in order to initiate an arc. • *Maintaining the arc:* Arc voltage must be present to maintain the arc (typically 17 to 40 volts). • *Puddle fluidity and puddle flow*: Arc voltage directly affects both the width of the weld bead and the fluidity or wetness of the puddle. An increase in arc voltage causes an increase in puddle width and fluidity, while a decrease in arc voltage, causes the puddle to be

Term	Definition
	narrower and less fluid.
welding machine (welding power source)	A *welding machine* is an apparatus that is specifically designed to deliver an electric current of proper voltage to amperage ratio and of sufficient capacity for welding.

Basic Joints

Basic joints are shown in Figure 5.

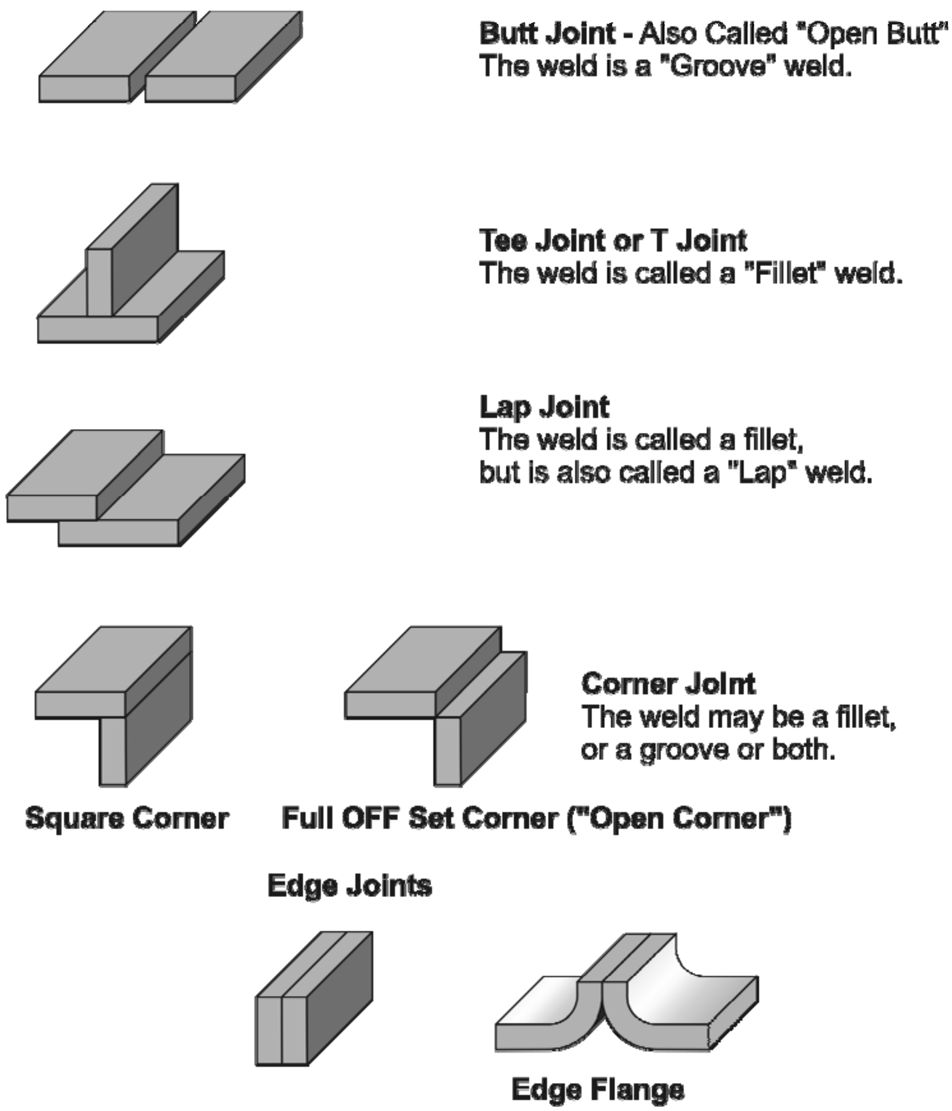

Figure 5 - Basic joints.

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Welding Positions

Welding positions are shown in Figure 6.

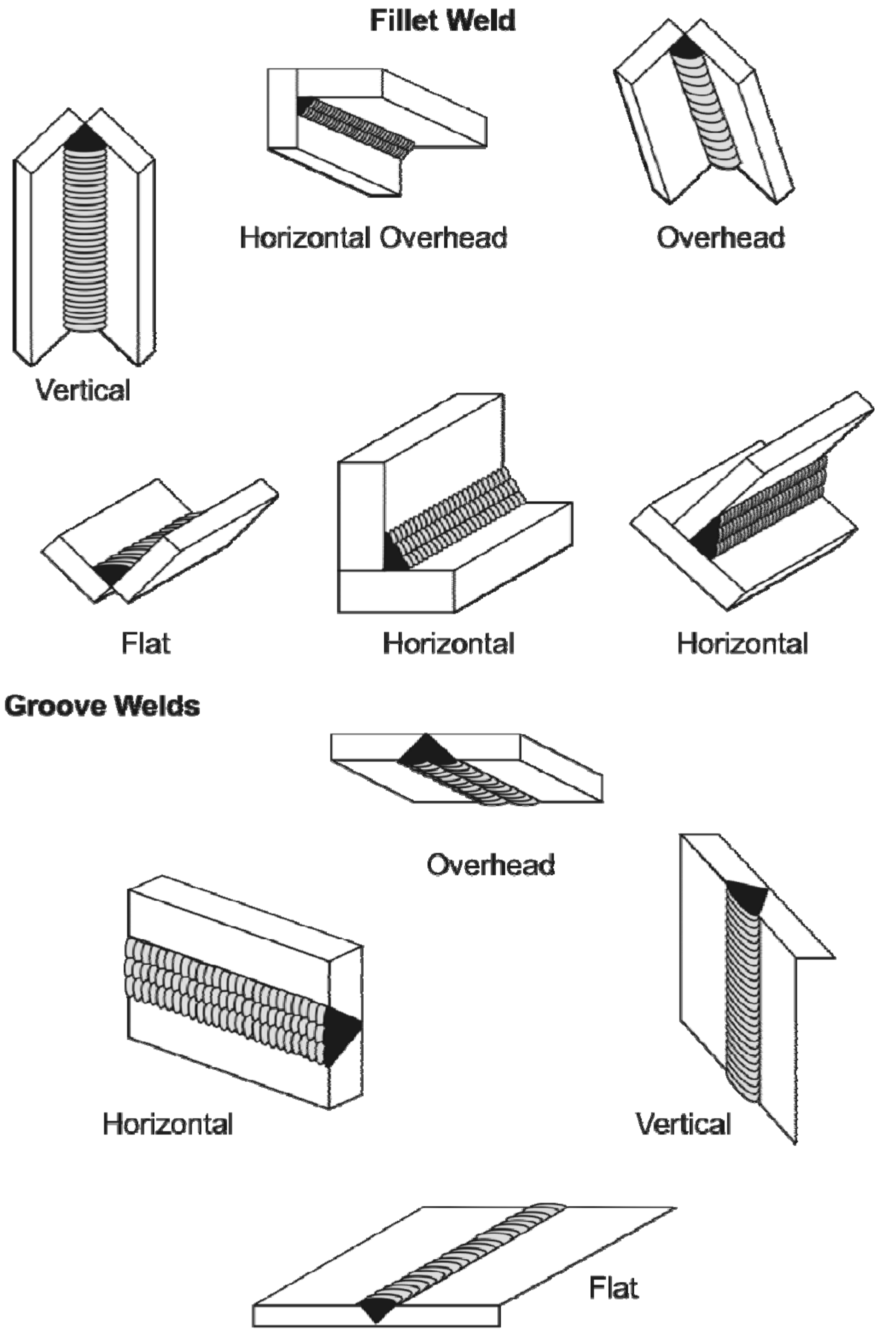

Figure 6 - Welding positions.

Groove Weld Edge Preparations

Groove weld edge preparations are shown in Figure 7.

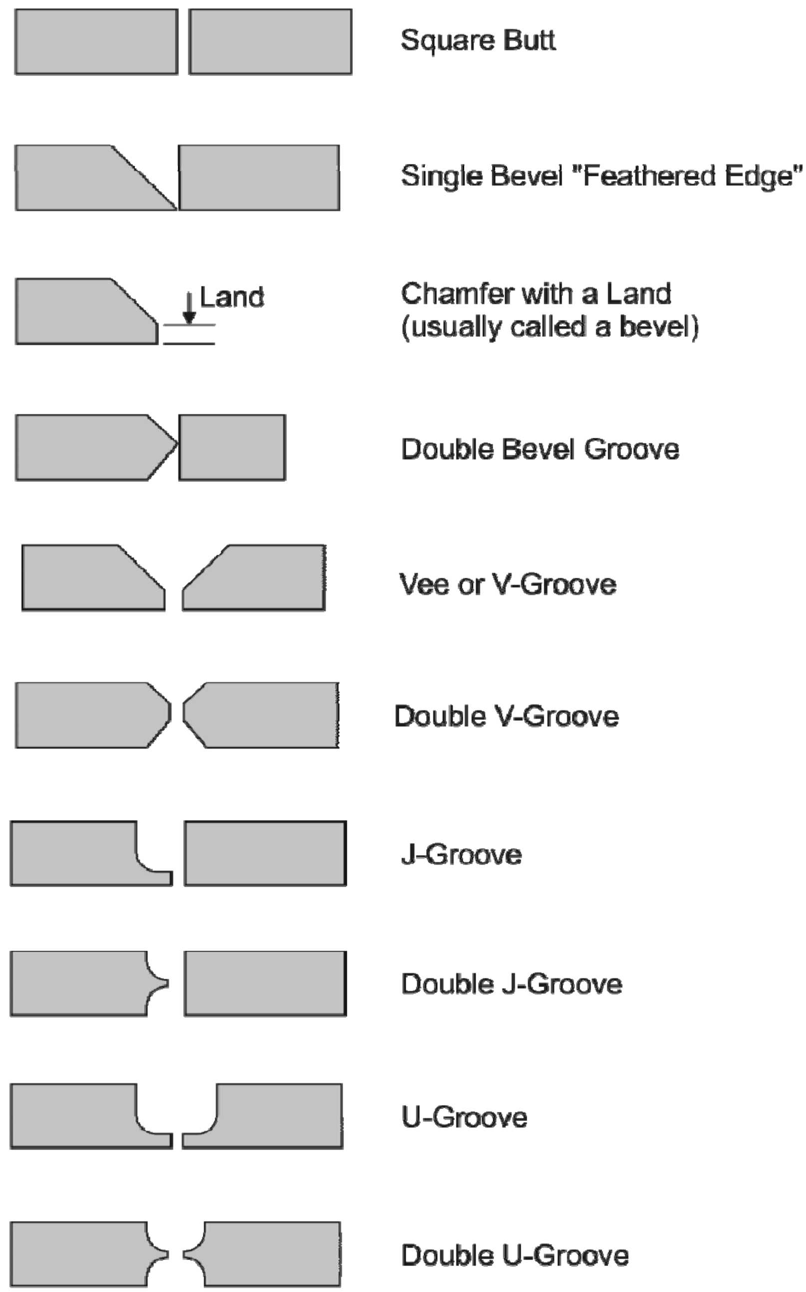

Figure 7 - Groove weld edge preparations.

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Weld Components

Weld components include the following.

Fillet Weld

A fillet weld is shown in Figure 8.

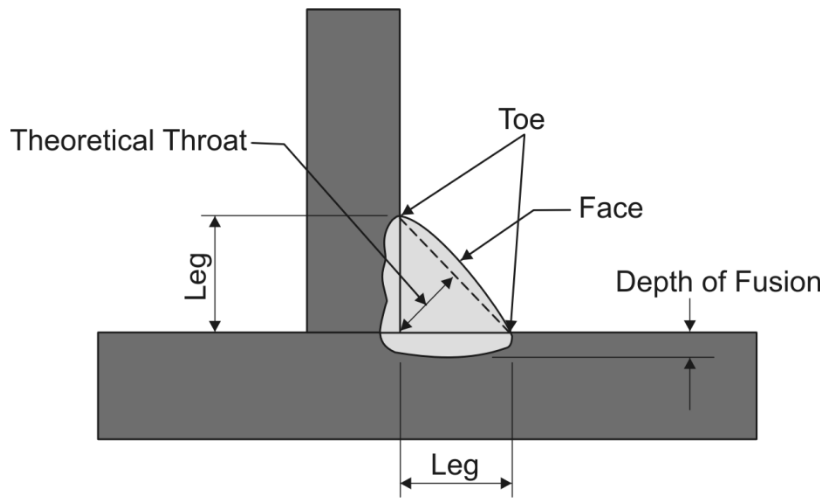

Figure 8 - Fillet weld.

Groove Weld

A groove weld is shown in Figure 9.

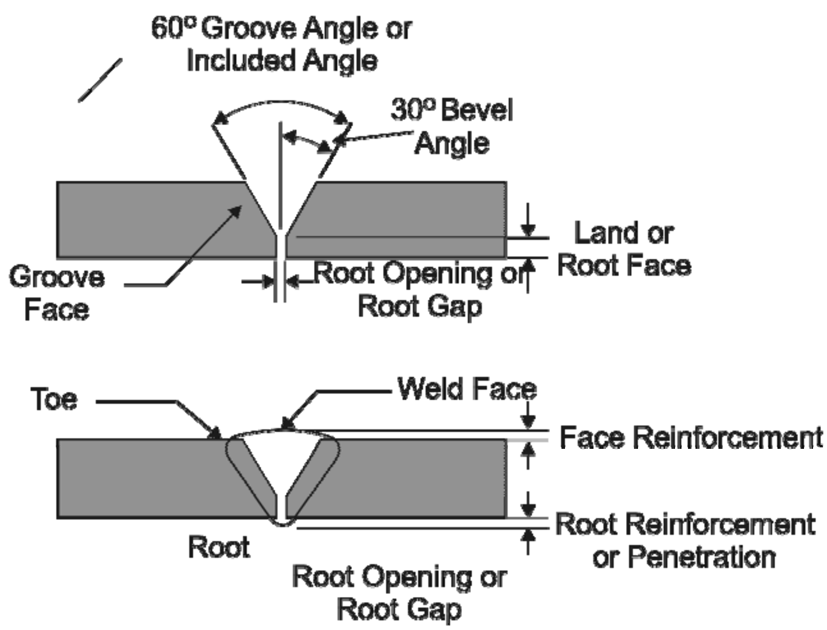

Figure 9 - Groove weld.

Structural Shapes

Various structural shapes are shown in Figure 10.

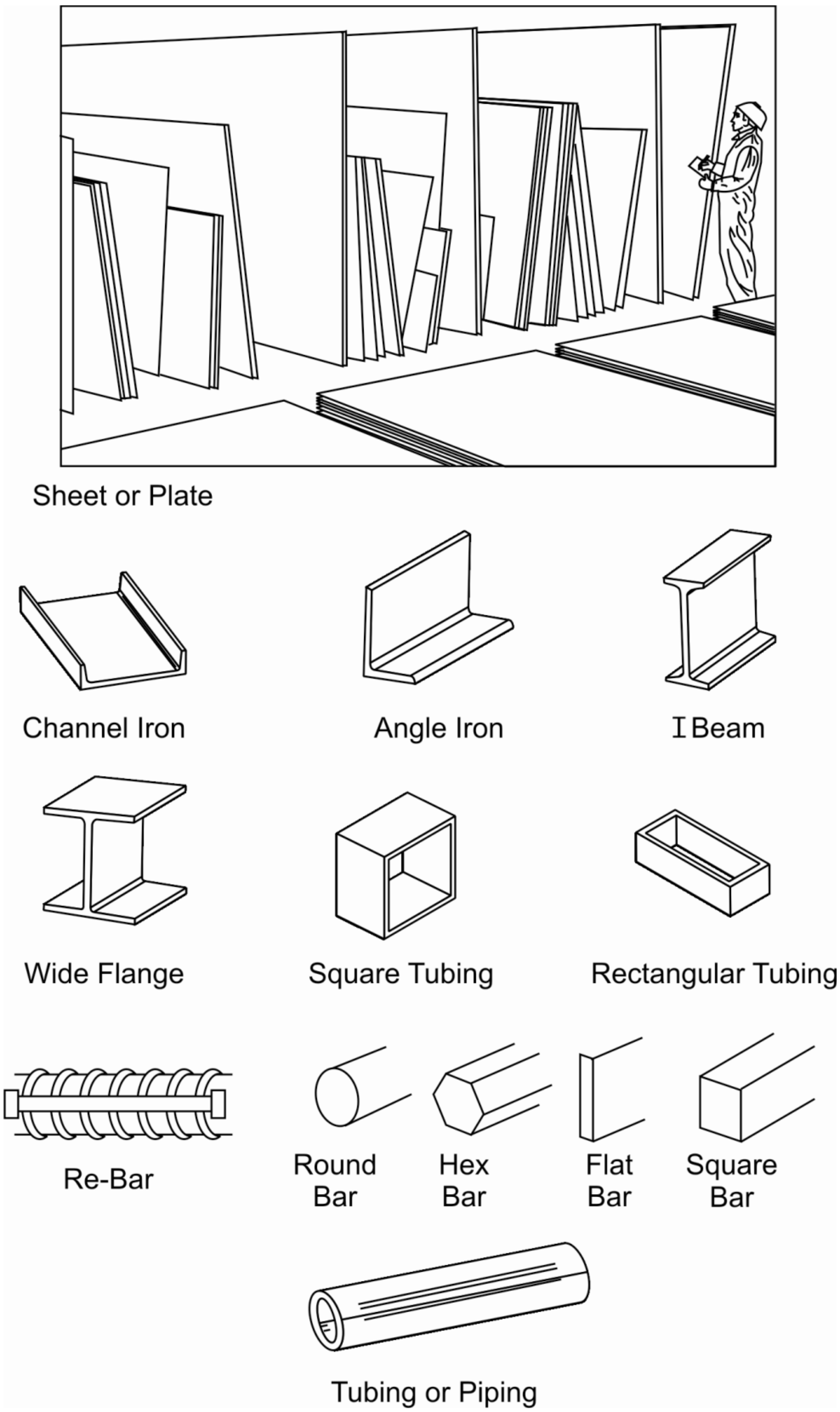

Figure 10 - Structural shapes.

NOTES

Objective Two

When you have completed this objective you will be able to:

Describe selected machine types, welding currents and polarities.

Machine Types

There are three main types of welding machines. They are:

- alternating current (AC) transformers,
- AC/DC transformer-rectifiers and
- generators and alternators.

Alternating Current Transformers

Alternating current transformer welding power sources convert the typical high voltage, low amperage alternating current available at an electrical outlet in your shop, to low voltage, high amperage AC current that is suitable for welding. Figure 11 is an AC transformer type welding power source that has a welding current range of 40 to 225 amperes. It produces a smooth AC arc for welding a wide variety of materials including low carbon, low alloy and stainless steels.

Figure 11 - AC transformer welding power source. (Courtesy Lincoln Electric)

Table 1 outlines advantages and disadvantages of the AC transformer.

AC Transformers	
Advantages	**Disadvantages**
Low initial cost	Not portable
Low maintenance	No choice of polarity
Lower operating costs	Limited electrode selection
Generally quiet operation	More difficult to strike and maintain an arc
No accumulative arc blow	Restricted welding processes

Table 1 - Advantages and disadvantages of an AC transformer.

NOTES

Welding Currents

The two types of current used in welding are:

- direct current (DC) and
- alternating current (AC).

Direct Current

Direct current flows in one direction only and has either a positive or negative value. There is no change of direction as there is with AC. The electron theory states current flows from negative to positive. The operator can select the direction of current flow across the arc by connecting the electrode to the negative pole (straight polarity) or the electrode to the positive pole (reverse polarity). Each polarity produces unique welding characteristics. All SMAW electrodes will function on DC. Some rods will work best on straight polarity and some are designed to be used with reverse polarity. Given a choice, most welders will prefer to use DC rather than AC because of superior versatility and arc stability.

Direct Current Straight Polarity

Direct current straight polarity (DCSP), *direct current electrode negative*. In a SMAW DC welding circuit, straight polarity occurs when the electrode cable is connected to the negative terminal of the welding machine. You may be able to remember the terminology if you think of the negative sign (–) as being a straight line.

Using straight polarity with SMAW results in the following electrode and arc characteristics.

- The electrode melts somewhat faster, which results in faster metal deposit. Approximately two thirds of the arc energy is associated with the electrode (negative terminal).
- Penetration is shallow.
- Metal flow is somewhat wider.

Figure 16 is an illustration of a DC welding machine that is connected to straight polarity.

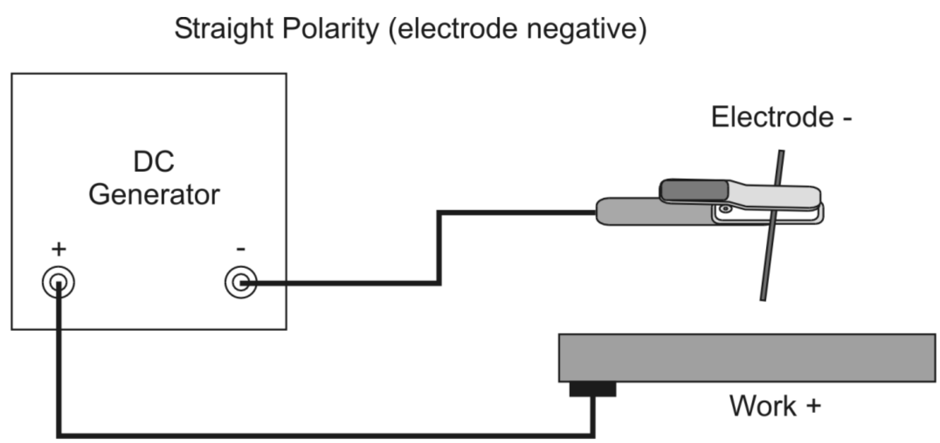

Figure 16 - Straight polarity (electrode negative).

Direct Current Reverse Polarity

Direct current reverse polarity (DCRP), *direct current electrode positive*. In a SMAW DC welding circuit, reverse polarity occurs when the electrode cable is connected to the positive terminal of the welding machine. Using reverse polarity with SMAW results in the following electrode and arc characteristics.

- The electrode melts somewhat slower and allows slower metal deposit. Approximately two thirds of the arc energy is associated with the base metal (negative terminal).
- Penetration is deeper, especially with a short arc length.
- Metal flow is generally narrow, unless a longer arc length is used.

Reverse polarity is the preferred choice when welding in deep grooves, when welding in vertical and overhead positions and for multi-pass welds. The E6010, E6011 and E7018 electrodes that you will use most often in relation to repair and modification of agricultural machinery and equipment are designed to be used on reverse polarity rather than straight polarity. When in doubt, choose reverse polarity.

Figure 17 is an illustration of a DC welding machine that is connected to reverse polarity.

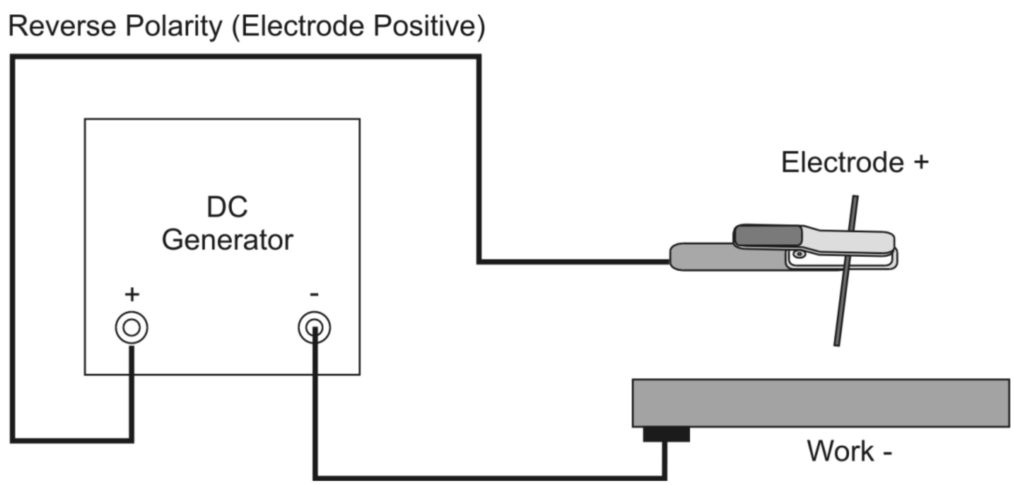

Figure 17 - Reverse polarity (electrode positive).

NOTE
To test for polarity, you can use an E6010 electrode. With normal heat settings for the electrode and using reverse polarity, the arc is fairly quiet (sounds like bacon frying), deeply penetrating and with minimal spatter. With the same current setting and using straight polarity, the arc emits a loud hissing sound with shallow penetration and there is much more spatter and smoke fumes emitting from the arc.

NOTES

Alternating Current (AC)

Alternating current reverses or changes direction of flow according to the number of cycles per second that the current is being produced. In North America, 60 cycle current is standard. With AC, the welding arc is somewhat less stable due to the changing of current flow across the arc. Some electrodes will loose the arc when used on AC. With alternating current, there can be no fixed polarity. The arc characteristics and weld results using AC is an average of the weld characteristics between direct current electrode positive and direct current electrode negative.

Figure 18 shows a single cycle of alternating current.

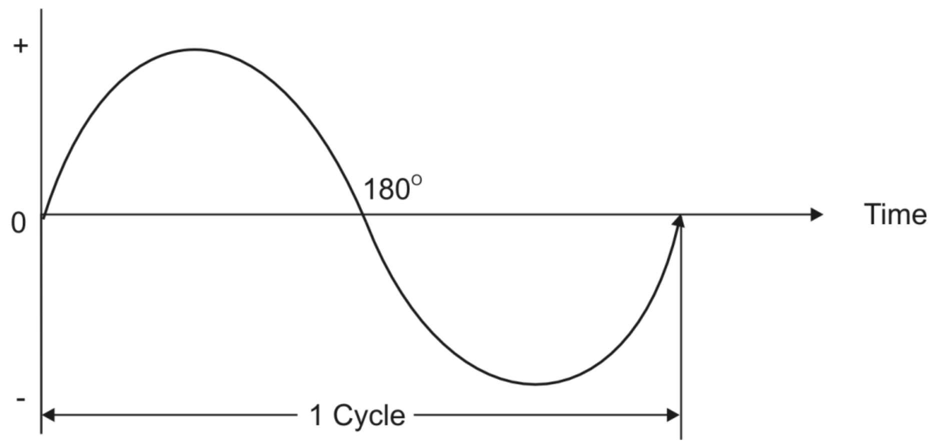

Figure 18 - One cycle of alternating current (sine wave).

Electrode Holders

Electrode holders (also known as *stingers*) come in two basic types, which are listed below.

- The alligator jaw type (Figure 20A) clamps the bare end of the electrode in a spring-loaded jaw.
- The twist head type (Figure 20B) has the bare end of the electrode inserted in the head and then tightened into place by mechanical pressure as the head is twisted.

Figure 20 - Electrode holders.

All electrode holders are rated by their amperage carrying capacity (for example, 200 amp or 300 amp). The size of electrode holder you choose must match the amperage you are using and the size of welding cable you have. The twist head type electrode holder has a removable head that can be replaced without having to disconnect the welding cable and replace the entire holder. The handle of any type of electrode holder is well insulated to protect you from electric shock and heat. The insulated holder also prevents accidental arc strikes when the welding circuit is energized.

Ground Clamps

Ground clamps are used to complete the welding circuit. They may be a spring-loaded clamping device, a magnetic clamp, a C-clamp device or a lug welded to the work and then securely attached to the end of the work lead cable. Regardless of the type of ground clamp used, it is very important that you have a clean, tight connection.

The spring-loaded clamping devices in Figure 21 make the location of the work lead easy to change, if required. Make sure the spring is forcing the clamp to make a tight connection on the work. These are the most common types for general purpose SMAW.

Figure 21 - Spring-loaded work lead clamps.

Be aware that a poor ground connection can cause accidental arcing. This accidental arcing may at best cause a surface cosmetic problem or may result in extremely hard and brittle spots to form on the workpiece affecting the metallurgical and structural integrity of the metal. Never connect the ground clamp onto a machined surface to avoid arcing damage to that surface. Also, never place the ground clamp where there is a danger of current passing through a bearing or bushing because arcing may occur within and damage the bearing parts and surfaces. This is particularly important when preparing to weld on machinery or machine components.

Since a poor ground connection results in increased resistance to current flow, you may experience an unstable arc or overheating in your welding cables, especially at the cable connections.

NOTES

Objective Four

When you have completed this objective you will be able to:

Demonstrate equipment set-up and adjustments.

Equipment Set-Up

When setting up for welding activities, the following items are worthy of consideration with respect to convenience and safety as well as performance.

- Position the welding power source nearby so it is convenient to make necessary adjustments, yet it is out of harm's way relative to flying grinding sparks, welding spatter and moving machinery.
- Lay out the cables neatly to minimize a tripping hazard and cable damage from welding fallout.
- Switch the machine on.
- Select welding current and polarity relative to the electrode to be used.

Set the Amperage

Follow this procedure to set the amperage.

- Make a rough estimate for a setting to start at. Base your estimate on past experiences using a similar electrode. Make proportional adjustments relative to wire size and coating thickness. Make reference to the electrode manufacturer's recommendations, if available.
- Set up a sample weld joint of similar thickness and position as the actual job at hand. Do some practice welds. By trial and error, observing the arc, puddle and weld characteristics and make fine tune adjustments to the amperage setting on the machine until you achieve the desired results.

NOTE
Avoid making amperage adjustments and polarity switching while the machine is actually welding. This is to avoid arcing within the machine components. You can leave the input power switch on, but simply stop welding, make adjustments, then continue welding.

Objective Five

When you have completed this objective you will be able to:

Describe the electrode designation system.

Types of Welding Electrodes

The two types of welding electrodes are:

- non-consumable and
- consumable.

Non-Consumable Electrodes

Non-consumable electrodes are not intended to be consumed into the weld puddle. Non-consumable electrodes are energized and usually form one of the electrical poles involved in the creation of an electric arc between the electrode and the workpiece. For example, with gas tungsten arc welding (GTAW), an electric arc is drawn between a non-consumable tungsten electrode and the work. If filler metals are used, they are fed from an external source. The tungsten electrode's function is to enable the creation of an electric arc between itself and the workpiece.

Consumable Electrodes

When you are using shielded metal arc welding (SMAW), you are using *consumable electrodes*, which means the electrode is melted into the weld puddle (consumed). A consumable electrode therefore, is called a *filler rod* because the metal from the electrode is melted into the weld. Arc welding processes usually require filler metals in order to fill the weld joint and to produce desirable properties of the finished weld. The *American Welding Society* (AWS) and the *Canadian Standards Association* (CSA) have developed specifications for carbon steel filler rods when using SMAW.

NOTES

The SMAW Process

SMAW is also known as *stick* welding and the electrode is sometimes called a *rod*. The electrode has a metal core wire and is covered with material that is called the *flux coating*. The ingredients in the coating are responsible for different operating characteristics and different weld deposit properties of the electrode. The development of flux-coated electrodes has resulted in the capability for making welds with properties that equal or exceed those of the parent metal.

The electrode is being consumed into the parent metal to form the weld bead and slag covering. Figure 22 illustrates a coated electrode. The size of the electrode is determined by the diameter of the core wire only. The thickness and composition of the flux coating is different, depending on which type of electrode you are using.

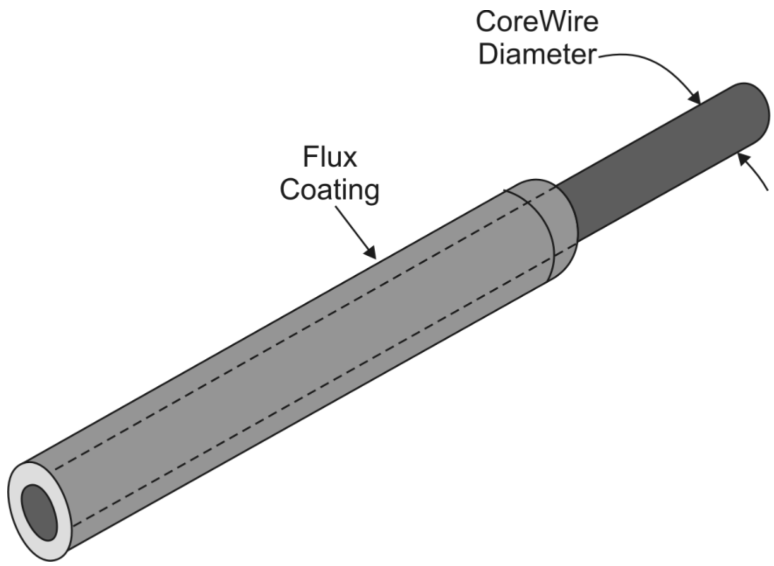

Figure 22 - Coated SMAW electrode.

The Core Wire

For the common E60 and E70 series of electrodes, the *core wire* is generally from the same wire stock. (It is an SAE 1010 carbon steel with a carbon range of 0.05 to 0.15%).

Wire Size

Electrodes are available in the following *wire sizes*: $^{1}/_{16}$" (1.6 mm), $^{3}/_{32}$" (2.5 mm), $^{1}/_{8}$" (3.2 mm), $^{5}/_{32}$" (4.0 mm) and $^{3}/_{16}$" (5.0 mm). In North America, electrodes are manufactured in imperial fractional diameters. The welder selects the wire size of a specific electrode type to suit the job at hand. Electrodes $^{1}/_{8}$" in diameter are required most often for repair and fabrication welding in all positions. Smaller electrodes are selected to weld on light gauge metal. Larger electrodes are selected to make efficient large welds in the flat and horizontal positions on thick plate. Electrodes larger than $^{1}/_{8}$" produce a large molten puddle which is difficult to control in the vertical and overhead positions.

The Coating

The *coating* (flux) on arc welding electrodes is a mixture of chemicals and binders baked onto the wire core. The burning or breaking down of the coating in the heat of the arc influences the weld quality and arc characteristics associated with each type of electrode.

Functions of the Coating

Functions of the coating are listed below.

- It stabilizes the arc. It provides ease of striking and helps maintain the arc.
- A gaseous shield is formed, thus excluding harmful oxygen and nitrogen from the molten puddle and the molten end of the electrode.
- It provides a slag cover over the deposited weld metal to exclude oxygen and nitrogen from the weld while it is cooling. The slag collects the impurities as they float to the surface of the puddle. The slag controls the shape and smoothness of the bead and controls the cooling rate, which improves the physical properties of the weld metal.
- It deoxidizes or dissolves oxides that form during the welding process and provides a cleaning action.
- It directs the arc from the end of the electrode. The wire core melts away faster than does the coating, thus creating a nozzle effect.
- It regulates the depth of penetration. Certain coating types cause a more forceful arc than do others.
- It serves as an insulator so an arc cannot be struck along the side of the electrode.
- Alloy elements are easily introduced into the weld deposit by way of the coating, rather than by using an alloy core wire. The properties of the weld can be influenced by the addition of alloys.

Figure 23 illustrates the melting of the electrode in the arc column and the resulting weld metal deposit covered by the slag.

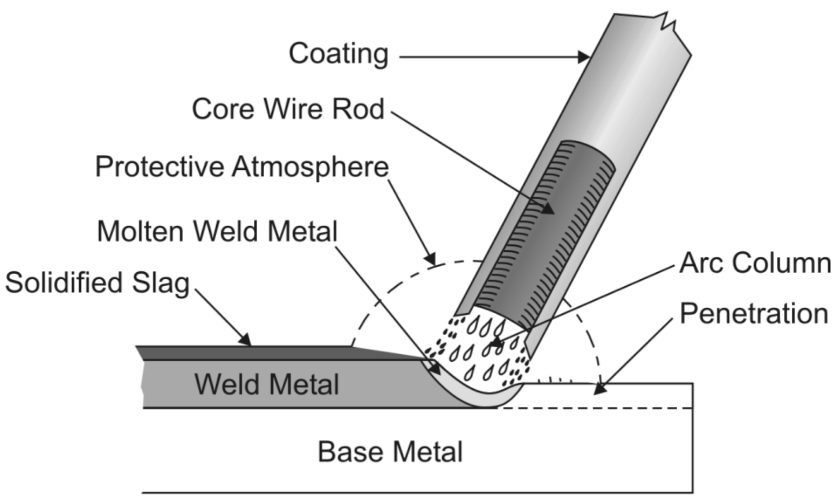

Figure 23 - Electrode coating and formation of slag.

NOTES

Electrode Classification System

SMAW electrodes designed for repair and fabrication of carbon steel are manufactured in accordance with a number standards, such as CSA W48.1 and AWS A5.1, as designated by the *Canadian Welding Bureau* (CWB), the Canadian Standards Association (CSA) and the *American Welding Society* (AWS). These standards specify such things as alloy composition, weld metal strength and toughness, size, type of coating, welding position and type of current for various types of electrodes. They use a standard *code system* to place this information on each electrode. The lettering printed on each electrode indicates the classification number.

Most of our electrodes are manufactured by American based companies and thus initially conform to the AWS classification system and are stamped with the AWS numbers. Electrodes sold in Canada are required to show the CWB/CSA classification system numbers. Many electrodes sold in Canada will be stamped with both numbering systems. The two systems use the same code. The only difference is that the Canadian system uses metric units (megapascals [Mpa]) to designate the tensile strength, while the American system uses imperial units (psi - pounds per square inch).

The classification for mild steel electrodes is explained as follows (E48018 is used in this example).

- The letter **E** designates an electrode. Often the *E* is dropped or ignored in casual communication.
- In the CSA system, the first three digits, **480,** designate the minimum tensile strength of the deposited weld metal in the as-welded condition in megapascals (MPa).
- In the AWS system, the comparable classification number would be E7018. The first two digits, **70,** are used to indicate the tensile strength measured in 1000 pounds per square inch. The minimum tensile strength of this electrode is 70 000 psi. (See Table 6).

Tensile Strength	
CSA (MPa)	**AWS (psi) x 1000**
410	60
480	70
550	80
620	90
690	100
760	110
830	120

Table 6 - Tensile strength classification for CSA and AWS.

- The second last digit, **1**, indicates the position in which the electrode is suitable for depositing satisfactory welds. In this case, *1* indicates all positions. Figure 24 lists the welding positions indicated by the other digits: *2*, *3* and *4*. Information specific to the second last digit is the same for both AWS and CSA classifications.

- The last digit, **8**, indicates the type of coating on the electrode, the current to be used with the electrode, the arc characteristics and job application. In this case, *8* indicates the electrode has a low-hydrogen coating, it operates on AC or DCRP current, it has a smooth arc with medium penetration and it can be used for dynamic loads. Information specific to the last digit is the same for both AWS and CSA classifications.

The CSA classification system for mild steel electrodes is given in Figure 24.

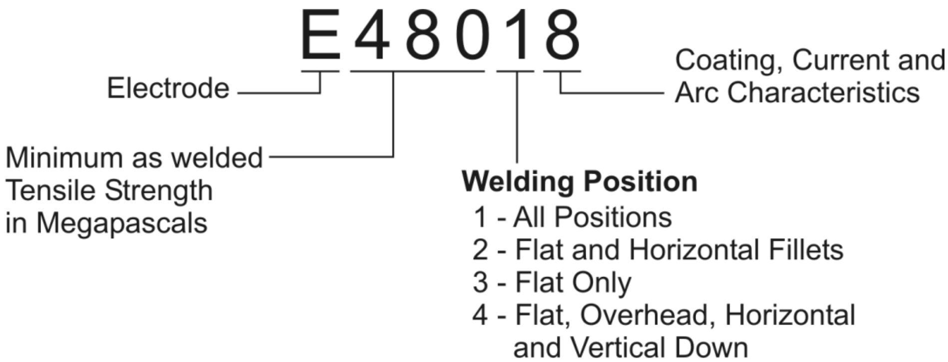

Figure 24 - CSA W48.1M1991 electrode classification system.

NOTES

Objective Six

When you have completed this objective, you will be able to:

Identify ferrous and non-ferrous metals

Definition of a Metal

A metal is an element or mixture of elements that has all or most of the following characteristics:

- solid at room temperature,
- opaque (not transparent),
- conducts heat and electricity,
- reflects light when polished,
- expands when heated and contracts when cooled (except bismuth) and
- has a crystal structure.

Ferrous and Non-Ferrous Metals

Ferrous metals contain iron as the main ingredient and are usually magnetic. *Non-ferrous* metals do not have iron in large enough amounts to have any major influence on the property of the metal.

Ferrous Metals

The most common ferrous metals are carbon steels and cast irons. They are alloys of iron and carbon with other elements added to impart distinct properties. Sometimes the elements are present as impurities. An exception to the rule is the 300 series (austenitic) stainless steels. They are non-magnetic even though they contain a large amount of iron. Figure 1 is an example of a ferrous metal. It is a punch and die made from very high carbon steel.

Figure 1 - Very high carbon steel punch and die.

Very high carbon steels used to make punches, dies, shear blades, cutting tools and other components are often called *tool steels* or *high-speed steels*.

Non-Ferrous Metals

Aluminum, magnesium, zinc, copper, lead and brass are examples of non-ferrous metals. They are usually non-magnetic. An exception to the rule is nickel, which is non-ferrous and also magnetic. Figure 2 shows the end of a titanium pipe being heated. Titanium is non-ferrous and has a low rate of thermal conductivity. The tissue paper wrapped around the pipe has not ignited even though the end of the pipe is red hot. Titanium melts at 1668°C (3035°F).

Figure 2 - Titanium pipe wrapped in tissue paper.

Metal Identification Methods

There are many different methods to identify a metal. These include:

- visual appearance and colour,
- fractured surface,
- relative weight,
- typical shape and
- texture.

Visual Appearance and Colour

The most practical method of identifying a metal is by examining it for its visual appearance and colour. These are some examples.

- Pure aluminum oxidizes rapidly and often has a thin oxide film covering its surface. The surface of unfinished aluminum is smooth and silvery.
- Steels and cast irons are usually silver-grey to grey depending on such factors as how the metal was formed and how its surface has been finished. Grey cast iron is grey in colour, and white cast iron is silvery white at its fracture.
- White cast iron and grey cast iron have a rough, dull grey surface.
- Malleable cast iron is lighter grey and smoother than white or grey cast iron.
- Copper and brass are red or yellow depending on the specific alloys in each.
- Nickel is a white to grey-coloured metal with a smooth, velvety texture.
- Lead is a very soft, malleable, bluish-grey metal. It can be scratched with your fingernail.

SMAW WELDING QUESTIONS

Complete the following questions on the bubble sheet previously used on welding safety

14. Electrode negative is:
    a) straight polarity.
    b) reverse polarity.
    c) AC transformer.
    d) alternating current.
15. Which term describes a noisy, uncontrollable arc that flares from side to side?
    a) arc voltage
    b) arc blow
    c) inductance
    d) resistance
16. Which current flows in one direction only and has either a positive or negative value?
    a) direct current
    b) alternating current
    c) open circuit voltage
    d) arc voltage
17. Which term expresses the strength of a current of electricity?
    a) amperage
    b) voltage
    c) electron
    d) conductor
18. Which term describes the property of an electrical conductor that opposes the flow of current?
    a) resistance
    b) inductance
    c) voltage
    d) amperage
19. Electrode positive means:
    a) straight polarity.
    b) reverse polarity.
    c) AC transformer.
    d) alternating current.
20. Loose ground clamp connections, when using SMAW, may cause:
    a) electrical shock.
    b) magnetic arc blow.
    c) high burn-off rates.
    d) arcing at the work clamp.
21. In the AWS classification for SMAW mild steel electrodes, what does the last digit represent?
    a) The type of shielding gas produced by the melting flux.
    b) The amount of metallic powder that is added to the coating.
    c) The welding position in which the electrode may be satisfactorily operated.
    d) The major ingredient in the coating and recommended current for best results.

22. What do the first two digits in the AWS classification for carbon steel SMAW electrodes represent?
    a) current type and application
    b) as-welded minimum tensile strength
    c) recommended welding positions
    d) iron powder content of the coating in %
23. 10. According to AWS, which number indicates the positions an E7024 can be used in?
    a) first number
    b) second number
    c) third number
    d) fourth number
24. What is one purpose of the flux coating on a welding electrode?
    a) To promote the formation of oxides and nitrides in the weld puddle.
    b) To prevent undercut and arc blow and minimize distortion.
    c) To prevent the formation of a gaseous shield around the molten weld metal.
    d) To protect the molten weld puddle from atmospheric contamination
25. What is one function of the slag produced from electrode coatings?
    a) To add more nitrogen and oxygen to the weld.
    b) To help maintain the arc and control penetration.
    c) To add alloying elements to the weld deposit.
    d) To prevent the weld from cooling too rapidly.
26. To weld thin materials, you would likely select an electrode with:
    a) deep penetration characteristics.
    b) a large diameter core wire.
    c) a small diameter core wire.
    d) a high as-welded tensile strength.
27. A ferrous metal has a high content of:
    a) carbon.
    b) nickel.
    c) iron.
    d) manganese.
28. Which statement describes a non-ferrous metal?
    a) high iron content and usually magnetic
    b) high iron content and usually non-magnetic
    c) contains little or no iron and is usually magnetic
    d) contains little or no iron and is usually non-magnetic
29. A metal that is red or yellow is most likely what type of metal?
    a) aluminum or magnesium
    b) malleable cast iron
    c) low or medium carbon steel
    d) copper or brass
30. What is the normal colour for steels and cast irons?
    a) silvery grey
    b) black
    c) yellow
    d) red