

Applying Shielded Metal Arc Welding (SMAW) Techniques

ANCIENT WELDERS and tools have been seen depicted on Egyptian tombs. Welding may be viewed as an ancient art, but the science of shielded metal arc welding and other welding processes is relatively new. Developments in the welding process and discoveries in metallurgy have led to technological wonders and have changed how we fabricate and build.



Objective:



Explain the fundamentals and techniques of shielded metal arc welding.

Key Terms:



alternating current
amperage
arc length
arc welding
conductor
crater
direct current
duty cycle
electricity

electrode
electrons
fillet weld
groove weld
padding
polarity
resistance
shielded metal arc
welding

surface welds
voltage
weaving
weld root
welder
welding
weldor

Arc Welding

Arc welding uses heat from an electrical source for the melting or fusion of metals. **Welding** is the melting, flowing together, and freezing of metals under controlled conditions. **Arc welding** is a process that uses electricity to heat and melt the metal. A **weldor** is the person

doing the welding, but a **welder** is the machine doing the welding. **Shielded metal arc welding** is welding in which fusion is produced by heating with an arc between a consumable stick electrode and the work piece. An **electrode** is a bare metal rod that is usually coated with chemical compounds called flux. The flux coatings burn in the intense heat and form a blanket of smoke and gas that shields the weld puddle from the air.

TERMS

The arc welding process and principles are based around the source of electricity. Therefore, it is necessary to have a fundamental knowledge of electricity and how it is used for welding. **Electricity** is the flow of tiny particles called electrons through a conductor. **Electrons** are negatively charged particles, and a **conductor** is something that allows the flow of electrons. **Voltage**, meanwhile, is a measure of electrical pressure. Most welders operate on a 220-volt source. A welder changes or transforms the 220-volt pressure to a much lower pressure at the electrode, usually between 15 and 25 volts. **Amperage** is a measure of electrical current flowing through a circuit and is an indication of the heat being produced. The amount of current available is determined by the amperage setting on the welder.

Polarity is the direction in which the current is flowing, while **resistance** is the opposition to the flow of current in a circuit. Resistance is what causes the electric energy to be transformed into heat. When electricity is conducted through a conductor, the movement of the electric energy heats the conductor due to the resistance of the conductor to the flow of electric current through it. The greater the flow of current through a conductor, the greater the resistance to it, and the greater the heat generated. Therefore, the higher the amperage setting, the greater the heat produced. When electrical current alternates or reverses the direction of electron flow, it is called **alternating current** (AC). The arc is extinguished every half-cycle as the current passes through zero, usually at the rate of 120 times per second. Electron flow in one direction is called **direct current** (DC), which is either straight polarity (DCSP) or reverse polarity (DCRP).

HISTORY

The art of welding is ancient, but the science of shielded metal arc welding is relatively new. In 1801, an English scientist discovered that an electric current would form an arc when forced across a gap. A French inventor used the carbon arc in 1881. Then in 1887, a Russian improved on the carbon arc and patented the process. In the same year, another Russian discovered that a bare metal rod would melt off by the heat of the arc and act as a filler metal in a weld. In 1889, an American experimented with the metallic arc and received a patent. A bare electrode was difficult to use and resulted in a weld that was porous, brittle, and not as strong as the base metal. A Swede found that welds were stronger and easier to make when a chemical coating was put on the metal electrode in 1910. The coating was called flux because it cleaned the metal and aided in mixing the filler metal with the base metal. However, it was difficult to apply. In 1927, mass production methods developed to apply the flux to the bare metal rod.

CLASSIFICATION

Welding machines are classified in several ways. One common way is by the type of output current produced by the welder: AC, DC, or AC/DC. Another way to classify welders is by their service. Limited input welders provide satisfactory operation and are fairly inexpensive to operate. The cost is about \$1 per ampere of output. Limited service welders are used where lower cost is desired because the operation is quite intermittent. Industrial welders have a high duty cycle, but their price is much higher.

Welders are also classified by power source. An electric motor-driven welder is self-contained and requires three-phase power. Electric power runs the motor, which turns a generator to produce DC welding current. An internal combustion engine drives a generator that produces the power for the welder to run. In contrast, line voltage welders run on the power supplied by the power company.

A fourth classification of welding machines is how long the machine can operate. A **duty cycle** is the percentage of a 10-minute period in which a welder can operate at a given current setting and is another way to classify welders. A welder with a 60 percent duty cycle can be operated safely for six minutes of a ten-minute cycle, repeated indefinitely. The duty cycle will be shorter if the welder is used at higher settings. Likewise, if the welder operates at lower settings, the cycle will be longer.

When buying a new welder, consider only one made by a well-known manufacturer and distributed by a reliable dealer. Check the nameplate to see if the welder is National Electrical Manufacturers Association (NEMA) rated and is approved and listed by Underwriters Laboratories (UL). Compare prices of welders, equal capacity, and the kinds of accessories available. Read the guarantee carefully, and ask questions.

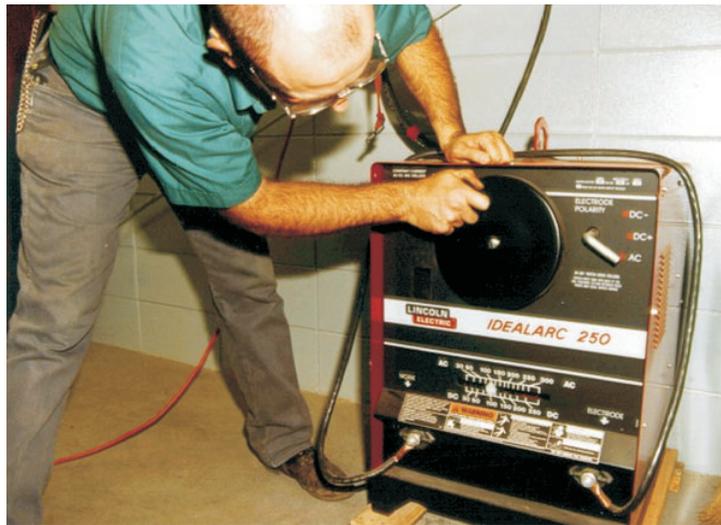


FIGURE 1. Welding machines.

EQUIPMENT AND SUPPLIES

Several other pieces of equipment and supplies are necessary to operate the shield metal arc welder.

- ◆ Two cables: No. 2 gauge
- ◆ An electrode holder that grips the electrode during welding and should be completely insulated, have a spring-grip release, and jaws that hold rods in 60-, 90-, 120-, and 180-degree positions in relation to the handle
- ◆ A ground clamp fastened to the work or to the welding table
- ◆ A chipping hammer, with a straight peen and a straight cone with a spiral wire-grip that is necessary to remove slag from the weld bead
- ◆ A wire brush used to clean dirt, rust, and slag from metal
- ◆ Pliers needed for handling hot metal
- ◆ Safety glasses or goggles
- ◆ Full gauntlet leather gloves
- ◆ Upper body protection
- ◆ A head shield to offer protection from the rays of the electric arc, heat, and spatter of the molten metal
- ◆ Filter lenses (No. 10 lens meets applications up to 200 amps)
- ◆ Electrodes

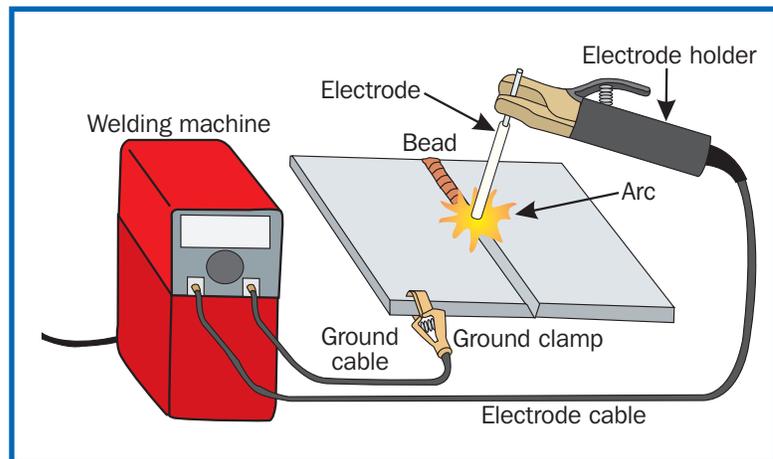


FIGURE 2. Components of an ARC welding system.

Electrodes

Electrodes convey electric current from the welding machine into a hot arc between its tip and the metal being welded. Electrodes are covered with flux. Because there are two classifications of electrodes, the American Welding Society (AWS) and the American Society for Testing Materials (ASTM) have set up standard numerical classifications for most electrodes. Every electrode has been assigned a specific symbol, such as E7014. The “E” indicates the electrode is used for electric welding. The first two digits of a four-digit number indicate tensile strength in thousands of pounds per square inch. For instance, an E7014 electrode produces a weld with 70,000 psi of tensile strength, and an E6011 electrode produces a weld with 60,000 psi of tensile strength. If the number has five digits, the first three digits indicate tensile strength. The next-to-last digit indicates welding position for which the electrode is recommended. The last digit indicates the operating characteristics of the electrode. NEMA has adopted color marking for some classes.



BROADENING AWARENESS...

AMAZING ASPECTS: Flux

The flux coating on electrodes provides several important functions. Flux protects the molten metal from the atmosphere. The flux covering burns in the intense heat of the arc, forming a blanket or shield of gas around the bead. Air contains oxygen and nitrogen which would combine with the metal, making it brittle and weak.

In addition, flux mixes with the weld metal, floating the impurities to the top in the form of slag. Slag covers the bead to protect it from the air and slows the rate of solidification and cooling. Flux also stabilizes the arc. After the arc is started, current flows across the gap between the end of the electrode and the work. Flux is designed to yield a stable arc with low spatter and to reduce fuming.

PREPARATION

One of the most important and most often neglected parts of the welding job is preparation of the metal for welding. The metal must be free of dirt, grease, rust, paint, and other impurities that may combine with a molten weld bead and cause it to be weakened. Metal should be cleaned by grinding, brushing, filing, or cutting before welding occurs.

COMMON WELDS

Preparing the correct type of joint for each kind of metal is crucial for securing strong welded structures. The basic types of joints are the butt, lap, tee, corner, and edge. These joints may be applied to the different types of welds: fillet, groove, plug, slot, and surface. A tee weld is a type of fillet weld.

- ◆ The **fillet weld** has two surfaces at right angles, and the bead is triangular in shape.
- ◆ The **groove weld** is a weld made in a groove between the two pieces of metal to be joined.
- ◆ The plug and slot welds are used to join pieces that overlap. The welds are placed in plug or slot holes. These types of welds commonly take the place of rivets in welded structures.

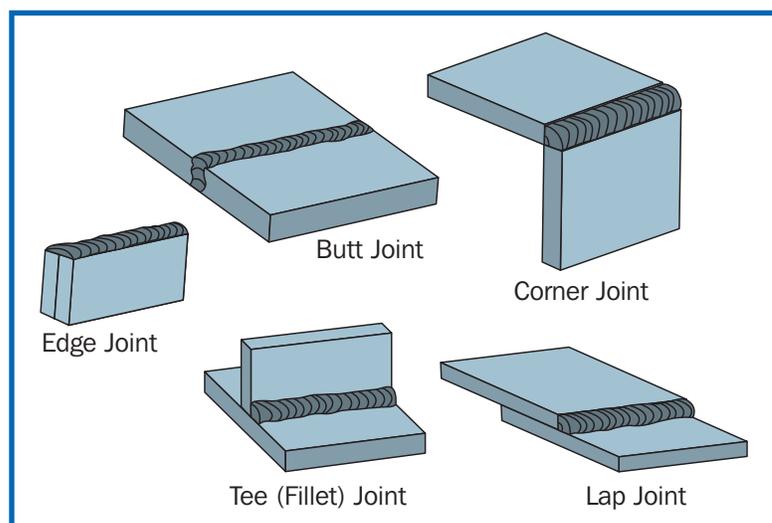


FIGURE 3. Common welds.

- ◆ **Surface welds** are beads deposited on a metal surface for the purpose of building up the base metal.

Butt Joint

The square butt joint is used on metal sections no thicker than $\frac{3}{16}$ inch. This joint is strong in tension loads, but it is not good for repeated loads and impact forces. The single V butt joint is often used on plate steel $\frac{3}{8}$ inch to $\frac{3}{4}$ inch in thickness. The joint is strong in loads with tension forces but is weak in loads that bend at the **weld root**, which is the bottom of the weld groove opposite the weld face. The single-bevel butt joint is used on metals from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch in thickness, and the bevel is 45 degrees. The double V butt joint is excellent for all load conditions and is often used on metal sections of more than $\frac{3}{4}$ inch in thickness.

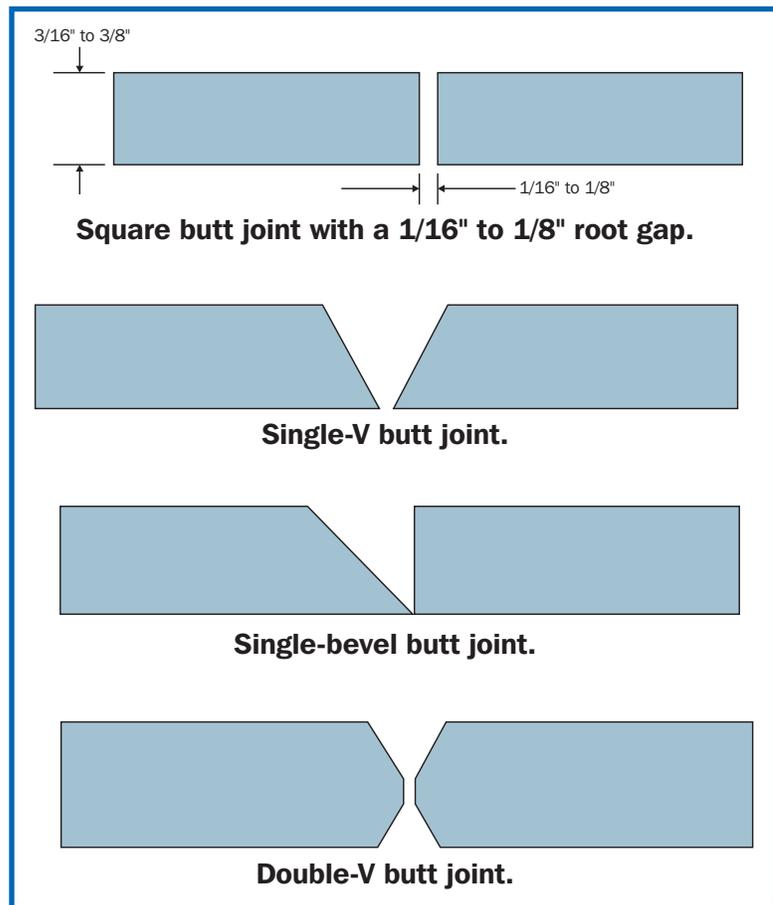


FIGURE 4. Common butt joints used in welding.

Lap Joint

The lap joint is a type of fillet weld. Its strength depends on the size of weld bead. The single lap joint is one of the stronger weld joints. It is used on metal up to $\frac{1}{2}$ inch in thickness. The double lap joint is almost as strong as the base metal.

Tee Joint

The tee joint is a fillet weld and can be used on metals up to $\frac{1}{2}$ inch in thickness. It can withstand strong longitudinal shear forces. The tee joint can be square, beveled, or double beveled.

Corner Joint

A corner joint can be flush, half-open, or full-open. The flush corner joint is primarily used on sheet metal. The half-open joint can be used on metals heavier than sheet metal and for joints that will not have large fatigue or impact loads. This joint can be welded from one side.

Yet the full-open corner joint is used for metals that will carry heavy loads, so it must be able to withstand large fatigue and impact loads. It can be welded on both sides.

Edge Joint

An edge joint is used for metals less than $\frac{1}{4}$ inch in thickness and can only sustain light load applications.

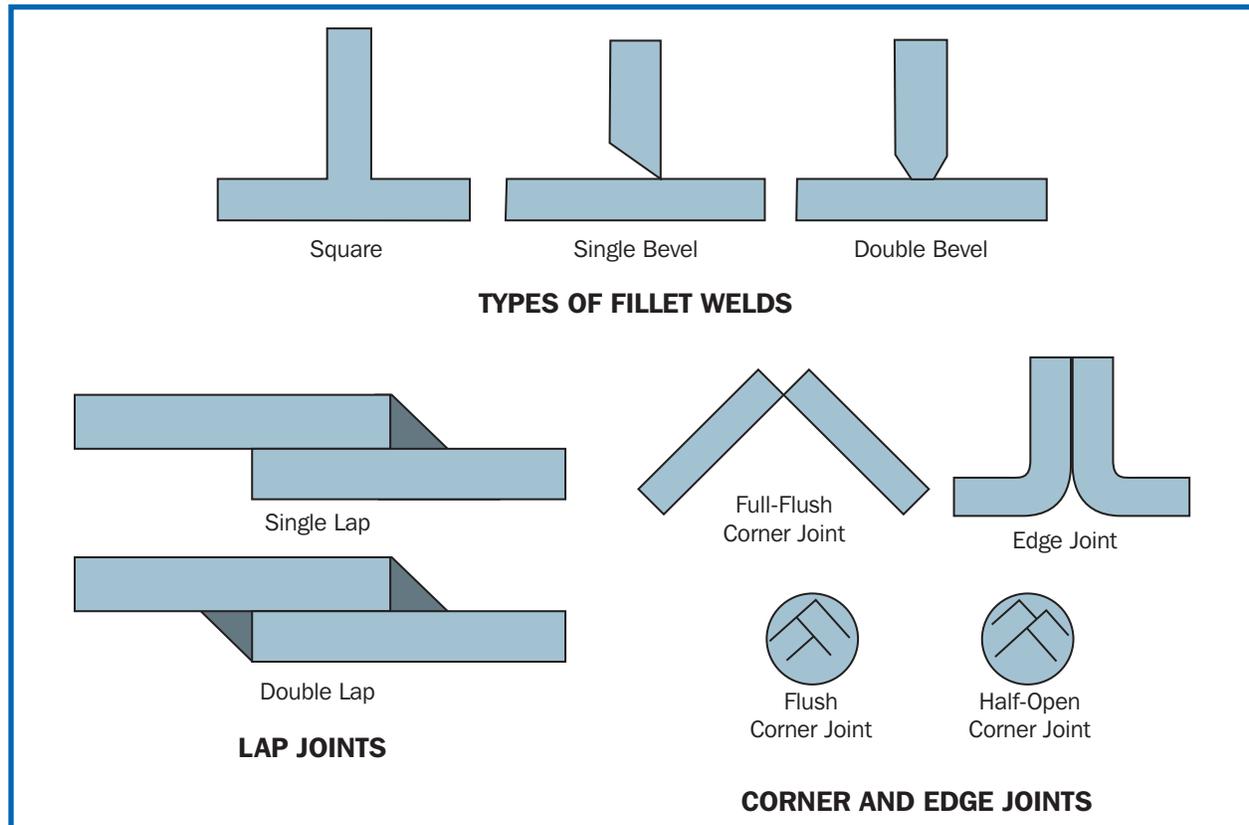


FIGURE 5. Common joints used in welding.

PROCEDURES AND TECHNIQUES

Good welds can be attributed to correct selection and manipulation of the electrode and welding current. The weldor must use proper amperage, maintain arc length, angle and speed, and perform proper welding techniques. Making good flat welds on steel is not difficult. The welding process requires attention, practice, and patience.

Proper Amperage

The proper amperage setting for any welding job is necessary for adequate penetration with minimum spatter. Correct amperage can be identified somewhat by sound. When the amperage is correct, a sharp crackling sound can be heard. A humming sound will indicate an amperage setting that is too low. As a result, the deposited electrode will pile up, leaving a narrow,

high bead that has poor penetration and little strength. A popping sound will indicate too high of an amperage setting, and the bead will be flat with excessive spatter. The electrode will become red hot, and the metal along the edge of the bead will be undercut. The correct amp setting depends on the thickness of the base metal and the diameter of the electrode.

Arc Length, Angle, and Speed

Learning to maintain the correct arc length for the electrode you are using is necessary to be successful. **Arc length** is the distance from the tip of the bare end of the electrode to the base metal. Arc length is equal to the diameter of the bare end of the electrode.

The correct angle of the electrode will depend on the type of weld to be completed. Hold the electrode at a 90-degree angle to the work as viewed from the end of the two plates being joined and 5 to 15 degrees in the direction of travel. The correct speed of travel affects the amount of electrode deposited and the uniformity of the bead. It should produce a bead that is 1.5 to 2 times the diameter of the bare end of the electrode.

Striking the Arc and Welding

Following proper procedures when preparing to weld and striking the arc will develop confidence in your abilities.

1. Prepare the work area so everything is ready and convenient before you start.
2. Make a final check to see that flammable materials are out of the way and unnecessary tools are not lying around.
3. Be sure the machine is turned off.
4. Set the machine to the desired amperage.
5. Insert the bare end of the electrode in the electrode holder, and hold the end of the electrode about 1 inch above the metal at the point where the weld is to be started.
6. Turn on the welder.
7. Lower the helmet over your eyes, bring the electrode in contact with the work, and withdraw it slightly. Current jumps the small gap and creates the electric arc. The

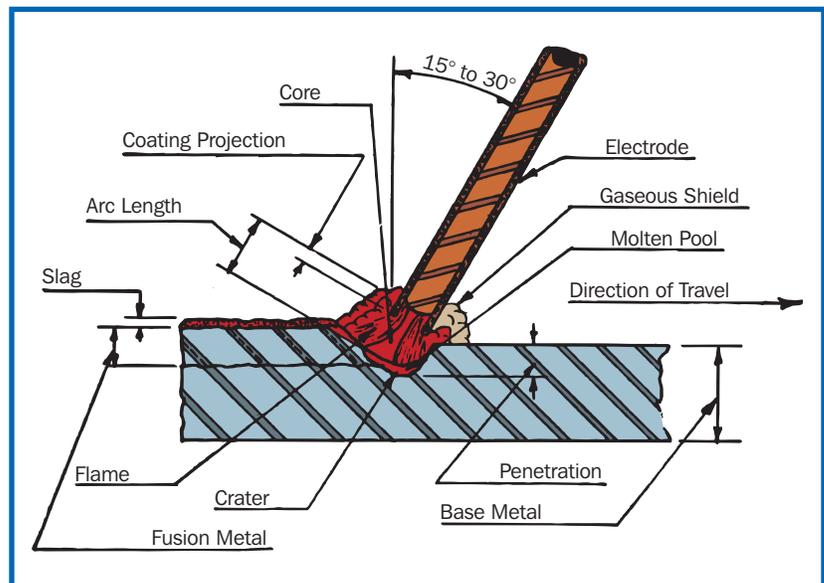


FIGURE 6. Shielded metal ARC welding.

moment the arc is struck, the concentration of intense heat, estimated between 6000° and 9000°F, melts the base metal and the end of the electrode and forms a molten metal pool called a **crater**.

8. There are two methods used in starting the arc. A striking movement is similar to striking a match. A tapping movement involves the electrode being quickly tapped on the surface of the metal to prevent it from sticking to the base metal. If the electrode is not instantly pulled away, it will fuse with the base metal and stick. If the electrode is pulled too far away, the arc will be extinguished.
9. Raise the tip of the electrode to about $\frac{3}{16}$ inch above the base metal to form a long arc that is held for a three count to preheat the base metal.
10. Lower the electrode to the correct arc length.

Movements

To make a wider bead or when doing out-of-position welding, use a motion of weaving or oscillating movements. **Weaving** is running a bead with a sideways or oscillating motion. It is a process used when covering a wide area with weld metal; it can also be used to maintain a large molten weld crater. **Padding** is the process of building up several layers of weld deposit by running overlapping passes. Padding is used to rebuild worn pieces by building up the piece to an oversized condition and grinding or machining it to the correct size. These movements usually require more time, and the beads are shorter per inch of electrode used.

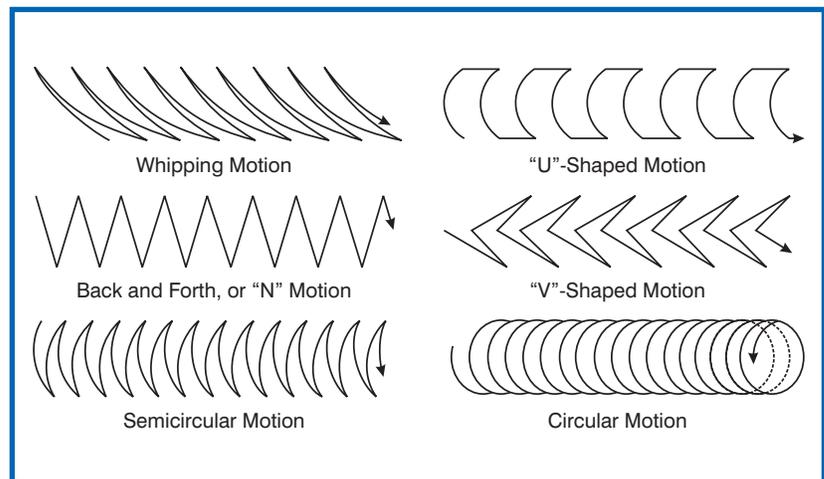


FIGURE 7. Electrode movement.



FURTHER EXPLORATION...

ONLINE CONNECTION: Welding Safety

Safety is extremely important with hot metal. Protective clothing should be worn always. Attention to safe handling of hot metal is critical. Once you have read through the welding safety practices and tips, develop an outline of how you would promote welding safety in your school shop. Develop a poster to help weldors avoid accidents. Use the following link to provide you with suggestions:

<http://www.lincolnelectric.com/>

Positions

There are four positions used when welding: flat, horizontal, vertical, and overhead. The flat position produces the strongest welds.

Controlling Distortion

Controlling distortion, warping, and cracking are major concerns when welding because of forces that cause their shape or position to change. During the welding process, the arc heats the area being welded, causing it to become larger or to expand. As heat is removed, the surrounding metal and air causes a cooling effect upon the heated area, which results in the metal becoming smaller or contracting. The laws of expansion and contraction cannot be avoided.

Several methods can be used to control distortion. The first method is to use a tack weld, which is a short bead placed at the edge of the end to which you are welding. The length of the tack weld should be twice the thickness of the base metal. Avoid over-welding by using as little weld metal as possible for the necessary strength. Another common method is to practice intermittent welding in which short beads are run and spaces are skipped between them. Run short passes and allow them to cool before running the next pass. You can also use the back step method to control distortion. It can be used when a short pass is started ahead and is run back into the previous weld.

Other common methods to help control distortion are the following examples:

- ◆ Balance the contraction of one bead by the contraction of another.
- ◆ Carefully hammer or peen a weld deposit to stretch the weld and to make up for contraction due to cooling.
- ◆ Clamp material in a jig or to other rigid support during welding and cooling.
- ◆ Preheat the materials being welded. Preheating makes welding easier and lessens the possibility of cracks.

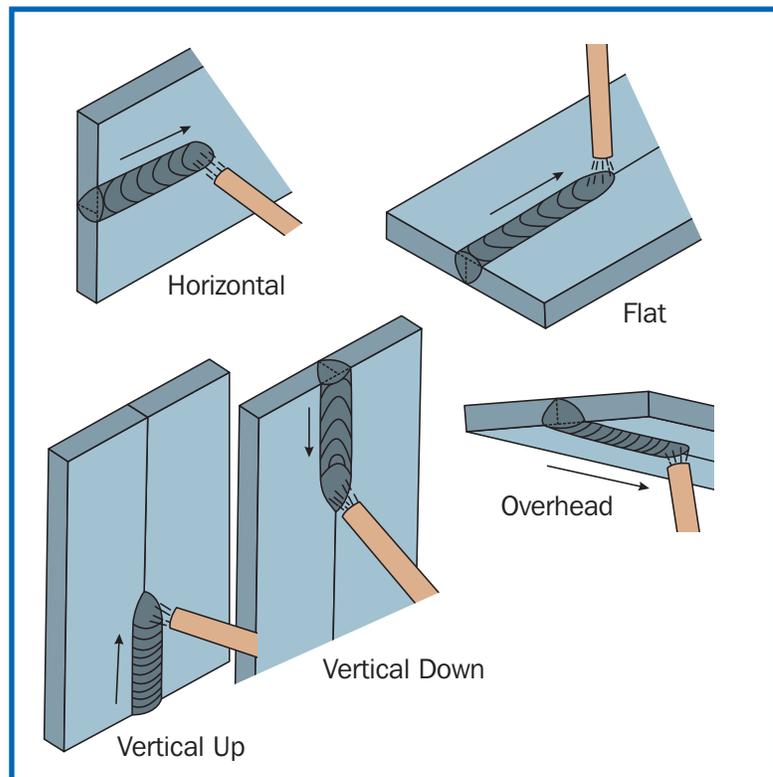


FIGURE 8. Basic welding positions.

SAFETY PRACTICES

Arc welding creates many dangers to the eyes and body. The brightest of the light can cause severe burns and injury to the eyes and skin. Read the following suggested practices and tips to minimize and/or eliminate shop accidents when arc welding.

Protective Wear

Always wear a welding helmet with an approved lens that is in good condition. A welding helmet protects from the rays of the electric arc as well as the heat and spatter of the molten metal. Use only filter lenses that are clearly labeled with standard shade numbers. Be sure they meet the specifications of the welding you are performing.

Upper body protection is necessary to protect against rays, heat, spatter, and slag while welding. Wear leather or special fabric gloves at all times to protect from hot electrodes, particles of spatter and slag, and the metal being welded. Wear high-top shoes to protect your feet and ankles from burns caused by weld spatter. Do not wear clothing with turned up cuffs, and keep your collar and pockets buttoned. Oily, greasy, and/or ragged clothing should not be worn. If leather clothing is not available, wear wool clothing rather than cotton. Wool does not ignite as readily, and it provides better protection from heat.

Equipment and Material Safety

Welding cables should be inspected for broken insulation and frayed conductors. Also, electrode holders and ground clamps should be checked for positive connections before beginning to weld. Loose connections and grounds may prove to be dangerous. In addition, the work area should be dry. If floors are damp, protective shoes should be worn (e.g., rubber-soled shoes).

All combustible materials should be cleared away from the welding area before beginning to weld. It is important to keep matches, lighters, papers, and cellophane wrappers out of pockets as these items ignite quickly and/or may explode. It is possible for flying sparks from the spatter to reach several feet from the welding operation. Sparks could ignite combustible materials, so the welding area should be cleared of rags, straw, paper, shavings, and other combustible items before starting to weld.

An exhaust system should be turned on before you begin. Welding fumes can spread to all parts of the shop and may result in injuries if inhaled. Special measures need to be taken to avoid noxious fumes that occur when welding or cutting metals containing zinc. Inhaling zinc fumes will cause you to feel ill for several hours after welding.

Work Environment Safety

Protect other workers by using a welding screen to enclose your area. Warn people standing nearby, by saying “cover,” to cover their eyes when you are ready to strike an arc. You should never look directly at the arc without protecting your eyes. The rays can penetrate through closed eyelids if you are welding at close range. Do not wear contact lenses while welding or

around a welder. Do not chip slag from a weld unless your eyes and those of others near you are protected by safety glasses.

A weldor should be on alert for fires. The operator's helmet is lowered, so clothing may catch fire without being noticed. In case of a clothing fire, strip off the article, if possible. Wrap yourself in a fire blanket, or improvise with a coat or a piece of canvas. If there is nothing at hand to wrap in, drop to the floor and roll slowly. In case of eye or skin burns, get first-aid treatment. All burns and injuries should be reported immediately to the instructor.

Hot metal should be handled with tongs or pliers to prevent burning your hands or gloves. Hot metal needs to be placed where no one will come in contact with it. An important habit to develop is feeling all of the metal cautiously before picking it up. Hot metal should not be left where it may be picked up or stepped on.

The welder should be disconnected when repairing or adjusting it. At the end of the work day, welders and equipment should be unplugged, and all equipment should be put away. Protect fuel tanks and fuel lines with wet sheet asbestos when welding near motors or power units. Clean accumulations of dry trash, husks, lint, and chaff off of farm machinery before welding. The paint on machinery may start to burn from the heat of welding.

Summary:



Shielded metal arc welding is welding in which fusion is produced by heating with an arc between a consumable stick electrode and the work piece. Arc welding uses electricity to generate heat. Common knowledge of basic electrical functions is necessary.

Welding machines are classified in several ways. One common way is by the type of output current produced: AC, DC, or AC/DC. They can also be classified by their service or by their power source. Another classification is how long the machine can operate.

Arc welding requires several other pieces of equipment and supplies. Preparation is one of the most important parts. Part of preparation is expressing the knowledge of common welds and joints. Once preparation is successfully completed, proper procedures and techniques need to be used and followed. Arc welding poses great dangers to eyes and skin, so it is important to wear a proper helmet, protective clothing. Also, welders should follow safety measures and should be attentive to others.

Checking Your Knowledge:



1. What is an advantage of using shielded metal arc welding?
2. How are welding machines classified?
3. What equipment is needed in order to operate the shield metal arc welder?

4. What do the digits on an electrode indicate?
5. How can distortion, warping, and cracking be controlled?

Expanding Your Knowledge:



How do you store electrodes? Can electrodes just sit out on the work station until needed? Can moisture or humidity cause damage to electrodes? Research the proper storage practices for electrodes. Use the following article for assistance: <http://www.keenovens.com/articles/store-rods.htm>

Web Links:



Arc Welding Safety

<http://nasdonline.org/document/1087/d000873/arc-welding-safety.html>

Welding Electrodes

<http://www.metalwebnews.com/howto/weldrod.html>

Guidelines for Shielded Metal Arc Welding

http://www.millerwelds.com/pdf/guidelines_smaw.pdf

Agricultural Career Profiles

<http://www.mycart.com/career-profiles>