Principles of SMAW

Objective(s):

1. Describe the SMAW welding process.
2. List and describe the advantages and limitations of SMAW.
3. Describe the concept of open circuit voltage.
4. Identify the different types of welding power sources used in SMAW welding.
5. Outline how different SMAW power sources develop a welding current.
6. Compare and contrast the effect different welding polarities have on the welding arc and weld metal.

Terms:

alternating current (AC): Electric current that flows half the time in one direction and half the time in the opposite direction. Contrast with direct current.

arc length: The distance from the electrode to the workpiece in an arc welding application.

classification: A system in which things are grouped based on shared qualities.

constant current (CC): Welding using a current that varies slightly with changes in voltage. Constant current (CC) is often used in shielded metal arc welding (SMAW) and gas tungsten arc welding (GTAW).

direct current electrode negative (DCEN): The arrangement of direct current arc welding cables and leads in which the electrode is the negative pole and the workpiece is the positive pole of the welding arc.

direct current electrode positive (DCEP): The arrangement of direct current arc welding cables and leads in which the electrode is the positive pole and the workpiece is the negative pole of the welding arc.

insulated gate bipolar transistor (IGBT): A type of filter used in inverter-based power sources that elevates incoming power to frequencies as high as 20,000 Hz.

open circuit voltage (OCV): The voltage between the output terminals of the welding machine when no current is flowing in the welding circuit.

primary winding: The first winding that current passes through in a transformer. The primary winding contains multiple thin wires that are wrapped into a coil.

reactor: A device used in arc welding circuits to minimize irregularities.

rectifier: A device used in an electrical circuit that converts ac into DC.

Terms Cont'd.:

secondary winding: The second winding that current passes through in a transformer. The secondary winding contains fewer, but thicker wires that are wrapped into a coil.

transformer: A device that transfers electrical energy from one circuit to another, without changing the frequency, using electromagnetic induction. A transformer is most often used to change the voltage of an input.

travel angle: The angle less than 90° between the electrode axis and a line perpendicular to the weld axis, in a plane determined by the electrode axis and the weld axis. This angle can also be used to partially define the position of guns, torches, rods and beams.

work angle: The angle 90° or less between a line perpendicular to the major workpiece surface and a plane determined by the electrode axis and the weld axis. In a T-joint or corner joint, the line is perpendicular to the nonbutting member. This angle can also be used to partially define the position of guns, torches, rods and beams.

Introduction

When you were a baby, you learned to crawl before you walked and you walked before you attempted to run. Later, you learned the alphabet before you learned to read or write. In the same way, learning the fundamentals of SMAW will help you understand the process, forming a steady foundation as you learn more about the techniques and applications that will help you become an accomplished welder.

What Is Shielded Metal Arc Welding?

Arc welding is a method of joining two pieces of metal into one solid piece. To accomplish this, the heat of an electric arc is concentrated at the joint of the two pieces of metal to be joined. The metal that is heated by the arc at the joint melts, and additional metal is commonly added to the molten puddle. This molten mass cools and solidifies into one solid piece.

With Shielded Metal Arc Welding (SMAW), the electric arc is made between the work piece and the tip of a coated metal wire called the electrode. The electrode is clamped in a holder and the electrode holder is held in the hand. With a work lead and cable connected to the work piece and the power source, the welder completes the welding circuit by striking the electrode on the base material that is to be welded. The welder then creates a gap in the welding circuit by holding the tip of the electrode 1/16 inch (in.) (1.6 millimeters [mm]) to 1/8 in. (3.2 mm) away from the base metal. The electric current jumps this gap and creates a very hot arc, which the welder guides along the joint to be welded, melting the metal as it is moved. This is known as arc length. Figure 1 shows the SMAW process.

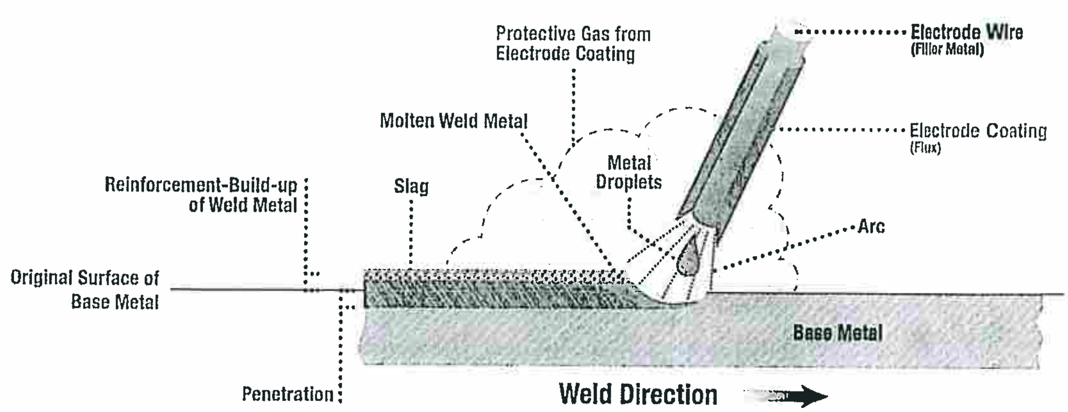

Figure 1. SMAW Process

SMAW is sometimes called "stick" welding or manual welding. It is a manual skill that requires the welder to have a steady hand, be in good general physical condition and have good eyesight. The welder watches and controls the weld puddle created by the arc. The welder's ability to do this well directly impacts the quality of the weld that is made.

What Happens in the Arc?

The temperature of the electric arc is over 6000° Fahrenheit (F.), which is more than enough to melt most metals. The arc is very bright and hot. It cannot be looked at with the naked eye without risking injury.

The arc melts the base metal and digs into it, much as water coming through the nozzle on a garden hose digs into the earth. This is shown in Figure 1 on page 3. The molten metal forms a pool that tends to flow away from the arc. As it moves away from the arc, it cools and solidifies. A slag forms on top of the weld to protect it during cooling.

The covered electrode has more function than to simply carry current to the arc. The electrode is composed of a metal wire core around which a baked chemical covering or coating has been extruded. This coating, during the welding process, forms the "shield" referred to in shielded metal arc welding (SMAW). The core wire melts in the arc, and tiny droplets of molten metal are transferred across the arc into the molten pool. The electrode provides additional filler metal for the joint to fill the groove or gap between the two pieces of the base metal.

The coating (shielding) also melts or burns in the arc. It has several functions: It makes the arc steadier, provides a shield of gas around the arc to keep oxygen and nitrogen in the air away from the molten metal, provides a flux for the molten pool, and may provide material for the weld joint to increase deposition. The flux picks up impurities, can add alloying elements to the weld, and forms the protective slag. The principal difference between various types of electrodes for mild steel are in their coatings. The different available electrode coatings provide variations in the operating characteristics of electrodes.

The fumes and gases that result from arc welding processes present potential hazards. The risk is greatest in the smoke plume, where the concentration of fumes and gases is highest. Welders must keep fumes and gases away from their breathing zones and general work areas by using natural or mechanical ventilation, fixed or movable exhaust hoods, or local exhaust at the arc. Since moderate wind speeds do not affect the quality of a SMAW weld, a reasonably placed fan or fume exhaust unit will not affect your weld.

The Arc Welding Circuit

In order to control the arc, the welder must understand the welding circuit and the equipment that provides the electric current used in the arc. The circuit begins where the electrode cable is attached to the welding machine and ends where the work cable is attached to the welding machine, as shown in Figure 2. The welding circuit consists of a power source, electrode cable, electrode holder, work clamp and a work cable.

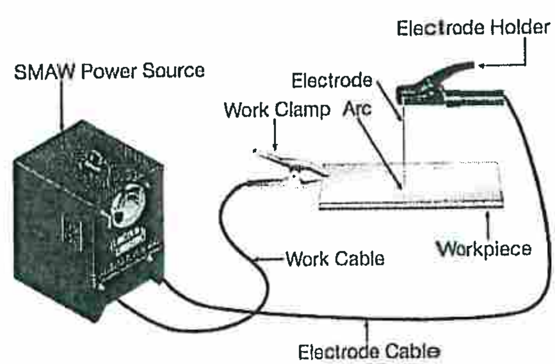

Figure 2. Arc Welding Circuit

When welding, the current must flow in a circular pattern that leaves the power source and returns to the power source via the electrical circuit. The path the current follows will determine the polarity the welder is using. In SMAW a welder can choose between alternating current (AC), direct current electrode negative (DCEN), and direct current electrode positive (DCEP). Figure 3 shows these three polarities. Each polarity has it specific advantages and limitations and will determine the type of electrode used by the welder. When welding with DCEN, current flows through the electrode cable to the electrode holder, through the holder to the electrode, and across the arc. On the work side of the arc, the current flows through the base metal to the ground cable and back to the welding machine. When welding with DCEP, the current flows in the opposite direction. AC (alternating current) switches the direction of current flow 120 times per second when using a traditional 60 hertz (Hz) power source. Regardless of the polarity used, the circuit must be complete for the current to flow, which means that it is impossible to weld if the cables are not connected to the machine or to either the electrode or the work.

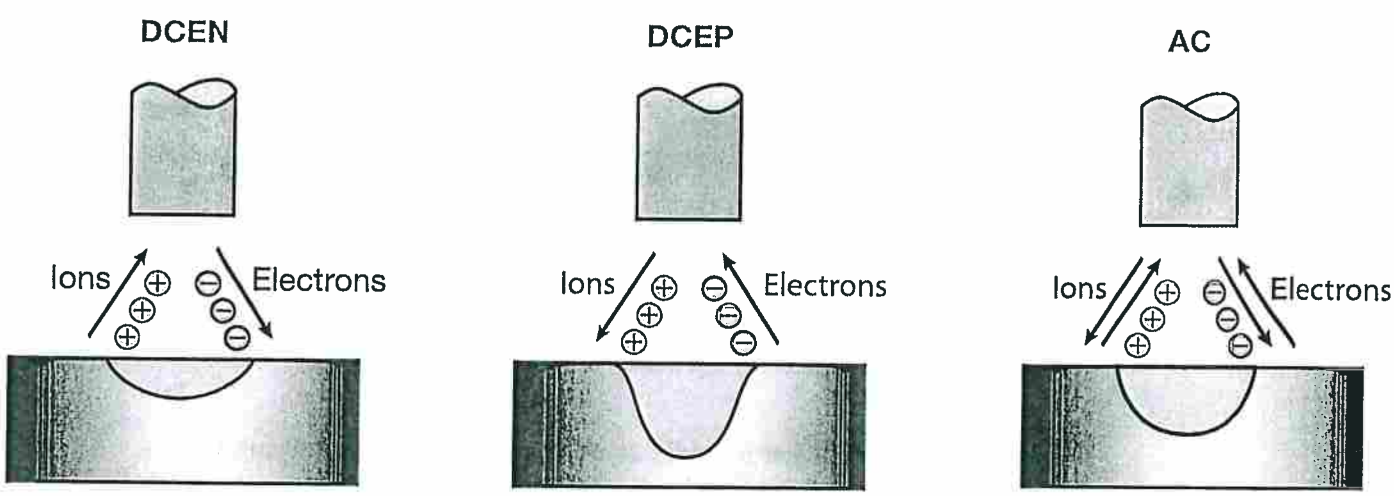

Figure 3. SMAW Polarities.

When welding with a direct current, a phenomenon called arc blow can cause unintended results in the weld joint. Arc blow involves an unbalanced magnetic field surrounding the arc. This lack of balance in the magnetic field causes the arc to "wander" around the joint. It can be minimized by using an AC welding polarity, decreasing amperage, or by using a back step technique while welding.

SMAW welding is performed using a power supply with a constant current (CC) output. A constant

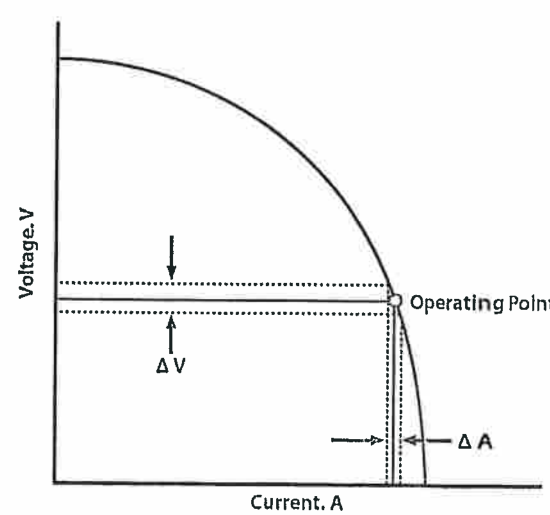

Figure 4. Constant Current Power Source

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current power source keeps the welding amperage constant, even when changes in the welding voltage occur (Fig. 4 on page 5).

With the SMAW process, changes in welding voltage occur when the arc length is altered (Fig. 5). Constant current power sources are commonly used with manual welding processes because they assist in regulating the amperage to help compensate for changes in arc length.

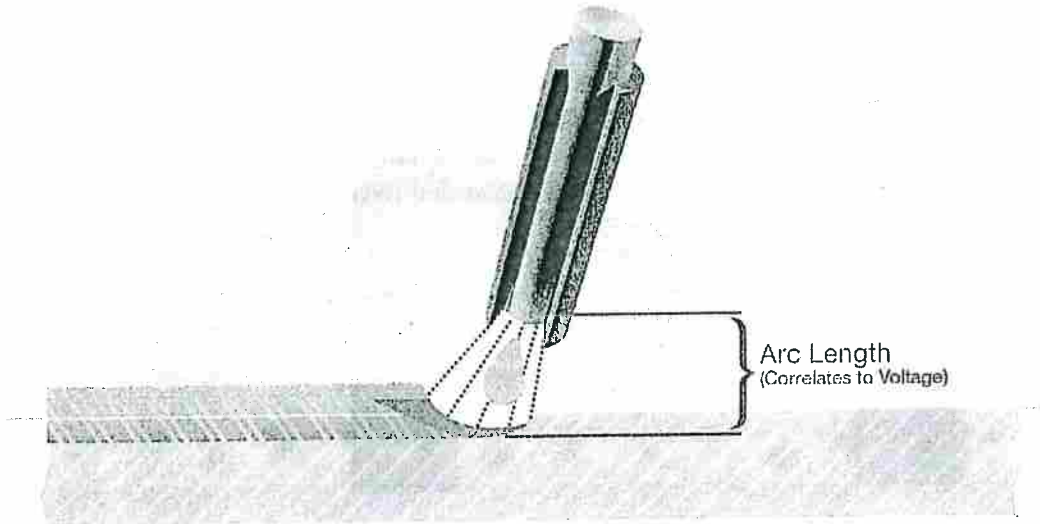

Figure 5. Arc Length Determines Voltage.

If primary electrical power is available, a transformer (for AC output) or a transformer/ rectifier (for DC output) is used to convert the high-voltage primary alternating current into secondary low-voltage/high-amperage output suitable for welding. Today, small, lightweight, and highly portable inverter power supplies can perform this function more efficiently, reducing operating costs. When primary power is not available, the same type of equipment may be powered by a generator. Open circuit voltage is an electrical term that is referred to for the SMAW welding circuit. The open circuit voltage is what helps initiate the arc in SMAW welding. Without this, initiating the arc for welding would be very difficult.

The Welder's Job

In addition to holding the arc, a good welder must be able to select the correct welding machine and amperage setting. They must also select the size and type of electrode for each job. Whenever a welding procedure specification (WPS) is available, it should be followed. A WPS is a welding standard, either purchased from the American Welding Society (AWS) or written by a competent Certified Welding Inspector. A WPS provides the required welding information for a specific joint configuration to assure repeatability by properly trained welders; that is, it outlines how a particular weld should be made.

A good welder must be able to manipulate the electrode and arc to make a satisfactory weld under varying conditions—while observing safety precautions at all times. Joint preparation, positioning the work, and a knowledge of distortion, metallurgy, and many other factors will affect the final result. Nearly anyone can "stick two pieces of metal together," but a good welder will study, train, and practice to ultimately become a fine craftsman following safe work practices.

Electrode Angles

When welding, the electrode should be held in the weld joint using the proper work angle. Work angle is the angle used to provide adequate penetration into the weld joint (Fig. 6). For flat groove welds the work angle is typically 90° and for fillet welds 45°. The travel angle is the angle that the electrode is tilted either in or against the direction of travel. The travel angle is usually between 20 - 30°. See Figure 7.

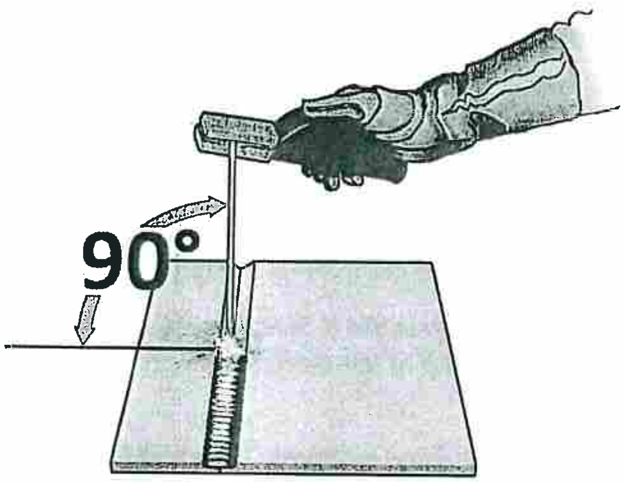

Figure 6. Work Angle

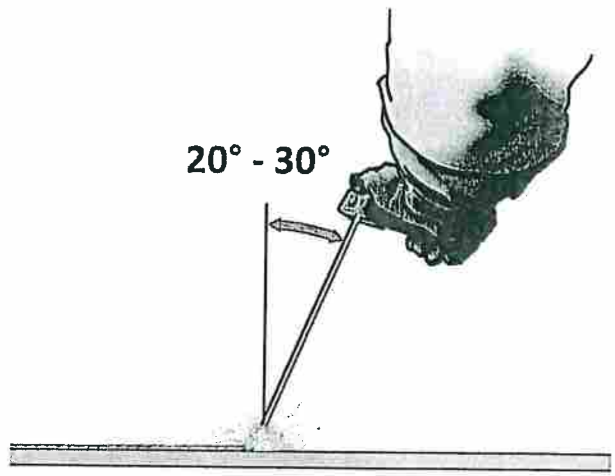

Figure 7. Travel Angle

Travel speed is determined by the size of the electrode being used, the type of electrode, the welding amperage and the desired weld bead size and shape. Manufacturers of SMAW electrodes, such as Lincoln Electric, publish this information along with welding procedures in many publications.

Tips for Success

- If the electrode work angle is too severe and exceeds the recommended 45° for fillet welds, the weld will be predominately placed on the plate the electrode is being directed towards and inadequate fusion can take place. Burnthrough on thinner material can also result.
- Travel angle is also a very important factor in determining the weld bead profile. Excessive drag angles will cause erratic arc characteristics and excessive spatter. The weld will be concave in nature, have pointed instead of crescent shaped chill rings, and will be of irregular size and shape. The weld integrity can also be adversely affected.

- Insufficient drag angles and pushing the electrode can cause other types of issues. In this case, the electrode coating (and slag) is pushed into the fluid weld bead causing slag inclusions. Insufficient drag angles can also cause the electrode to be buried below the weld puddle and the weld, solidifying on top of the electrode, thus causing the electrode to "stick" into the puddle.
- Using proper welding procedures that include correct amperage, arc length, travel speed, and electrode angle are critical in producing a properly sized weld bead with sufficient penetration and with an excellent bead profile.

Travel Speeds - Travel speed is determined by a number of variables:

- The size of the weld can determine travel speed.
- It should also be relative to the plate thickness of the material being welded.
- Sheet metal requires a faster travel speed.
- When welding on thick plate, travel speed should be slower.

Advantages of SMAW

There are several advantages to SMAW. The following is a list of most of the major advantages to SMAW welding.

Low Start Up Costs: SMAW welding machines are relativity inexpensive to purchase and require fewer pieces of other equipment to complete a ready-to-weld package.

Portability: SMAW is a very portable process because it does not require any external shielding gas and equipment due to the ability of the electrode to produce its own shielding gases.

Outdoor Weldability: SMAW welding can be done outdoors. The shielding of the weld puddle from the coating of the electrode is not susceptible to winds and, therefore, is an excellent choice for outdoor welding.

All Position Welding: SMAW can be done in all welding positions, which eliminates the need for expensive fixturing or manipulation of the part being welded.

Variety of Materials: Many base materials and alloys can be welded with the SMAW process, including steel, stainless, cast Iron, and even aluminum. Virtually all conductive metals and alloys have a compatible SMAW electrode. The filler materials are specific alloys that match the alloys in the base material.

Mechanical Properties: The coatings on the SMAW electrodes have deoxidizers, or scavengers, in them. The primary deoxidizers used are silicon and manganese.

Silicon and manganese combine with oxygen and nitrogen and remove these gases from the weld puddle. Oxygen and nitrogen are detrimental to welds and can cause weld bead porosity, or pinholes in the weld. Sources of oxygen and nitrogen are surface contaminants such as oil, rust, and mill scale. Due to the deoxidizers in the coatings, stick welding is somewhat tolerant of surface contaminants. These factors as well as other coating elements allow some SMAW electrodes to meet very stringent mechanical property standards for such things as nuclear welding, pressure vessels, seismic welding, etc.

Limitations of SMAW

There are several limitations to SMAW. The following is a list of most of the major limitations to SMAW welding.

Low Efficiency: The efficiency of a SMAW electrode can be defined as the percentage of the electrode that is consumed and becomes part of the weld. SMAW electrodes are 60% – 65% efficient. The primary reason for this low efficiency is stub loss, or the portion of the electrode that is unused and discarded. Other reasons for the low efficiency of the process are slag and spatter.

Operating Factor: Operating factor can be defined as the amount of arc on time in a shift of work, labeled as a percentage. SMAW welding has an operating factor of approximately 25% – 30%. In other words, only 25% – 30% of a workday is spent arc welding. Low operating factors can be attributed to the length limitation of the stick electrode. When the electrode is consumed in the arc, it needs to be replaced with a new one. The welding stops and time is taken to replace the electrode. Time is also used up in post-weld cleaning operations such as grinding spatter and removing slag.

Restarts: SMAW electrodes are only 9 – 18 in. in length. When the electrode is consumed in the arc, it needs to be replaced with a new one. This means that welding stops, and time is taken to replace each electrode. Also, time is used in post- weld cleaning operations such as grinding spatter and removing slag. Due to the length limitation of the shielded metal arc electrode, many welds have stops and starts (restarts) within the weld. Starts and stops are sensitive areas for weld defects.

Operator Skill: SMAW welding requires a higher level of operator skill. This process is more challenging than some other arc welding processes to learn. The shielded metal arc electrode has the tendency to stick to the work-piece. When this occurs, amperage rises, and voltage decreases to a value of zero. At this point, the shielded metal arc electrode produces a short circuit and it "sticks" to the work piece. This occurs primarily on arc starting and during welding when the arc length becomes too short.

Amperage Limit: Electrodes used in SMAW are limited by the amperage that they can be run which in turn controls the deposition rate for the process. High amperages used with semi-automatic or automatic welding are impractical because of the long and varying length of the stick electrode. The welding current is limited by the resistance heating of the electrode. The electrode temperature must not exceed the "break-down" temperature of the coating on the electrode. If the temperature exceeds this limit, the chemicals in the coating will react with each other or with air and will not function properly at the arc.

Slag Removal: A protective slag covering forms in SMAW welding. This slag has several functions: it protects the weld as it cools from contaminants, it shapes the weld bead, and it holds the weld in place for out of position welding. Elements are placed in the coating for the sole purpose of forming a slag to perform these functions. However, slag must be chipped off for multiple pass welding (Fig. 8). If the slag is not chipped off, a weld defect called a slag inclusion can occur. In this case, the weld would have to be ground out and the part re-welded. The slag also has to be removed if the part is going to be painted for the same reasons as those for removing spatter. Slag removal causes additional non-productive time for cleaning. This tends to increase the labor costs involved in the welding operation.

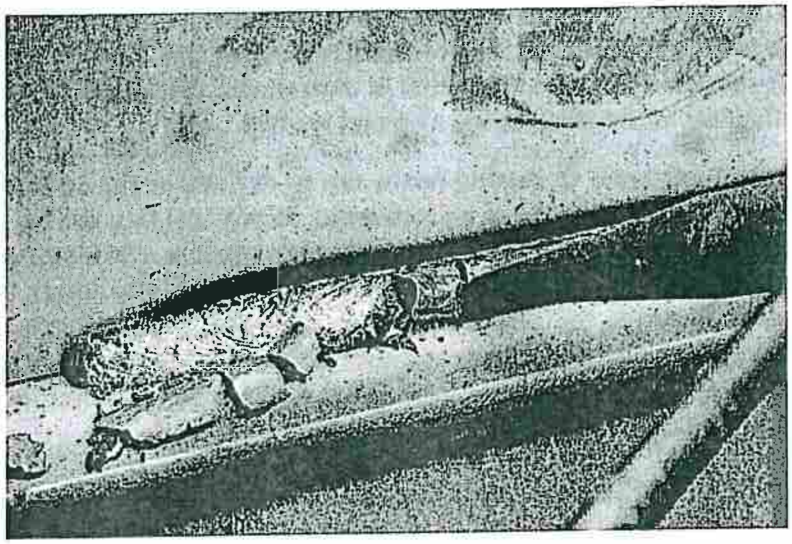

Figure 8. Slag Removal

Spatter: Spatter is usually ground off the finished part for appearance purposes. This increases the amount of clean up time and reduces the amount of production time. Spatter is only a visual defect and can be ground off if necessary as in the case of cosmetic welds. Spatter may be ground off if the part is to be painted after welding. In some cases, if the spatter ball does not cling to the part, it will fall off as the part is put in service. This will cause the paint on the part to chip off.

Power Sources

Power companies produce electricity by several means: coal-burning, oil, nuclear, and hydroelectric. No matter what the source of production, in general, power companies produce AC. AC is produced because it can be transformed very easily from a very high voltage level all the way down to your household voltage (Fig. 9), and it can be transmitted over long distances without appreciable loss, as would

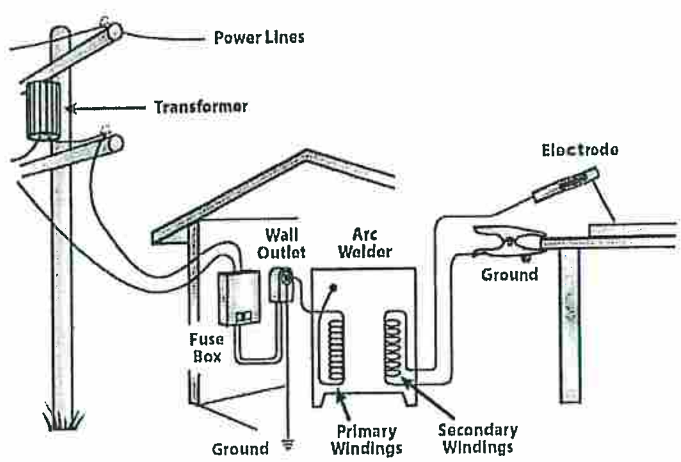

Figure 9. Transforming AC Power

be the case with DC. Electricity by power companies is made at approximately 13,500V. It is then stepped up as high as 350,000 volts (V) and low amperages for long distance travel. It is then sent to substations to reduce the voltage to travel to local distribution centers. From the distribution centers, it is sent to a series of transformers again to reduce the voltage to useful voltages, i.e. 575V, 460V, 230V, and 115V and to raise the amperage for usage in shops and homes. This electricity is delivered to you at almost the instant it is produced and travels at nearly the speed of light (186,000 miles per second). All arc-welding processes require a continuous supply of electrical current with sufficient amperage and voltage to maintain an arc. This current can be AC or DC but it must be supplied to the welding electrode through a power supply that has precise control. Proper settings and controls of the power supply allow desirable arc characteristics and optimize efficiency. Voltage and current can be supplied to the power supply from power lines, as discussed above, or developed within itself as in the case of engine-driven alternators and generators. Either way, power sources provide a voltage range for welding from about 13-45V, and current from 2 A (amps) to 1500 A or more. The welding process and consumables determine not only the size of the power supply needed but also the type of power supply needed, i.e. constant current or constant voltage.

Transformer Machines

The transformer in a power supply is a step-down transformer that takes high-voltage, low-amperage AC input supplied from power companies and changes it to low-voltage, high-amperage AC welding current. For example, your input power may be 230V on a 50 A branch circuit. This voltage is much too high and the amperage is much too low for welding applications. The transformer takes this condition and reverses it to a much lower voltage, in the range of 13-45V (most applications 15-35V) and increases the amperage to a much higher level appropriate for welding. Figure 10 shows the electrical components of a transformer type welder, and Figure 11 on page 12 is an example of a transformer type welder.

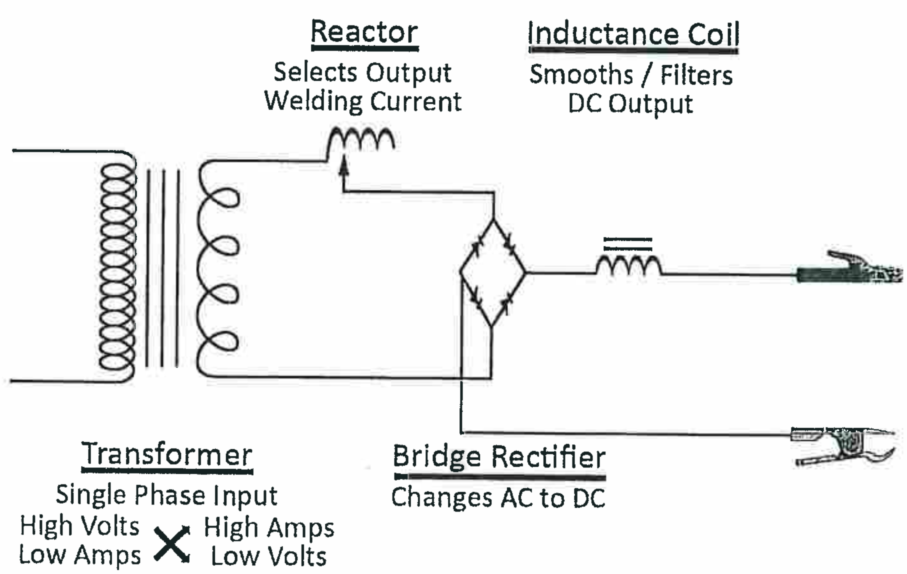

Figure 10. Electrical Components of a Transformer Type Welder

Figure 11. IdealArc® 250, a Transformer Type Welder

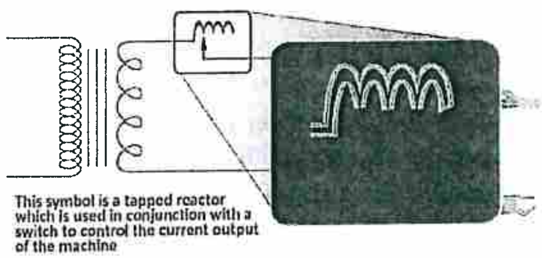

Figure 12. Reactor

From the transformer, the electricity goes to a control that stabilizes and adjusts the welding current. This is called the reactor (Fig. 12). The reactor can be a tap reactor that selects amperage ranges to weld with. A tap reactor "taps" into segments of the secondary of the transformer and provides step control. This is the least expensive means of controlling welding output and can be found on the Lincoln AC 225 power source . Another reactor is a moveable iron reactor such as the one used on the Idealarc 250 in Figure 11. To change the output amperage the operator must turn the "wheel" on the front of the machine. This will move the reactor thus changing the output current.

This is generally done by keeping the windings in the transformer stationary and moving the "chunk" of iron between the windings to control amperage. A moveable iron provides continuous step-less control of amperage. A saturable reactor or S.C.R. (silicon controlled rectifier) can also be used and also provides a continuous step- less control for more precise control of welding output. An S.C.R. is an electrical control that uses a low voltage, low amperage DC circuit to change the effective magnetic characteristics of the reactor core. This is the most common type used on power sources today.

In a power supply that delivers only alternating current to the arc, these are the internal electrical components of the power supply. We now need to discuss how we convert this alternating current to direct current of to DC, which is the current primarily used in arc welding.

In power supplies that deliver DC and/or AC and DC current to the arc, there needs to be a device that changes this now low-voltage, high-amperage AC into DC. This device is called a rectifier (Fig. 13 on page 13). A rectifier converts AC to DC and is very efficient and very reliable. A rectifier allows current to flow in only one direction. Remember that alternating current takes a sine wave path. This represents one cycle in which current flows in one direction for half of the cycle, stops at the zero line, and reverses its direction of flow for the other half cycle. This cycle repeats itself over and over again at a frequency of 60 Hz or 60 times a second in the United States. A rectifier does not allow current to reverse itself. It only allows current to flow in one direction. In essence, it directs current in the same direction rather that allowing it to change direction. This is called direct current of DC. The direction of current flow determines whether the polarity is DC+ or DC-.

We often call the current coming out of a rectifier "choppy" or rippled DC. In other words, the path of current is not as smooth as it could be and therefore, the arc characteristics are not as smooth as they could be. A device is placed inside power supplies to correct this problem. This device is called an inductance coil (Fig. 14), which is sometimes called a choke or stabilizer. The main function of the choke is to smooth out the rectified rippled DC and therefore, smooths out the DC arc characteristics.

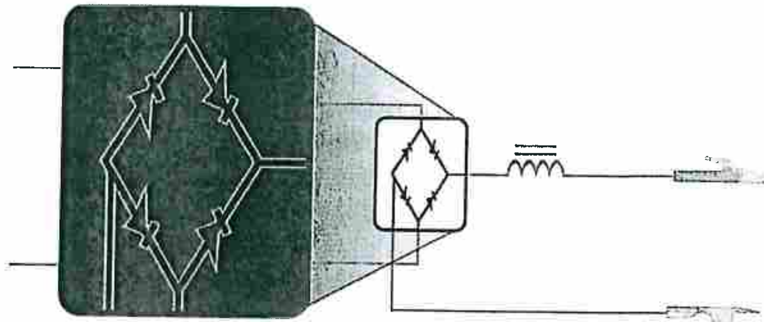

Figure 13. Bridge Rectifier

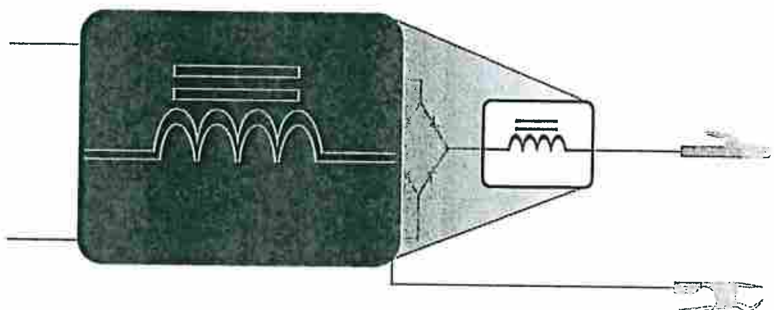

Figure 14. Inductance Coil

Lincoln Equipment

Most of the Lincoln Electric transformer based power supplies come as complete packages that include the work cable and clamp, the electrode holder and cable, a sample package of electrodes and a Basic Welding Guide for Beginner Welders, and finally, they all come with an input power cord and plug ready to plug into a 230V single phase receptacle. See Figure 15 on page 14 for an example.

Inverters

An inverter is a state-of-the-art AC and/or DC transformer power source. There are several advantages of inverters over traditional transformer designed power supplies, which will be discussed later. There are also a few concerns or limitations of inverters that will also be discussed. The design of an inverter is more complex than that of a traditional power supply with more components and electrical circuitry. Figure 16 is a block diagram depicting the six main components of an inverter.

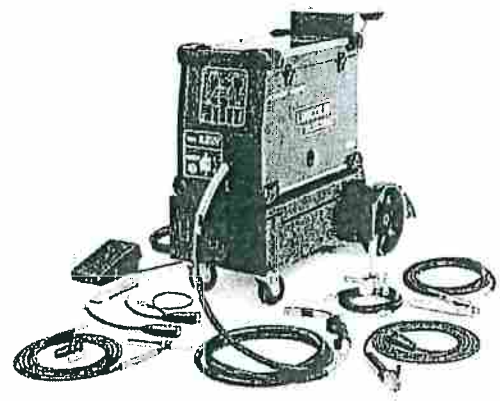

Figure 15. Power Wave® C300 Inverter Type Welder

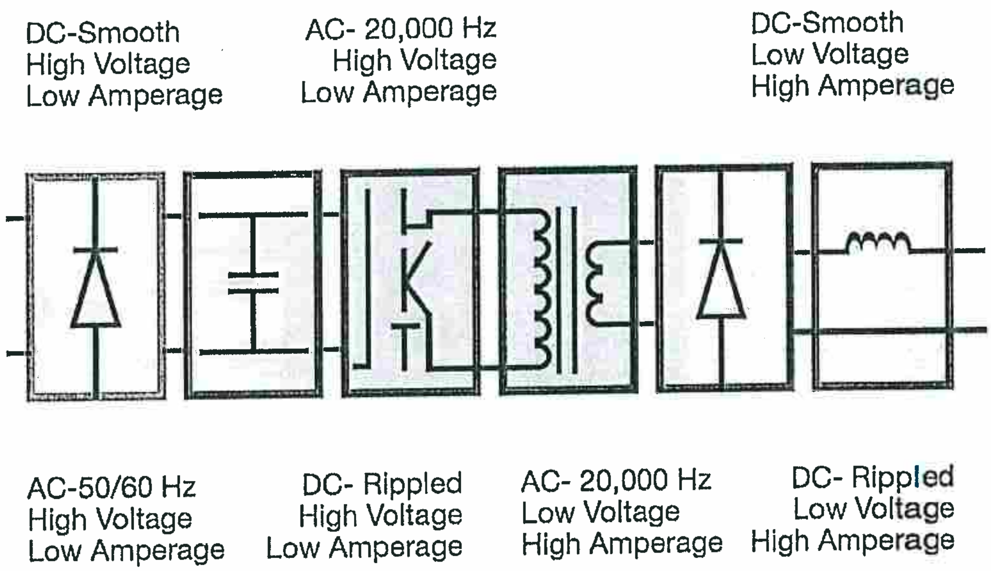

Figure 16. Main Components of an Inverter

The input power coming in to the inverter power supply is alternating current or AC as produced by power companies. It is of high-voltage and low-amperage, and is not suited for welding. The frequency is 60 Hz in the United States and 50 Hz in many foreign countries. In an inverter-based power supply, this input power is immediately passed through a rectifier. Remember that a rectifier is a device that only allows current to flow in one direction and, in essence, changes AC to DC or direct current. This direct current (DC) is rippled, not smooth, and is still high-voltage and low-amperage, which is not suitable for welding.

This rippled DC is next passed through a filter to smooth it out. This has the same effect as the choke or inductance coil in the basic transformer designed machine. This power is still of high-voltage and low-amperage and is not suitable for welding as of yet.

The next component of an inverter is a device that identifies and distinguishes an inverter from a basic transformer designed machine. This component is a high-speed switching device and can come in many forms that include FETs (field effect transistors), IGBTs (insulated gate bipolar transistors), and Darlington switches. An IGBT requires an incoming DC signal. The IGBTs elevate the frequency to levels such as 20,000 Hz as found in all Lincoln Electric inverters. They supply pulsed DC current to the main transformer primary winding. Each switchboard feeds current to a separate, oppositely wound primary winding of the main transformer. The reverse direction of current flow through the main transformer primaries and the offset timing of the IGBT switch boards induce an AC square wave output signal at the secondary of the main transformer.

The rest of the inverter greatly resembles that of a basic transformer machine. From the IGBT, we have alternating current (AC) at 20,000 Hz at high-voltage, low-amperage. This is passed through a step-down transformer to change this AC to low-voltage and high-amperage at 20,000 Hz .

Summary

Because shielded metal arc welding is one of the most basic ways to learn welding, it is still widely used today. Understanding the basic principles of the SMAW process will help you select the proper size and type of electrode for each job, manipulate the electrode properly and allow you to create a successful weld. Knowledge of the advantages and limitations of the SMAW process will increase your ability to use the process properly and effectively.

Principles of SMAW Assessment

Name: ______________________________ Date: ______________

True or False

Directions: *Choose True if the statement is correct. Choose False if the statement is incorrect.*

1. Arc blow is a magnetic field caused by electrical current flow.

   True False

2. The distance from the tip of the electrode to the base material being welded is arc length.

   True False

3. The SMAW process only uses AC polarity.

   True False

4. DCEP describes the flow of welding current as coming from the work lead and moving towards the electrode holder.

   True False

5. Generator welders are not portable (independent of an electrical source).

   True False

6. Alternating current (AC) is the preferred type of current for welding for SMAW.

   True False

7. One of the advantages of an inverter power source is the small size and lighter weight compared to other power sources.

   True False

8. The heat generated by the electric welding arc can reach temperatures up to 1000° Fahrenheit (F).

   True False

9. A welding inverter is less complex than the other traditional welding power sources.

   True False

10. Welding transformer/rectifier power sources use an inductance coil to stabilize the direct current being produced.

    True False

11. The welding voltage of a welding power source is 120 volts (V).

    True False

Principles of SMAW Assessment

True or False

Directions: *Choose True if the statement is correct. Choose False if the statement is incorrect.*

12. The stops and re-starts necessary with SMAW electrodes increase the risk of weld defects.

    True — False

13. With a 60 hertz (Hz) power source, alternating current changes the direction of current flow 60 times per second.

    True — False

14. Direct current has neither a positive or negative value 120 times per second.

    True — False

15. SMAW has one of the highest operating factors of the arc welding processes.

    True — False

Multiple Choice

Directions: *Choose the letter of the best answer.*

16. The advantage(s) of the shielded metal arc welding (SMAW) process is/are:
    - A. Low cost of equipment
    - B. Low cost of consumables
    - C. Ability to weld in various environments
    - D. All of the above

17. Open circuit voltage is best described as the:
    - A. Electrical flow of energy
    - B. Electrical charge to the electrode to ignite the arc
    - C. Voltage when the power supply is switched to OFF
    - D. The shock to the operator when the ground is disconnected

18. The most basic type of welder is a(n):
    - A. Transformer
    - B. Transformer/rectifier
    - C. Generator
    - D. Inverter

19. Which of the following is not part of the welding electrical circuit?
    - A. Electrode
    - B. Workpiece
    - C. Electrode/work cables
    - D. None of the above

Principles of SMAW Assessment

Multiple Choice

Directions: *Choose the letter of the best answer.*

20. Welding power sources use a ________ type of transformer to create electricity for welding.
    - A. Steady state
    - B. Solid state
    - C. Step-up
    - D. Step-down

21. The transformer inside a welding power source converts high voltage, low amperage electricity into ________ electricity for welding.
    - A. High voltage, high amperage
    - B. Low voltage, low amperage
    - C. High voltage, low amperage
    - D. Low voltage, high amperage

22. Which of the following electrical characteristics is kept constant with a constant current power source?
    - A. Voltage
    - B. Amperage
    - C. Polarity
    - D. All of the above

23. To increase the penetration of a bead, you should select which welding polarity?
    - A. DCEN
    - B. DCEP
    - C. AC
    - D. Both DCEP and AC

24. Which polarity is also referred to as reverse polarity?
    - A. AC
    - B. DCEN
    - C. DCEP
    - D. None of the above

25. Changes in the welding arc length will also change the following electrical characteristic(s):
    - A. Voltage
    - B. Current
    - C. Watts
    - D. Ohms

