Arc Welding Operations

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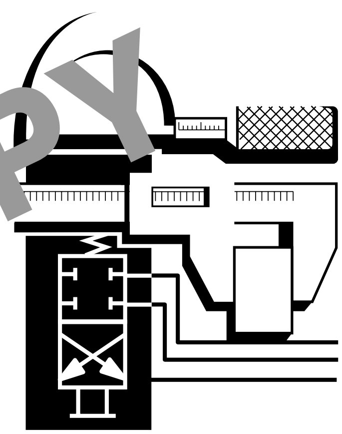
ARC WELDING OPERATIONS

Lesson One

Shielded Metal Arc Welding



TPC Training Systems

41901

Lesson

1 Shielded Metal Arc Welding

TOPICS

How the Process Works
Welding Current and Measurement
Arc Length
Welding Machines (Power Sources)
Polarity
Tools and Accessories
Selecting an Electrode
Equipment Setup and Operation
Personal Protection for Welding

OBJECTIVES

After studying this Lesson, you should be able to…

- Define *arc length* and explain its importance.
- Explain how the metal arc welding process works.
- Tell what provides the shield in shielded metal arc welding.
- List factors to consider when selecting an electrode.
- Describe the personal protective equipment necessary for welding.

KEY TECHNICAL TERMS

Shield 1.03 cloud of gas around the arc
Slag 1.03 crusty flux deposit on the weld
Voltage 1.05 measure of electrical pressure
Amperage 1.05 measure of number of electrons flowing
Wattage 1.06 measure of electrical power
Arc voltage 1.07 voltage present during welding
Open-circuit voltage 1.08 voltage present when no welding is being done
Current rating 1.17 maximum current output of a welding machine
Duty-cycle rating 1.18 safe nonstop operating capacity of a welding machine
Polarity 1.23 positive/negative arrangement of welding cables
DCEP 1.24 direct current, electrode positive
DCEN 1.25 direct current, electrode negative
Arc blow 1.27 deflection of arc by magnetic forces
Atmospheric arc blow 1.27 movement of arc by wind or drafts
Speed 1.45 advance of the electrode along the joint
Weave 1.45 side-to-side motion of the electrode
Feed 1.45 movement of the electrode into the arc as it is consumed

In shielded metal arc welding (sometimes called stick welding), the intense heat from an electric arc is used to melt and fuse metals to form a weld. It is one of the oldest and most widely used welding processes. Although used mainly for joining iron and mild or low-carbon steel, shielded metal arc welding is well suited to maintenance tasks because the equipment is relatively inexpensive, simple to operate, and can be used for welding many different kinds of metals.

This Lesson describes the shielded metal arc welding process and explains how the welding machines and accessories are set up and used. It also points out some of the factors to be considered when selecting an electrode. In addition, it describes the personal safety equipment needed for welding, and emphasizes the precautions that should be taken against arc flash, fumes, and fire hazards created by welding operations.

How the Process Works

1.01 *Shielded metal arc welding*, abbreviated *SMAW*, is one of the most common electric arc welding processes. A typical SMAW outfit consists of an electric power source (the welding machine), two welding cables, a "ground" or work connection clamp, an electrode holder, and a covered metal "stick" electrode. Electric current from the welding machine is used to form an electric arc between the tip of the electrode and the work. The work or base metal thus becomes part of the welding circuit, as shown in Fig. 1-1.

1.02 Welding is started by touching the end of the electrode to the base metal, then lifting the electrode about 1/4 in. (6 mm). This action forms the arc, which immediately produces temperatures exceeding 11,000°F (6000°C). The intense heat concentrated in the arc area instantly melts the base metal and begins to burn the covering off the electrode and melt the core. The melted core becomes filler metal for the weld, and the decomposition of the flux covering forms a protective gaseous atmosphere around the arc area, as illustrated in Fig. 1-2 on the following page.

1.03 The word "shielded" in shielded metal arc welding refers to the cloud or *shield* of gas that forms around the arc area as the electrode covering or flux burns away. The gas shield protects the molten metal in the arc area against contamination from oxygen and nitrogen in the surrounding air. If the gas shield was not present, oxides and nitrides would form in the molten weld puddle, and the finished weld would be weak and brittle. Additional shielding is provided by the electrode flux covering in the form of a crusty deposit called *slag*. The slag deposit protects the hot weld metal against contamination as it cools and solidifies.

1.04 Some of the shielding gas developed near the arc column is ionized (electrically charged). The ionized gas promotes better electrical conductivity and stability in the arc column. To improve weld quality, some electrodes contain special additives such as deoxidizers that purify the weld deposit, or alloying ingredients that alter the composition of the weld deposit. When properly made, joints welded by the SMAW process are as strong as or stronger than the base metal itself.

Welding Current and Measurement

1.05 Two kinds of electrical measurements are important in arc welding.

Fig. 1-1. Components of a shielded metal arc welding circuit

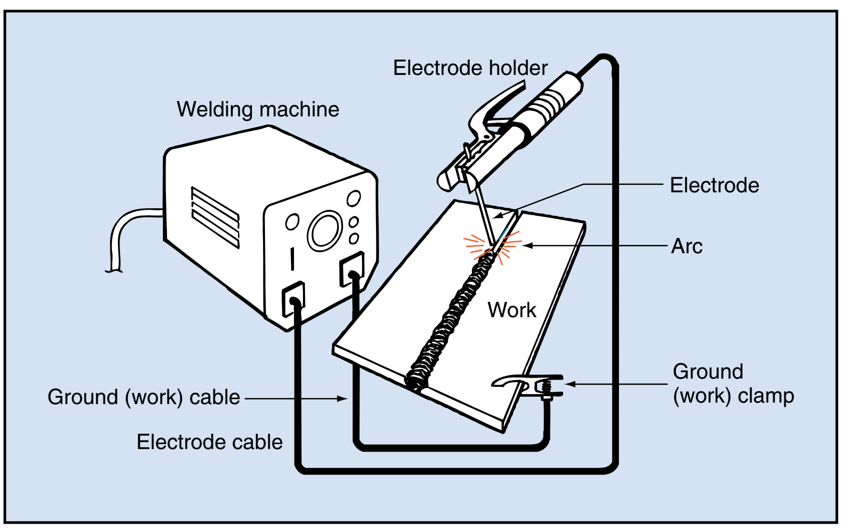
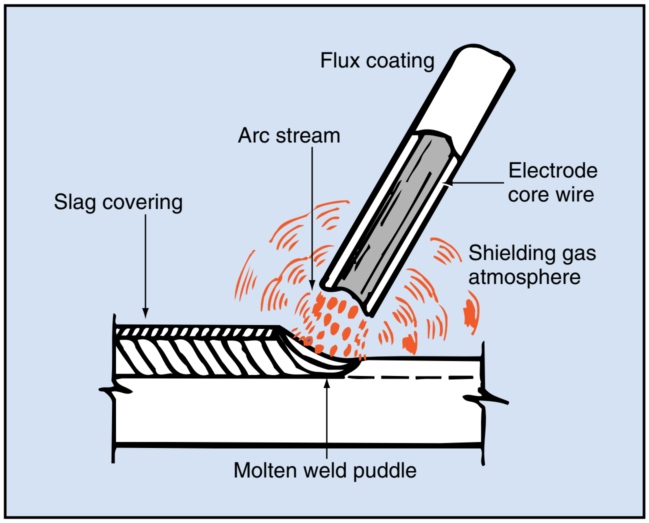


Fig. 1-2. Typical arc from a covered electrode



- **Voltage** is the amount of electrical energy (measured in joules) provided by the welding machine per unit of electrical charge (measured in coulombs). One joule of energy per coulomb of charge is defined as one *volt*. The voltage provided by the welding machine determines how large a gap the arc can cross. The greater the voltage, the larger the gap the arc can cross.

- **Current** is the amount of electrical charge (measured in coulombs) flowing through the arc per unit of time (measured in seconds). A current of one coulomb per second is defined as one *ampere*. The current determines the thickness of the arc. A high current produces a thick arc; a low current produces a thin arc.

Together, voltage and current determine how fast electrical energy (which creates heat in the arc) is delivered during the welding process. If you multiply the voltage (joules per coulomb) by the current (coulombs per second), the result is the number of joules of energy delivered per second. This rate at which energy is delivered determines how fast heat is created in the weld, which is one of several factors that determine how high a temperature can be created.

1.06 In a welding current, electrons flow through a conductor from negative (–) to positive (+). Resistance to this flow produces heat. The greater the resistance, the greater the heat. Air has a high resistance to current flow, and as the electrons jump the air gap between the end of the electrode and the work, a great deal of heat is produced. Electrons flowing across an air gap produce an arc.

1.07 Arc voltage and open-circuit voltage are the two kinds of welding voltages with which you should be familiar. *Arc voltage*, sometimes called the *closed-circuit* or *working voltage*, is the voltage present in the welding circuit while an arc is struck and welding is being done. Arc voltage normally ranges from 15 to 40 V. It varies measurably with the length of the arc.

1.08 The exact amount of the arc voltage depends on the *open-circuit voltage*, which is the voltage generated by the welding machine when no welding is being done. Open-circuit voltage is normally between 50 and 100 V, but it drops to the arc voltage level when an arc is struck and welding begins. How and where the open-circuit voltage is adjusted depends on the size and style of the welding machine being used.

Arc Length

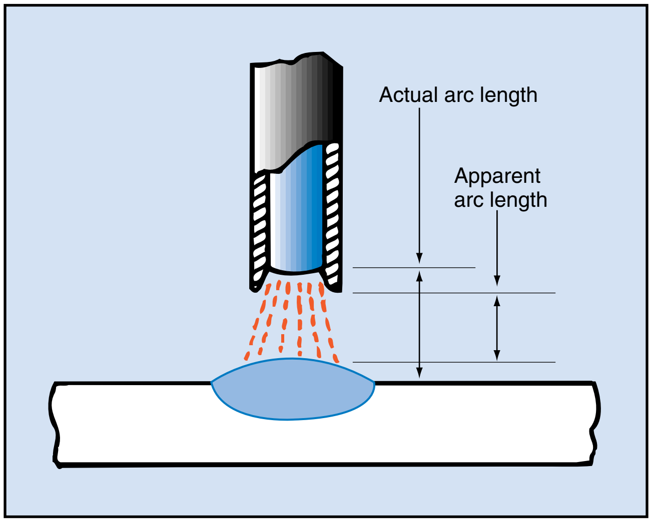
1.09 The resistance is affected by the arc length and the chemical composition of the gases formed as the electrode covering burns and vaporizes. As the arc lengthens, the resistance increases, thus causing a rise in the arc temperature. The shorter the arc, the lower the arc temperature produced. The best results are usually obtained with an arc length approximately equal to the diameter of the electrode.

1.10 The high temperature created in a long arc can cause burn-through, excessive porosity, and undercutting of the adjacent base metal. These problems can be controlled by advancing the electrode faster with less side-to-side motion.

1.11 The shorter arc introduces different problems. The short arc is cooler, which can result in poor penetration, increased exposure of the deposited metal to oxidation and contamination, decreased concentration of welding heat, and an erratic, unstable arc. When a short arc cannot be avoided, slower and smoother electrode manipulation helps minimize these problems.

1.12 The arc produced by a covered electrode is actually longer than it appears, because the end of the electrode core burns away faster than the flux

Fig. 1-3. Actual vs apparent arc length



covering. Thus, the end of the core is actually slightly recessed in the flux covering, as shown in Fig. 1-3, so that it is really farther from the weld puddle surface than indicated by the edge of the covering.

1.13 The slight receding of the core end has a negligible effect on arc voltage and current variations compared to the changes introduced by the slight shaking and wiggling that are almost impossible to avoid when welding manually. However, the recessed core can present a minor problem when starting an arc with a partially used electrode. The protruding flux covering can interfere with direct contact between the core metal and the base metal. When this problem occurs, simply chip away part of the covering to expose an edge of the core.

Welding Machines (Power Sources)

1.14 Many types and sizes of welding machines are available. SMAW generally requires a *constant-current machine* because its current output, although not actually constant, does not change significantly with the small variations in arc voltage caused by minor changes in arc length. Because of its relatively stable current output, the constant-current machine is preferred for manual welding operations where minor variations in arc length and arc voltage are practically unavoidable.

1.15 An alternative to the constant-current machine is the *constant-voltage* (constant-potential) *welding machine.* Its volt-amp output curve is a nearly horizontal line. It is designed to provide relatively constant welding voltage, while the welding current can vary from near zero to the extreme of a high, short-circuit current. The current adjusts itself according to the arc length, which is established by electrode manipulation and the rate of burn-off. The output curves of both machines are compared in Fig. 1-4.

1.16 If a constant-voltage machine is used in a manual welding operation, the unavoidable variations in arc length produce large fluctuations in the current, resulting in an unstable, nonuniform arc. For this reason, constant-voltage machines are more commonly used in automatic or semiautomatic welding operations, such as the gas metal arc welding (GMAW or MIG) process, where the consumable electrode is mechanically fed into the arc. The steady electrode feed rate establishes a stable arc and uniform arc length.

1.17 A welding machine is limited in operation by two ratings that are based on its designed capabilities. The size or *current rating* of a machine is its maximum current output. A current rating of 400 A means the machine can deliver up to 400 A of welding current.

1.18 The *duty-cycle rating* of a machine is its safe operating capacity for nonstop welding. Duty cycles are expressed as the percentage of a 10-min period over which a machine can deliver its rated maximum welding current output without damage or

Fig. 1-4. Output curves of constant-current and constant-voltage welding machines

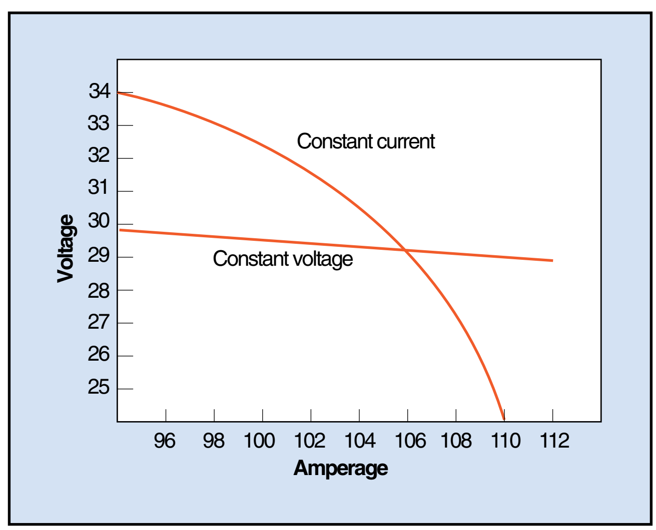


Table 1-1. Characteristics of dc and ac welding power sources

	dc (direct current)	ac (alternating current)
Welding cable length	Must be as short as possible. Voltage drop in excessively long cables can cause overload and/or weak arc.	Voltage drop in long cables is less than with dc. Cables should never be longer than required for the job.
Low amperage settings	Excellent results possible with low amperages and small diameter electrodes.	Not suited to low amperages with small diameter electrodes. Produces a more stable arc at higher amperages.
Electrodes	Most classes of covered electrodes can be used. Best control of weld puddle.	Only electrodes designed for ac or ac/dc can be used. Special covering ingredients are included to improve arc stability and aid re-establishing the arc during each cycle.
Arc starting	Easier that with ac, particularly with small diameter electrodes.	More difficult than with dc. Electrodes, especially small ones at low amperages, tend to stick or freeze to the base metal.
Arc length	Shorter arc is easier to maintain than with the same electrode and ac.	Shorter arc is difficult to maintain except with specially designed electrodes.
Arc blow	Common problem resulting from magnetic forces. Occurs frequently at joint ends, in corners, and in complex or massive structures. Causes excessive spatter and weak, nonuniform weld beads.	Rarely a problem because whatever magnetic forces may be produced are continually expanding and collapsing with current alternations.
Metal thickness	Often used for welding sheet metal and thick sections because of the easily started, steady arc (DCEN). Also excellent for thick sections (DCEP).	Well suited for welding thick sections with high amperages where arc blow might be troublesome.
Welding positions	Affected more by electrode size and composition than by type of current used. Small-diameter electrodes generally are suitable for all-position welding because lower amperages can be used. Larger-diameter electrodes generally are limited to flat or horizontal positions.	

overheating. Thus a 400-A machine with an 80% duty cycle can deliver 400 A of welding current for a total of 8 min out of every 10, and must idle at least 2 min out of every 10 for cooling. This means you can weld continuously for 8 min and stop for 2 min, but you are exceeding the duty cycle if you try to weld for 16 min nonstop and then stop for 4 min. The 10-min periods are successive, and total arc-on welding time cannot overlap into the next period.

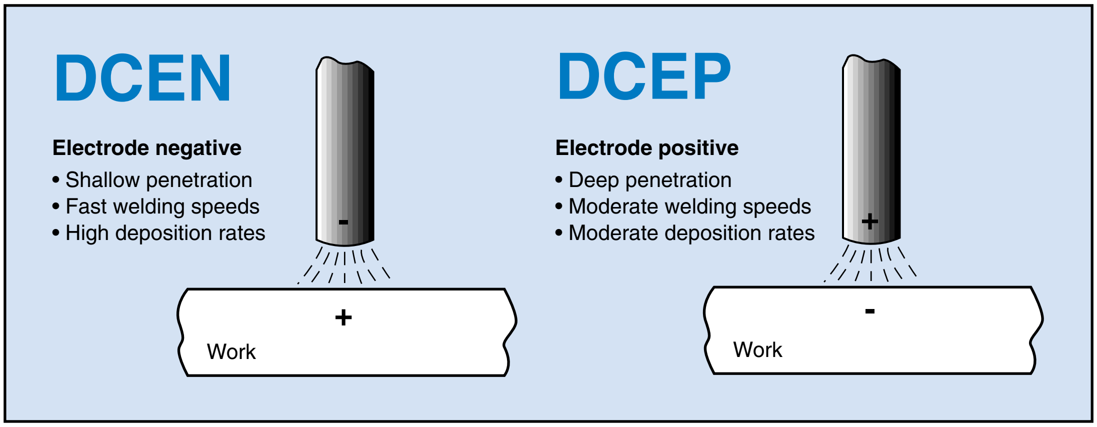
1.19 Before attempting to operate any welding machine, you should become familiar with both the power-off and the power-on control settings and operating procedures. Learn how and where the machine is connected to plant power, how to connect the welding cables, and how to put the machine in operation.

1.20 Familiarize yourself with machine controls, meters, and scales, so you can properly and safely perform a welding task. Learn how to read and interpret the scales and meters on the control panel. Check with your supervisor or study the manufacturer's operating manual to obtain this information. Instructions and procedures vary from one model to another, so be sure you have the correct manual.

1.21 Both AC and DC power sources for SMAW can produce acceptable results, and each has certain advantages and disadvantages. The important characteristics of AC and DC welding power sources are compared in Table 1-1. Most AC power sources contain a transformer that steps down line voltage (240 V or 480 V, single- or 3-phase) to the level required for welding (normally less than 100 V).

1.22 DC power is produced by a DC generator or a transformer-rectifier unit. The generator is driven by an electric motor or by a gasoline or diesel engine. In the transformer-rectifier unit, the transformer steps down AC line voltage, and the rectifier converts the AC to DC. Combination AC/DC power sources are also widely used. They consist of a transformer-rectifier unit with

Fig. 1-5. **Electrode negative and electrode positive DC welding**



means for selecting either AC or DC for welding. The most recent development is welding power sources is the inverter type, which is smaller, lighter weight, and more efficient. Both AC and DC models are available.

Polarity

1.23 An understanding of the *polarity* or positive/negative arrangement of welding cable connections is important for DC arc welding. Current flows in only one direction in a DC electrical circuit. Switching the cable connections changes the polarity (and thus the direction of current flow) in the welding circuit. Changing the DC polarity affects the heat distribution between the work and the electrode, and it changes other conditions in the weld area as shown in Fig. 1-5. Polarity does not apply to AC arc welding because the current is constantly changing directions. Alternating current in the United States is supplied at 60 Hz (cycles per second), which means that it goes through a complete cycle (change in direction of flow from positive to negative to positive) 60 times per second.

1.24 **DCEP.** When the positive (+) lead from the power source is connected to the electrode, the circuit is considered to be *electrode positive*, or *reverse polarity*. With electrode positive, the arc is forceful and digs into the base metal for deep penetration. It is used in most welding.

1.25 **DCEN.** With *electrode negative*, also called *straight polarity*, the negative (–) lead is connected to the electrode and the positive (+) lead is connected to the work. With this setup, the arc is not as forceful and is used to weld sheet metal and other thin material. There is also a rapid melt-off of the electrode, and metal is deposited about one-third faster.

1.26 The choice between DCEN (direct current, electrode negative) and DCEP (direct current, electrode positive) is determined by the type of electrode used, but other variables should also be considered. They include composition and thickness of the base metal, the requirements of the finished weld, and the welding position. Although most electrodes can be used with either polarity, some electrodes are designed to be used with only one polarity. On some DC welding machines, polarity is changed by unplugging and reversing the welding cable connections. Others have a polarity switch so that the correct polarity can be selected without disconnecting the cables.

1.27 **Arc blow.** One drawback to using DC welding current is the problem of arc blow. *Arc blow* is a deflection or wandering of the arc caused by magnetic forces that build up in the arc area. In a severe case, magnetic arc blow can cause molten metal to splash out of the weld puddle. A similar problem, called *atmospheric arc blow*, can occur if strong winds or drafts are allowed to blow through the arc area. Magnetic arc blow is limited to DC welding, but atmospheric arc blow can occur in either AC or DC welding.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. The welding arc in SMAW is formed by electric ________ from the welding machine.	1-1. CURRENT Ref: 1.01
1-2. What forms the welding shield in SMAW?	1-2. A CLOUD OF GAS CREATED BY THE BURNING OF THE FLUX COVERING Ref: 1.03
1-3. Arc voltage normally ranges between 15 and 40 V, while open-circuit voltage ranges between ________ and _______V.	1-3. 50; 100 Ref: 1.07, 1.08
1-4. The arc from a covered electrode can appear slightly ________ than it actually is.	1-4. SHORTER Ref: 1.12
1-5. A welding machine limited to a total of 6 min of operation (at rated amperage) out of every 10 min has a _______% duty cycle.	1-5. 60 Ref: 1.18
1-6. Changing the polarity of DC welding current affects the ________ between the work and the electrode.	1-6. HEAT DISTRIBUTION Ref: 1.23
1-7. With DCEP, the electrode is ________.	1-7. POSITIVE Ref: 1.24, Fig. 1-5
1-8. Winds or strong drafts in the arc area of AC or DC welding can cause atmospheric________.	1-8. ARC BLOW Ref: 1.27

Tools and Accessories

1.28 **Holders.** Most shielded metal arc welding outfits include a set of welding cables, one with an electrode holder and the other with a clamp. Holders and clamps are made in a variety of styles, one of which is the spring type illustrated in Fig. 1-6. The holder has spring-loaded metal jaws with grooved faces for securely holding the electrode in position. Electrical contact is made when the metal jaws of the holder are closed on the bare (uncovered) end of the electrode.

1.29 **Clamps.** The "ground" or work connection clamp for welding, such as shown in Fig. 1-6, should not be confused with the electrical grounding connection in other industrial appliances. The welding cable and the clamp that is connected to the base metal are commonly referred to as the ground cable and clamp, even though they do not always technically serve as an electric ground connection. For all welding tasks, the ground or work clamp is *always* attached to the base metal to complete the welding circuit when an arc is struck.

1.30 **Cables.** Selecting the correct size (diameter) of welding cable is important. Cables too small in diameter for the current they must carry will overheat and cause unnecessary loss of power. Cable size and length also directly influence the voltage drop (voltage "used up" in forcing the welding current through the cable). Excessive voltage drop lowers the quality of finished welds. The voltage drop is greater in a long, small diameter cable than in a short, large diameter cable. Always use the diameter of welding cable specified by the manufacturer of the welding machine. Avoid using long cables if shorter cables are available and suit the job conditions.

1.31 **Cleaning.** The common weld-cleaning tools are a chipping hammer and a wire brush. These tools are sometimes combined, as shown in Fig. 1-7 on the following page. They are used to remove crusty slag deposits from new welds. As soon as the weld is solid, slag is chipped away with a few sharp blows of the chipping hammer, followed by vigorous brushing with a wire brush to remove remaining traces of slag. Cleaning is especially important after each pass of a multipass weld. When cleaning a weld, always wear goggles or a face shield for protection against flying bits of slag.

Selecting an Electrode

1.32 **Core.** One of the first steps in preparing to weld is to select an electrode. A neat, sound weld depends on using the proper electrode. Electrodes are classified by their core material: mild steel, high-carbon steel, special alloy steel, cast iron, and nonferrous. Mild steel electrodes are the most commonly used because most SMAW operations involve mild steel base metals. In general, the electrode core material is matched as closely as possible with the composition of the base metal. Electrode diameter varies with the thickness of the base metal.

1.33 Some electrodes are designed for AC or DC, and some for DC welding only—only a few work equally well with both. All electrodes can be used for flat position welding, but some have special properties. One electrode, called a *fast-fill type*, provides large weld deposits in a short time. It is useful for rapid buildup in large joint gaps. Others, called *fast-*

Fig. 1-6. Spring-type work clamp and electrode holder

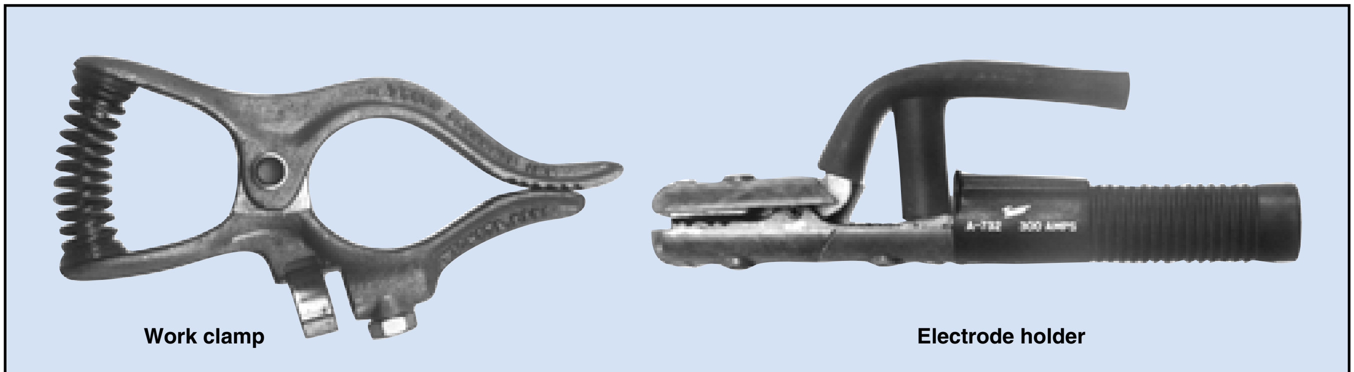
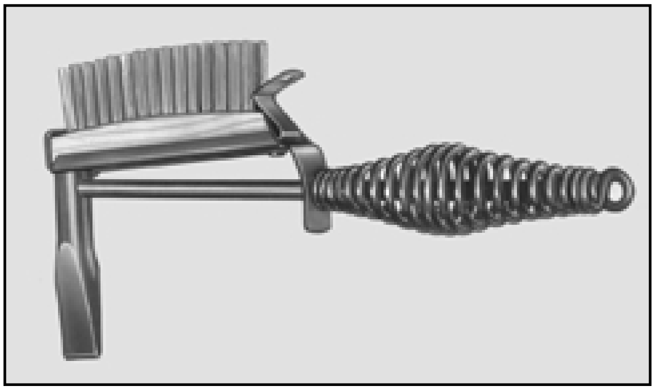


Fig. 1-7. Chipping hammer and brush for removing slag



freeze types, solidify more quickly than others. They make better out-of-position welds by reducing the amount of sagging and dropout of weld metal normally experienced in vertical and overhead joints. *Fill-freeze types* have characteristics between the other two groups. A fourth group, the *low-hydrogen type*, is especially suited to welding steels, especially those that are difficult to weld.

1.34 Joint design and fitup also influence the choice of an electrode. If, for example, the mating edges of a butt joint are not beveled, or the joint gap is very narrow, select an electrode that will provide deep penetration. For wide joint gaps, select an electrode designed for faster, heavier metal deposition, such as a fast-fill.

1.35 **Flux.** Another factor to consider is the composition of the electrode's covering. In general, the covering material provides shielding gas and forms slag. Some coverings contain metal powders to increase the deposition rate. Others contain special additives that help stabilize the arc, add alloying ingredients to the weld, improve the bonding properties between the base metal and the electrode metal, or deoxidize the weld. More specific information on electrodes and their coverings is presented in another Lesson of this Unit.

1.36 The size and characteristics of the selected electrode determine the arc current settings on the welding machine. For the current values suitable for various electrodes, refer to the instructions and tables provided by the electrode manufacturer. Normally, the recommended amperage for an electrode is given as a range of values rather than a single number. Within that range, fine adjustments can be made to obtain the best penetration and deposition of weld metal under varying field conditions. For example, the higher heat and greater penetration provided by a slightly higher-than-normal current setting (within the recommended range) might be best when welding thick metals. For thinner metals, however, a slightly lower setting might be better.

Equipment Setup and Operation

1.37 **Safety.** After selecting the proper electrode, the next step is to set up the equipment. First, remove all paper, trash, and other flammable materials from the welding area. Then assemble the required accessories and safety equipment (fire extinguishers, curtains or shields, and special protective clothing), and position the welding machine if it is portable. If the work can be moved, try to place it for flat position welding. Before turning on power, set the machine controls to coincide with the manufacturer's instructions for the proper voltage and current.

1.38 **Electrode.** Insert the bare end of the electrode between the jaws of the holder. Good electrical contact is important, so keep the holder jaws clean. Sometimes wiggling the electrode slightly from side to side in the holder helps improve electrical contact and assures firm seating of the electrode in the holder jaws.

1.39 Practice different ways of handling the electrode holder before starting to weld. Grip the holder lightly in whichever hand is comfortable for you. To avoid fatigue from lifting excessive lengths of electrode cable, arrange the cable so it is supported about 4 ft (1.2 m) from the holder. This arrangement allows freedom of movement, yet it reduces the length of cable you must support while welding. Never coil or loop the cable around any part of your body.

1.40 After making the necessary power-off settings, attach the ground clamp, turn the power on, and make the necessary power-on settings or adjustments. To strike an arc, position the end of the electrode about 1 in. (2.5 cm) above the weld starting point. Lower your helmet and, with a rapid tapping or scratching motion, touch the electrode to the base metal. Immediately after contact, raise the end of the electrode slightly to establish an arc whose length is approximately equal to the electrode diameter.

1.41 If the electrode is not raised quickly, it will stick to the work. Sticking causes a short circuit, and the electrode begins to heat up. Twist or bend the electrode to break it free. If the electrode is stuck fast and does not break away, quickly release the electrode from the holder or shut power off to stop the current flow. Let the electrode cool. It can then be broken free with a gloved hand. With a little practice, you can learn to strike an arc without the electrode sticking.

1.42 **Ground.** If you have difficulty striking an arc, check to be sure the ground clamp is securely attached. Scrape off any rust, paint, or dirt on the clamp jaw faces or on the base metal that could be preventing adequate electrical contact between the clamp and the work. Always attach the clamp to a clean, bare area on the work. Wiggling the clamp back and forth a few times might also improve contact.

1.43 Other methods of attaching the ground cable include bolting it directly to the work, clamping it with a C-clamp, and tack-welding a piece of scrap to the work and bolting or clamping the cable to the scrap. It is important to have a good electrical connection to complete the welding circuit. Arcing can occur at the ground clamp if the cable-to-work connection is loose.

1.44 When current settings are correct and proper arc length is maintained, a continuous crackling noise similar to the sound of bacon frying is heard while welding. An uneven or erratic sound indicates the arc length is too long or the current is too high. Arcs which are too short make a popping sound and can flash on and off, indicating the electrode is sticking and short circuiting to the base metal.

1.45 **Motion.** Weld beads made manually with SMAW require three separate but coordinated motions or manipulations of the electrode. The electrode is advanced along the joint with a side-to-side motion while being fed into the arc area. Welding conditions vary from job to job, so manipulation techniques also vary. All three motions should be made smoothly and uniformly, adapting the electrode *speed*, *weave*, and *feed* rate to the conditions that exist.

1.46 Observe the arc area closely through the dark lens of your welding helmet. Maintain a steady travel speed that will produce adequate penetration and weld metal buildup in the joint. Use a weaving motion or stringer (straight) bead according to the width and fitup conditions of the joint gap. Try to match the electrode feed rate as closely as possible with the rate of burn-off by observing and maintaining a uniform arc length. Practice coordinating these motions. If possible, practice on some scrap metal. Experiment with variations to the motions while observing the effects of the variations.

Personal Protection for Welding

1.47 Welding gloves and a welding helmet are necessary for all arc welding tasks. Additional items of personal protective apparel, such as shown in Fig. 1-8, are recommended as conditions and hazards become increasingly severe. Hot workpieces should always be handled with pliers or tongs. Gloves help prevent burns from accidental contact. Avoid the pain and mental anguish always associated with picking up a piece of hot metal or a hot electrode stub with your bare hands. *Assume all metal in the welding area is hot until proven otherwise!*

1.48 The major personal hazards in arc welding are the brilliant *arc flash*, harmful *infrared* and *ultraviolet* radiation, and flying sparks. *Never* look directly at the welding arc without a dark shield for your eyes. Looking at the arc even momentarily can be painful to the eyes and cause temporary vision problems. Extended exposure with no protection, however, can cause

Fig. 1-8. Personal protection against welding glare, heat, sparks, and harmful radiation

Fig. 1-9. Cape and bib for overhead and eye-level welding

severe eye damage and permanent partial or total loss of sight. Thus, a welding helmet with at least a number 9 filter must *always* be worn while arc welding for protection against the arc flash and weld spatter.

1.49 Infrared radiation from the welding arc have a penetrating heating effect. They cause more discomfort than harm when the exposure is of short duration. When welding for long periods, however, wear reflective apparel or place a reflective shield between your body and the arc to minimize the effects of infrared radiation.

1.50 The ultraviolet radiation from an electric arc are similar to those that cause sunburn. But, because the radiation is more concentrated in welding, the burns can be more severe. For protection against “arc sunburn,” simply avoid exposing your skin to radiation from the arc. Ordinary clothing blocks the radiation, so normal welding apparel should include a long-sleeved shirt buttoned at the sleeves and collar, full-length trousers, and a welding helmet with proper filter lens. When you stoop or crouch while welding, be sure your trouser legs do not “hitch up” to expose skin above your socks or boot tops.

1.51 Do not wear trousers with cuffs, or shirts and aprons with large pockets. A flying spark landing in a cuff or open pocket can cause serious burns to your skin and clothing before it can be removed or extinguished. Wear high-top boots or leggings that cover your instep, ankle, and shin. Do not wear low-cut shoes or footwear with exposed laces. Flying sparks can easily enter a low-cut shoe, and laces can trap and hold a spark or drop of molten metal.

1.52 For overhead welding tasks and vertical welds made at or above eye level, wear protective clothing such as illustrated in Fig. 1-9. The idea is to protect your neck and upper body from the shower of sparks and hot metal falling from the weld area. A bib added to the cape extends protection to just below your waist. Also wear a cap or hat to protect your hair from falling sparks.

1.53 *Always avoid* breathing the fumes and smoke produced by arc welding. Certain metals and electrode coverings can produce especially hazardous smoke and fumes. They are particularly dangerous in a confined space, such as the inside of a tank or boiler, or where ventilation or air circulation is poor. Check local and federal safety recommendations to assure that all necessary precautions are taken for the welding task to be performed.

1.54 Under normal conditions, existing plant ventilation systems might be adequate for maintenance or repair welding jobs of short duration. Permanent welding stations should have separate ventilation systems to adequately remove smoke and fumes. Under particularly hazardous conditions, such as in confined areas or where toxic gases might be present, it might be necessary to wear an air-fed respirator because of the lack of breathable air. Determine what hazards might be encountered in a given welding work area and take steps to protect yourself from them.

1-9. The welding ground clamp is always connected to the ________.	1-9. BASE METAL Ref: 1.29
1-10. A cable that is too long can affect the quality of a weld because of the excessive ________ drop it causes.	1-10. VOLTAGE Ref: 1.30
1-11. Metal powders are added to some electrode coverings to increase the ________rate.	1-11. DEPOSITION Ref: 1.35
1-12. If the workpiece can be moved, it is usually placed for ________ position welding.	1-12. FLAT Ref: 1.37
1-13. When striking an arc, as soon as the electrode contacts the base metal, raise the electrode slightly to prevent a ________.	1-13. SHORT CIRCUIT Ref: 1.40, 1.41
1-14. An erratic sound when welding indicates the arc is too ________ or the current is too ________.	1-14. LONG; HIGH Ref: 1.44
1-15. To maintain a uniform arc length in manual welding, try to match the electrode feed rate with the electrode ________ rate.	1-15. BURN-OFF Ref: 1.46
1-16. Permanent partial or total loss of sight can result from exposure to the ________ without protection.	1-16. ARC FLASH Ref: 1.48

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. The shield in shielded metal arc welding is provided by

- ☐ a. decomposition of the base metal
- ☐ b. decomposition of the electrode covering
- ☐ c. gas from a pressurized cylinder
- ☐ d. the welding machine

1-2. Which of the following is present when the welding machine is energized but no welding is being done?

- ☐ a. Arc blow
- ☐ b. Arc voltage of about 25 V
- ☐ c. Open-circuit voltage of 50 to 100 V
- ☐ d. Rated welding current

1-3. Which of the following results when a shorter-than-normal arc is maintained?

- ☐ a. Higher melt rate
- ☐ b. Hotter arc
- ☐ c. Lower arc temperature
- ☐ d. More current

1-4. Which type of welding machine should be used for manual welding operations where slight variations in arc length are unavoidable?

- ☐ a. Constant-current
- ☐ b. Constant-impedance
- ☐ c. Constant-potential
- ☐ d. Constant-resistance

1-5. The two ratings that indicate the operational limitations of a welding machine are its duty-cycle rating and its

- ☐ a. arc voltage setting
- ☐ b. current rating
- ☐ c. line voltage capabilities
- ☐ d. physical dimensions

1-6. It is essential to make certain the polarity is correct for all

- ☐ a. AC welding
- ☐ b. DC welding
- ☐ c. overhead welding
- ☐ d. shielded metal arc welding

1-7. In straight-polarity welding, the electrode is

- ☐ a. bypassed
- ☐ b. grounded
- ☐ c. negative
- ☐ d. positive

1-8. Magnetic arc blow is a problem that occurs only in

- ☐ a. AC welding
- ☐ b. DC welding
- ☐ c. reverse-polarity welding
- ☐ d. straight-polarity welding

1-9. Which of the following need not be considered in the selection of a covered electrode for a given SMAW operation?

- ☐ a. Core material composition
- ☐ b. Electrode diameter
- ☐ c. Length of the weld
- ☐ d. Type of current

1-10. Which of the following items should be used for personal protection in all arc welding operations?

- ☐ a. Foot and shin guards
- ☐ b. Helmet and gloves
- ☐ c. Leather cape
- ☐ d. Welding apron

SUMMARY

SMAW equipment consists of an electric power source, two welding cables, an electrode holder, and ground clamp. AC or DC current forms an electric arc of intense heat, which fuses the *base metal* and the *core* material of the welding electrode. As it burns, the flux covering of the electrode forms a cloud of gas around the arc, *shielding* the molten metal in the arc area from oxygen and nitrogen in the surrounding air.

Welding current is rated by *voltage* and *amperage*. *Open-circuit voltage* drops to *arc voltage* as soon as the arc is struck. Only practice with the equipment will enable the student to learn to maintain proper *arc length* and how to form good welds.

Welding machines are available in both *constant-current* and *constant-voltage* designs, although the constant-current type is preferred for manual SMAW. When selecting or using a welding machine, you must be aware of both its *current rating* and *duty-cycle rating*. Welding is performed using both AC and DC current. When using DC current, the electrode may be either positive (*DCEP*) or negative (*DCEN*). Again, each has its advantages and requires specific techniques.

A variety of electrodes is available. Select the right one for the material being welded and practice proper *speed*, *weave*, and *feed* rates.

Before beginning to weld, be fully aware of safety considerations. Be properly dressed, use the proper equipment for the job, and be prepared to shut down the operation in case of any emergency. In addition to the obvious hazards of heat, sparks, and molten metal, always protect yourself against *arc flash*, *infrared* and *ultraviolet radiation*, and *fumes*.

Answers to Self-Check Quiz

1-1. b. Decomposition of the electrode covering. Ref: 1.03

1-2. c. Open-circuit voltage of 50 to 100 V. Ref: 1.08

1-3. c. Lower arc temperature. Ref: 1.09

1-4. a. Constant-current. Ref: 1.14

1-5. b. Current rating. Ref: 1.17

1-6. b. DC welding. Ref: 1.23

1-7. c. Negative. Ref: 1.25

1-8. b. DC welding. Ref: 1.27

1-9. c. Length of the weld. Ref: 1.32, 1.33

1-10. b. Helmet and gloves. Ref: 1.47

Contributions from the following sources are appreciated:

Figure 1-6. Tweco Products, Inc.
Figure 1-7. Lenco-NLC, Inc.
Figure 1-8. Steelgrip, Inc.
Figure 1-9. Steelgrip, Inc.