SHIELDED METAL ARC WELDING

DEFINITION AND GENERAL DESCRIPTION

Shielded Metal Arc Welding (SMAW) is an arc welding process in which coalescence of metals is produced by heat from an electric arc that is maintained between the tip of a consumable covered electrode and the surface of the base metal in the joint being welded.

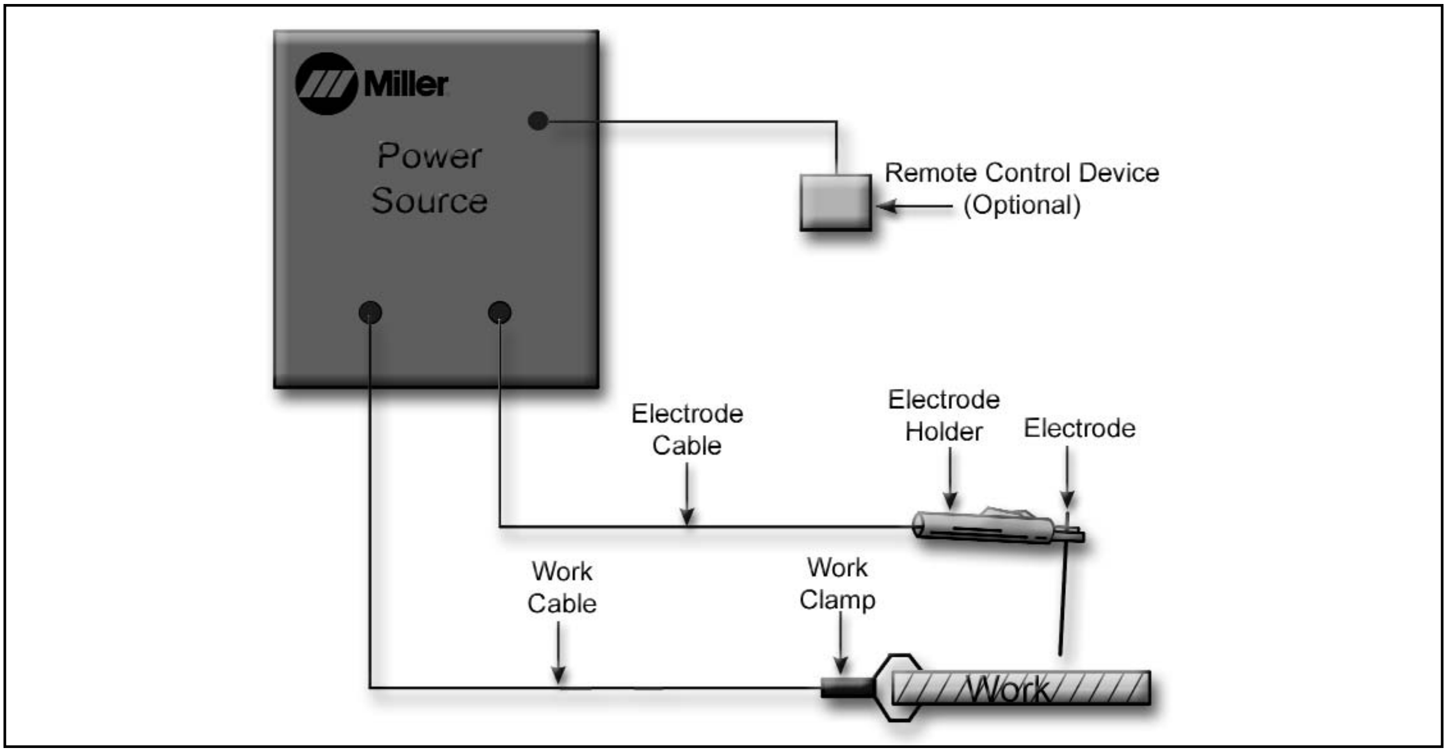
Stick Welding Application

Shielded Metal Arc welding is one of the most widely used processes, particularly for short welds in production, maintenance and repair work, and for field construction. The following are advantages of this process:

1. The equipment is relatively simple, inexpensive, and portable.
2. The filler metal, and the means of protecting it and the weld metal from harmful oxidation during welding, are provided by the covered electrode.
3. Auxiliary gas shielding or granular flux is not required.
4. The process is less sensitive to wind and draft than gas shielded arc welding processes.
5. It can be used in areas of limited access.
6. The process is suitable for most of the commonly used metals and alloys.

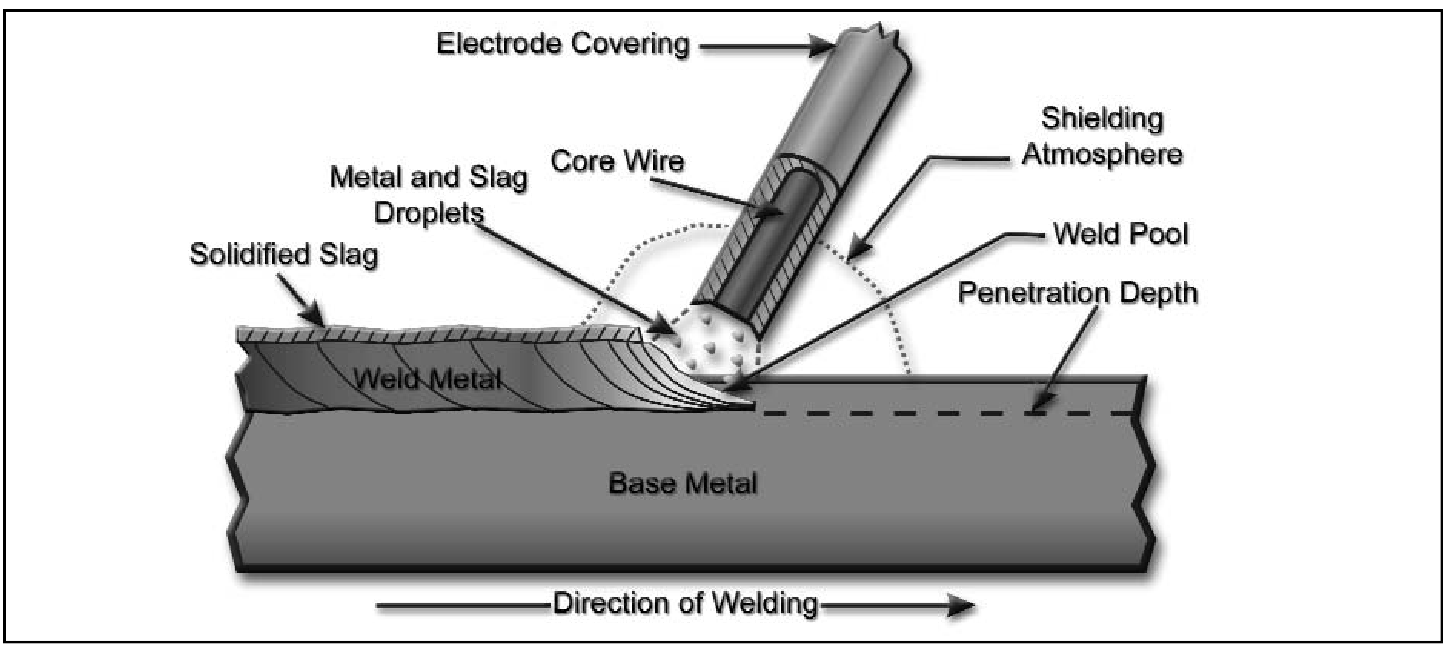
PRINCIPLES OF OPERATION

Shielded Metal Arc welding employs the heat of the arc to melt the base metal and the tip of a consumable covered electrode. The electrode and the work are part of an electric circuit. This circuit begins with the electric power source and includes the welding cables, an electrode holder, a workpiece connection, the workpiece (weldment), and an arc welding electrode. One of the two cables from the power source is attached to the work. The other is attached to the electrode holder.



SMAW System

Welding commences when an electric arc is struck by making contact between the tip of the electrode and the work. The intense heat of the arc melts the tip of the electrode and the surface of the work close to the arc. Tiny globules of molten metal rapidly form on the tip of the electrode, then transfer through the arc stream into the molten weld pool. In this manner, filler metal is deposited as the electrode is progressively consumed. The arc is moved over the work at an appropriate arc length and travel speed, melting and fusing a portion of the base metal and continuously adding filler metal. Since the arc is one of the hottest of the commercial sources of heat [temperatures above 9000° F (5000° C) have been measured at its center], melting of the base metal takes place almost instantaneously upon arc initiation. If welds are made in either the flat or the horizontal position, metal transfer is induced by the force of gravity, gas expansion, electric and electromagnetic forces, and surface tension. For welds in other positions, gravity works against the other forces.



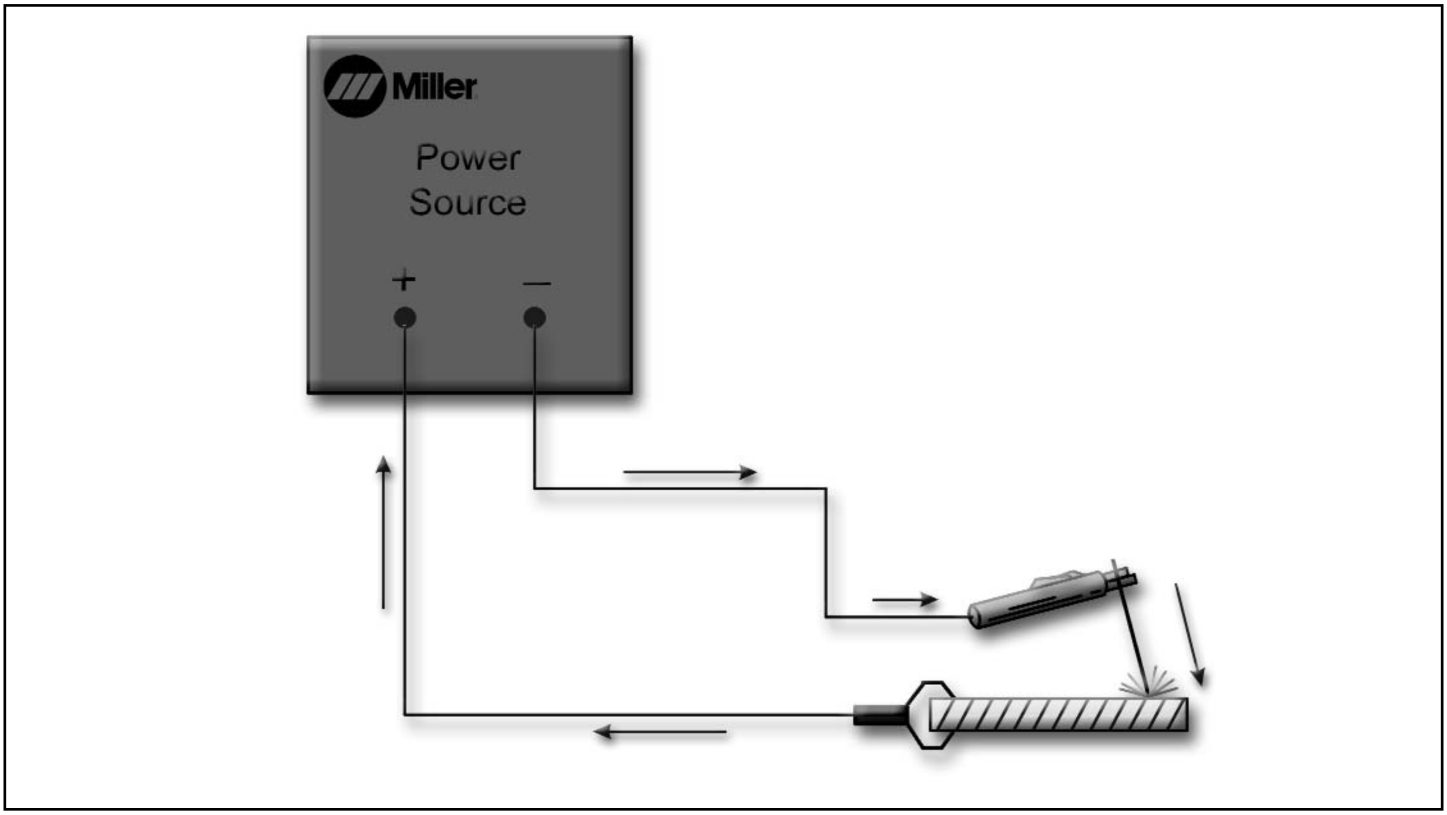
SMAW Welding Arc

The process requires sufficient electric current to melt both the electrode and a proper amount of base metal. It also requires an appropriate gap between the tip of the electrode and the base metal or the molten weld pool. These requirements are necessary to set the stage for coalescence. The sizes and types of electrodes for shielded metal arc welding define the arc voltage requirements (within the overall range of 16 to 40 V) and the amperage requirements (within the overall range of 20 to 550 A). The power source must be able to control the level of current within a reasonable range in order to respond to the complex variables of the welding process itself.

Selecting The Type Of Current

The welding current used for stick welding may be either alternating current or direct current depending on the electrode being used.

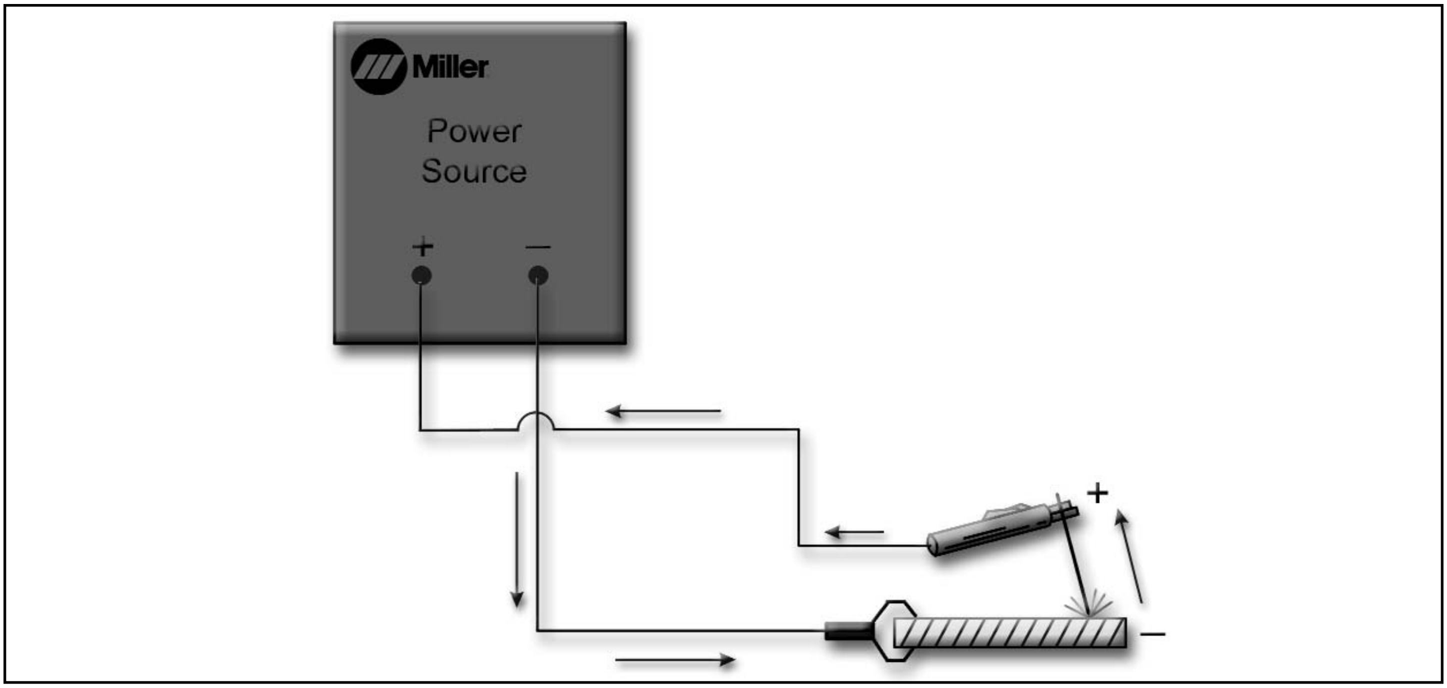
DIRECT CURRENT is the most common current choice for stick welding. The current flows in one direction only and has many advantages over alternating current for the stick process. These advantages include: fewer arc outages, less spatter, easier arc starting, less sticking, and better control in out-of-position welds.



Direct Current Welding Circuit

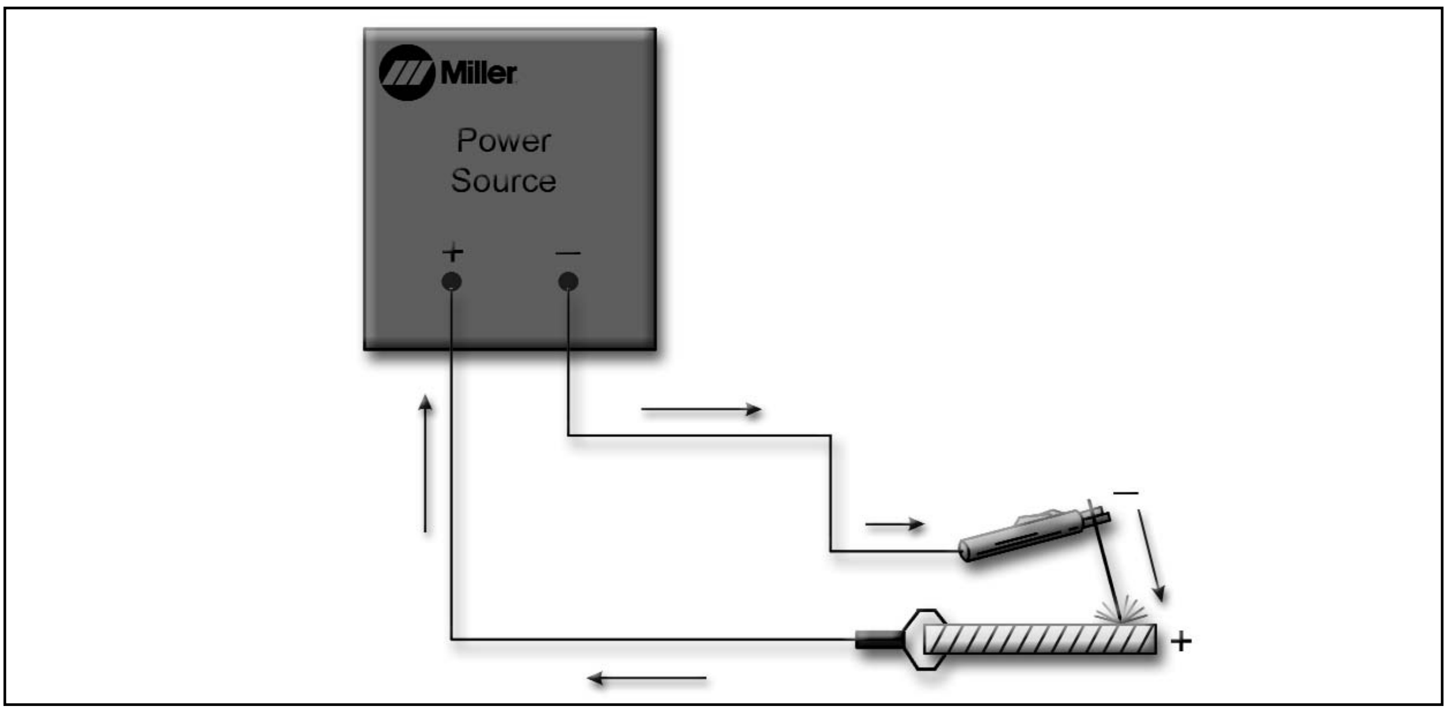
The polarity of the direct current welding arc or the direction of electrical current flow is very important. When the electrode cable is connected to the power sources positive output connection and the work cable is connected to the negative output connection this is a DCEP or Reverse Polarity connection. When the electrode cable is connected to the negative and the work cable is connected to the positive this is a DCEN or Straight Polarity Connection.

For SMAW, the DCEP connection is used most often. It provides for the best penetration and bead profile. For this reason most electodes are made to weld with DCEP.



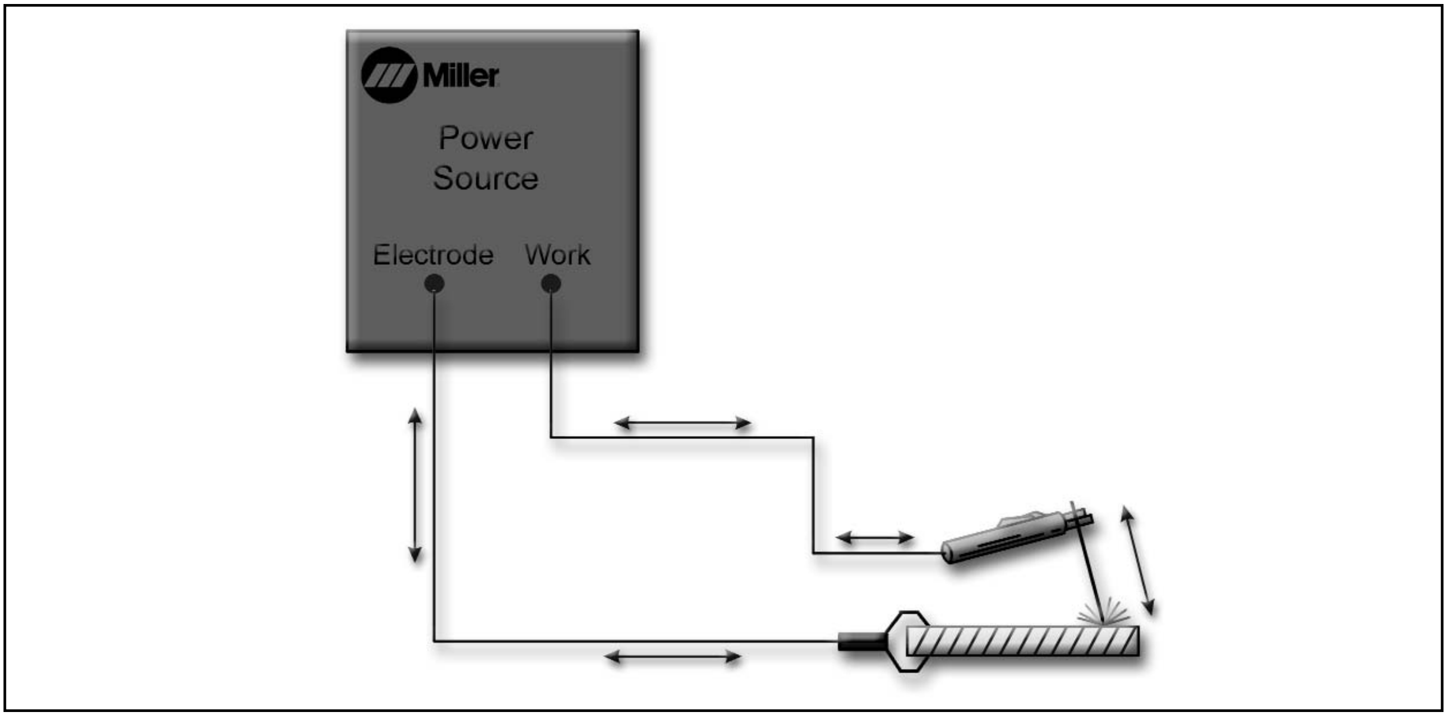
Direct Current Electrode Positive Connection

Using a DCEN connection for SMAW will result in a narrow bead with little penetration. This connection works well when welding on sheet metal or for hardsurfacing electodes.



Direct Current Electrode Negative Connection

ALTERNATING CURRENT (AC) is an electrical current that has both a positive and a negative half-cycle value (polarities) alternately. Current flows in a specific direction for one half-cycle, stops at the "zero" line, then reverses direction of flow the next half-cycle at regular intervals. The AC sine wave represents the current flow as it builds in amount and time in the positive direction and then decreases in value and finally reaches zero. The current then reverses direction and polarity reaching a maximum negative value before rising to the zero value. This alternating repeats as long as the current is flowing.



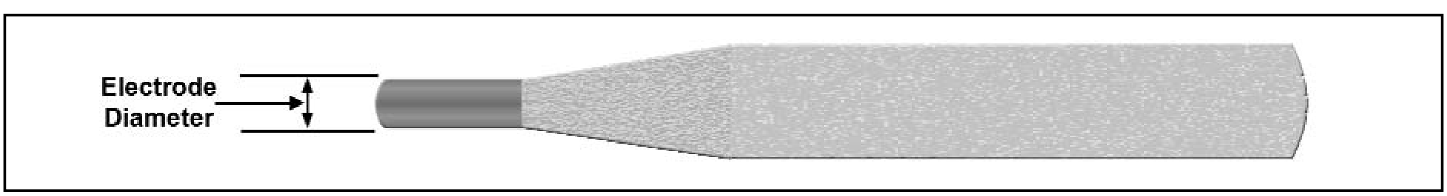
Alternating Current Welding Circuit

An AC only SMAW power source is the most economical type of welding power source available. Because of the alternating characteristic of the current, however, the resulting arc and weld will tend to have more spatter, less penetration, and more arc outages than a weld made with direct current. One situation when alternating current would work better than direct current is if the operator is encountering magnetic arc blow.

MAGNETIC ARC BLOW or ARC BLOW is an arc magnetism phenomena that causes the arc to fluctuate or move in various and erratic directions. Magnets have a north pole (+) and a south pole (-) and it is known that like charges repel and unlike charges attract. This magnetic attraction and repelling occur in some types of direct current welding operations. It is due to the principle that as an electric current moves through a conductor, a magnetic field is created. The strength of this magnetic field will vary with the amount of welding current, position of the electrode on the joint, and size of pieces being welded. This varying arc condition obviously tends toward instability of the arc. It may be responsible for lack of fusion, porosity and an unevenly welded joint. It is normally not experienced in alternating current arc welding.

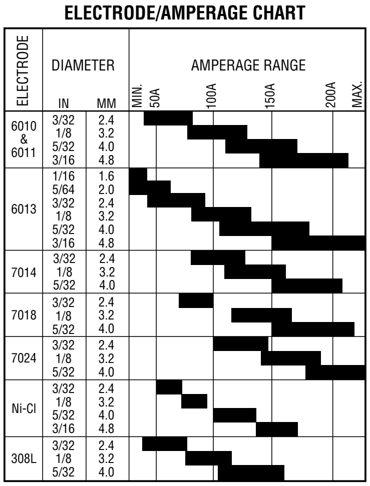
Setting Current

The amount of current needed to weld a part depends on several factors, including: type and position of joint, metal type and thickness, electrode type and diameter. With experience, the operator is able to determine how much current is need for the job at hand. For inexperienced operators there are several ways to establish a starting point for setting current.



One method for determining the amount of amperage needed is to take the diameter of the electrode, which is expressed as a fraction, and convert it to a decimal. That number becomes the starting point for amperage. For example, the decimal equivalent of 1/8” is .125”. The amperage starting point for amperage on a 1/8” electrode would be 125 amps. Because each type of electrode has a different amperage range this method is not very accurate, however, it is a simple way to establish a starting point.

On some power sources there will be a chart that shows the amperage ranges for different diameters and types of electrodes. The illustration below shows one of these charts. This chart may also provide the operator with other information on the electrode such as the type of current the electrode operates on, the positions it can be used in, and the polartiy needed for DC operation.

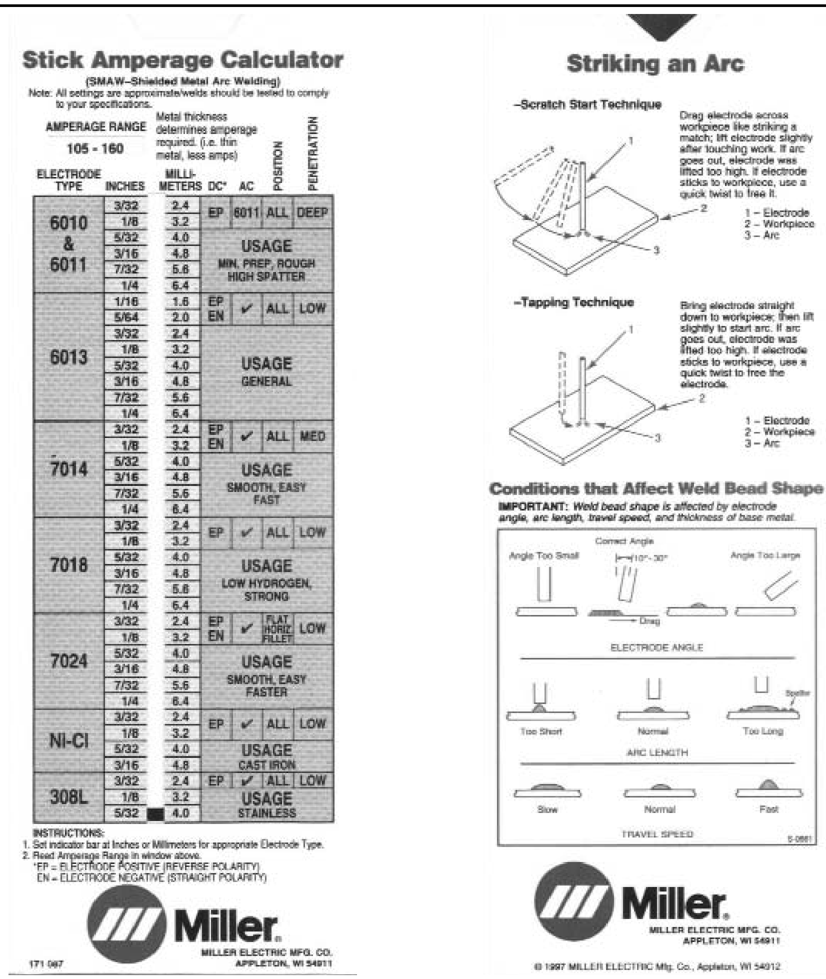


ELECTRODE	DC*	AC	POSITION	PENETRATION	USAGE
6010	EP	—	ALL	DEEP	MIN. PREP, ROUGH, HIGH SPATTER
6011	EP	✓	ALL	DEEP	
6013	EP, EN	✓	ALL	LOW	GENERAL
7014	EP, EN	✓	ALL	MED.	SMOOTH, EASY, FAST
7018	EP	✓	ALL	LOW	LOW HYDROGEN, STRONG
7024	EP, EN	✓	FLAT HORIZ. FILLET	LOW	SMOOTH, EASY, FASTER
Ni-Cl	EP	✓	ALL	LOW	CAST IRON
308L	EP	✓	ALL	LOW	STAINLESS

*EP = ELECTRODE POSITIVE (REVERSE POLARITY)
EN = ELECTRODE NEGATIVE (STRAIGHT POLARITY)

Electrode/Amperage Selector Chart

Another tool for determining the amount of amperage needed is a calculator such as the one shown below. This calculator contains the same type of information as the chart shown above. However, it can be carried with the operator for use on any power source.

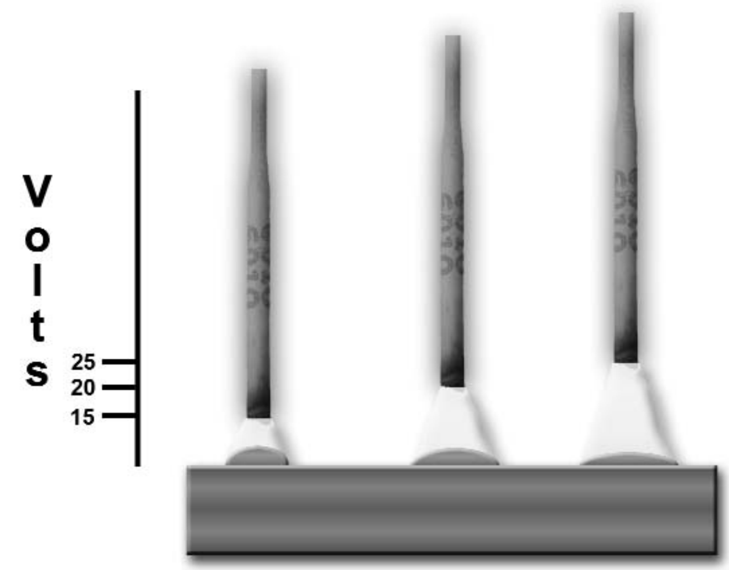


Stick Amperage Calculator

Arc Force (Dig)/Arc Control & Hot Start

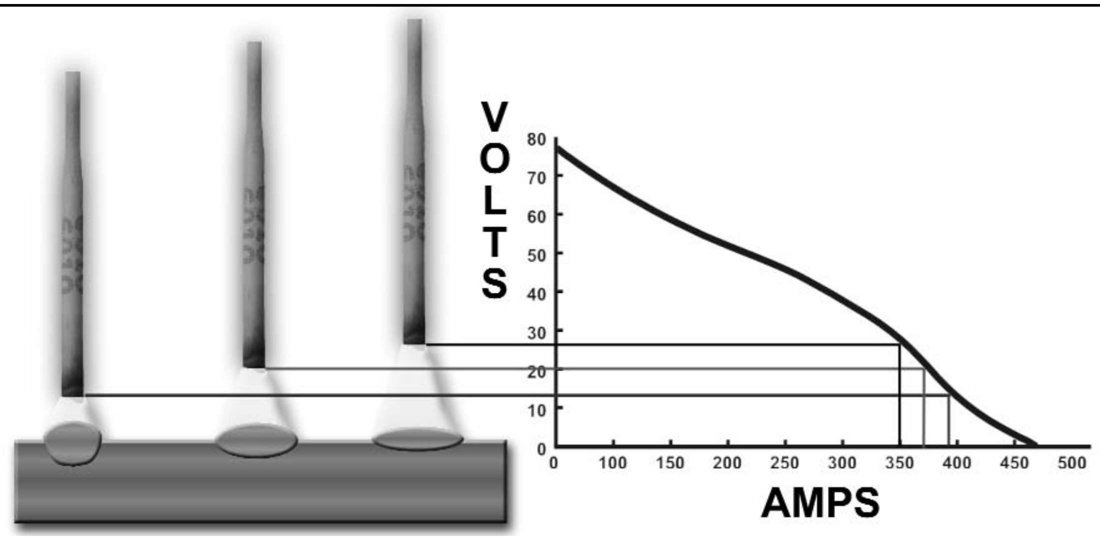
Many of MILLER Electric's power sources that have constant current output are equipped with a feature called Arc Force, Dig or Arc Control, and Hot Start. These features can be a big advantage to the welder who knows what these controls are designed to do.

Arc Force (Dig)/Arc Control-Additional Amperage In A Low Voltage Situation
To understand arc control, you must understand the relationship between arc length and voltage. A basic fact for electric arc welding processes is this: As arc length increases, voltage goes up; and as arc length decreases, voltage goes down. When a welder is using a constant current machine, he or she is controlling load voltage by controlling the arc length. However, as arc length decreases and voltage goes down - such as during arc initiation when the arc length is zero, or during open root welds - there is a tendency for the electrode to stick.



Arc Length-Arc Voltage

Traditional SMAW power sources were designed in such a way that as the operator changed the arc length, the amperage would do the opposite of the voltage. For example, if the operator decreased the arc length, the voltage would decrease and the amperaage would increase. If the operator increased the arc length, the voltage would increase and the amperage would decrease. This characteristic allowed the operator some control of the amount heat going into the workpiece and can be illustrated by looking at the volt/amp curve of the power source.

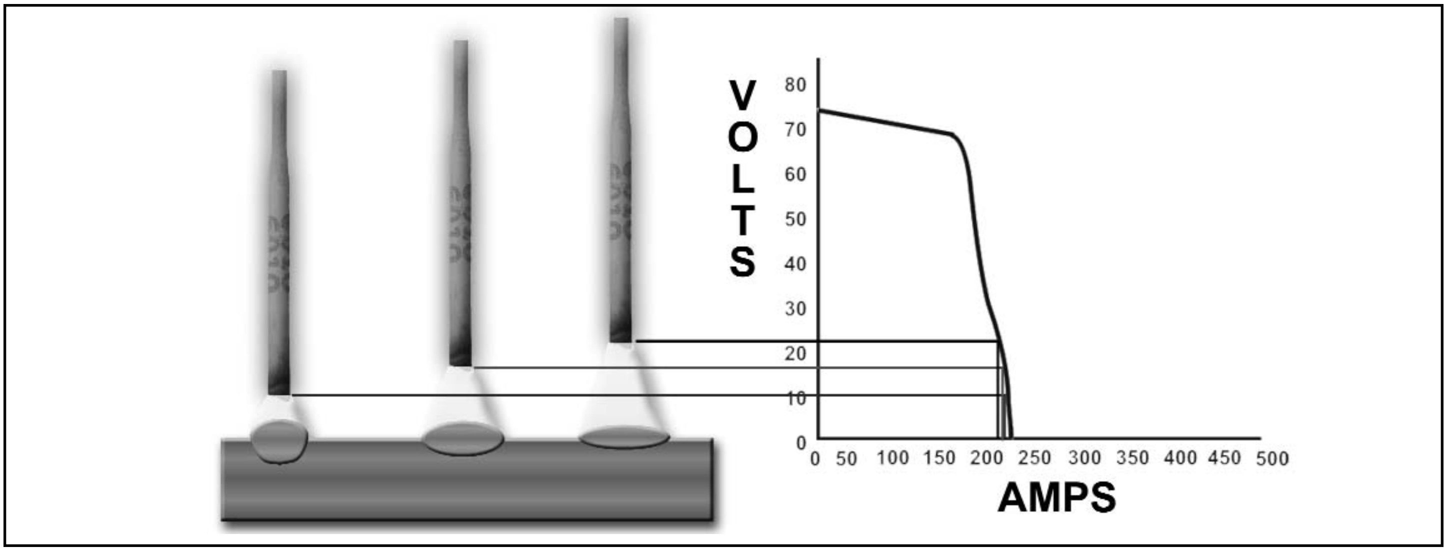


Traditional Welding Power Source

These power sources worked well for stick welding, but were limited with the TIG process because in that process it was best if the amperage did not change as arc length changed.

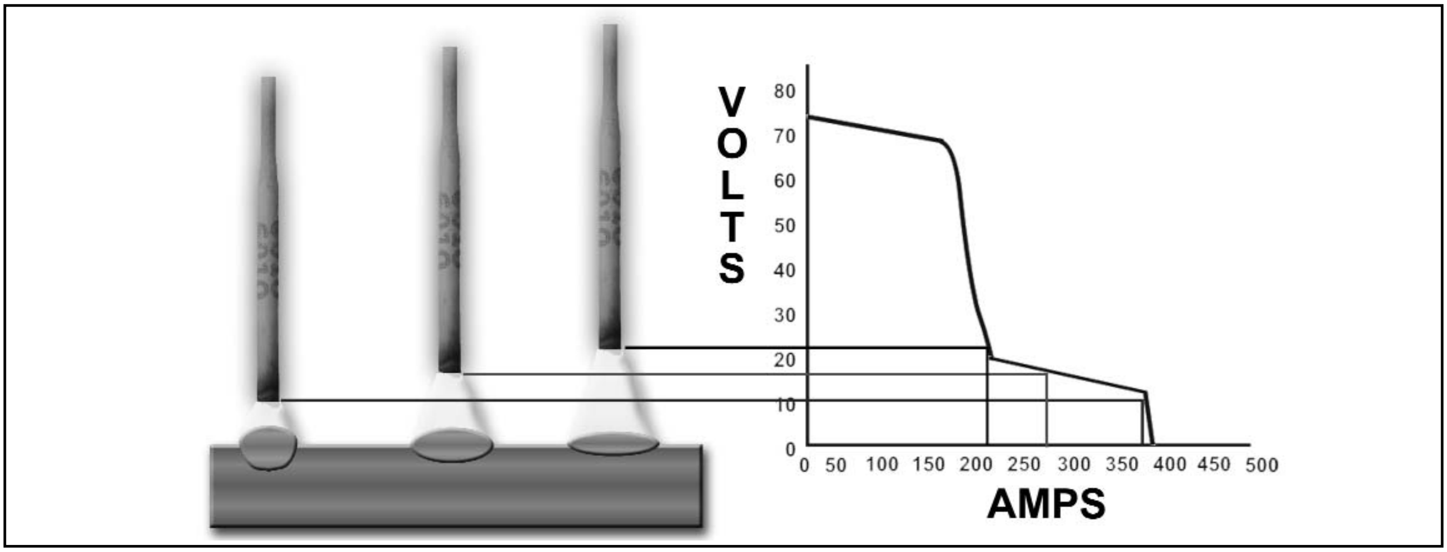
Power sources equipped with Arc Force allow the operator to change the shape of the volt/amp curve to suit the needs of the process being performed.

With no Arc Force added to the circuit, the shape of the volt/amp curve is more vertical meaning that the amperage will not change much as the arc length is changed.



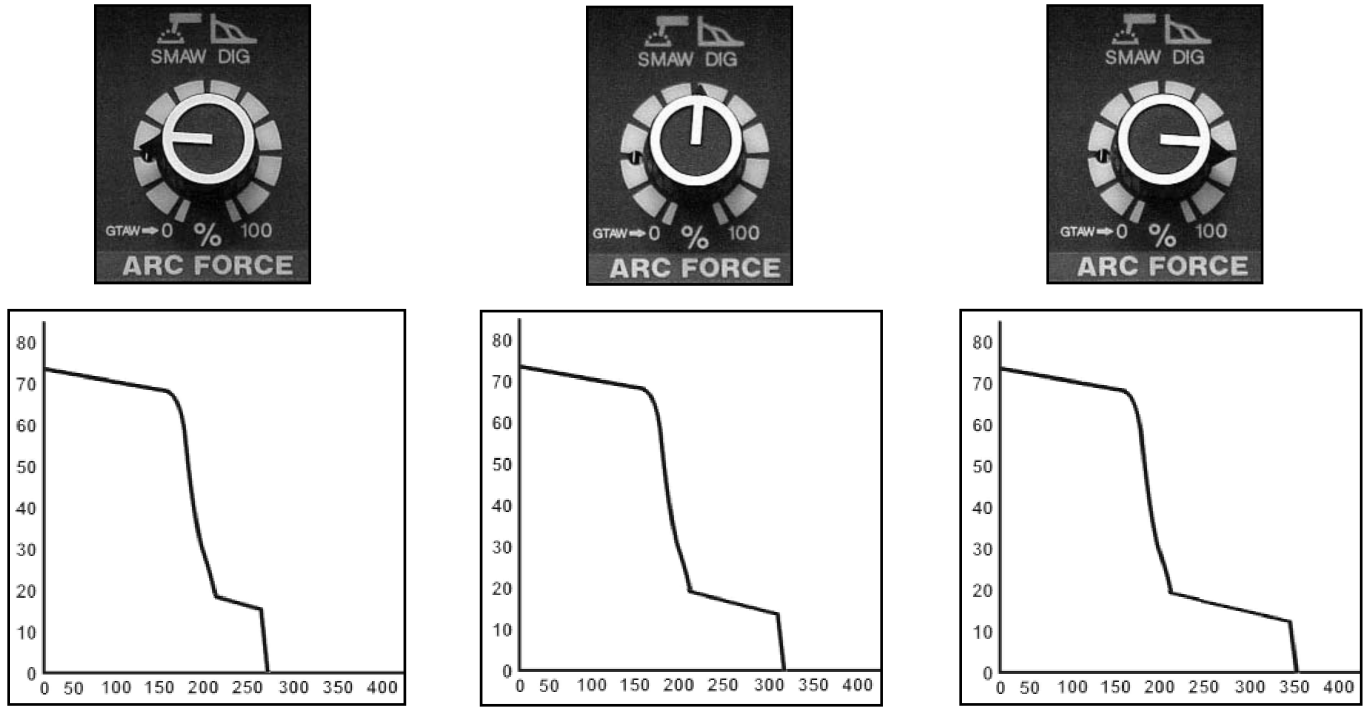
No Arc Force

When arc force is added to the circuit, the power source will deliver more amperage to the arc whenver the load voltage goes below 20 volts.



Arc Force Added To The Circuit

Arc control may be variable - the user may set the level of extra amperage to be supplied. The scale surrounding the arc control knob is used as a reference (it does not reflect actual amperage). As this knob is turned from 0 towards 100, the amount of additional amperage is increased. When arc control is set at 100, maximum additional amps are supplied.



25% Arc Force **50% Arc Force** **75% Arc Force**

Arc Force Adjustments

Each welder will have his or her own ideas on where to set the arc control for different types of electrodes. Some general recommendations are:

- For open root welds on plate or pipe, generally an EXX10 or EXX11 electrode would be selected for the first pass. During the first pass the welder is trying to achieve full penetration. By adding arc control, usually toward the high end of the scale, the welder has the ability to control amperage by arc length. When the operator requires deeper penetration, all that needs to be done is to decrease arc length and the amperage will increase, causing increased penetration.

- For electrodes that are not used for open root welds, the welder should increase arc control to the point where the electrodes don't stick at the start or while welding.

- For carbon arc gouging, setting arc control towards maximum will reduce stubbing.

- When using voltage sensing feeders on CC machines for flux cored wires (FCAW), increasing arc control can provide improved starts.

- For TIG welding (GTAW), the load voltage is typically between 10 to 16 volts with argon shielding gas. Because this level is always below 19 volts, arc control should be set at zero or switched "off." If arc control is set above zero, the arc control would always be "on", and that portion of additional amperage would always be in the circuit. The result would be the same as if the main amperage control were increased.

In summary, arc control (to the level set) only comes into the welding circuit when load voltage is below 19 volts. Arc control can keep electrodes from sticking, can increase penetration, and can eliminate a lot of operator frustration.

Hot Start

When this feature is selected, 70 to 100 additional amps are automatically provided for 1/10 of 1 second at the arc starting. This provides a higher starting amperage than the set amperage value and is in addition to the arc force amperage.

Hot Start is used for Shielded Metal Arc Welding and Air Carbon Arc Cutting/Gouging processes. It may be used for Flux Cored Arc Welding when welding in the constant current mode. It should not be selected when Gas Tungsten Arc Welding.

Consumable Covered Electrodes

The core of the covered electrode consists of either a solid metal rod of drawn or cast material or one fabricated by encasing metal powders in a metallic sheath. The core rod conducts the electric current to the arc and provides filler metal for the joint. The primary functions of the electrode covering are to provide arc stability and to shield the molten metal from the atmosphere with gases created as the coating decomposes from the heat of the arc.

The shielding employed along with other ingredients in the covering and the core wire, largely controls the mechanical properties, chemical composition, and metallurgical structure of the weld metal, as well as the arc characteristics of the electrode. The composition of the electrode covering varies according to the type of electrode.

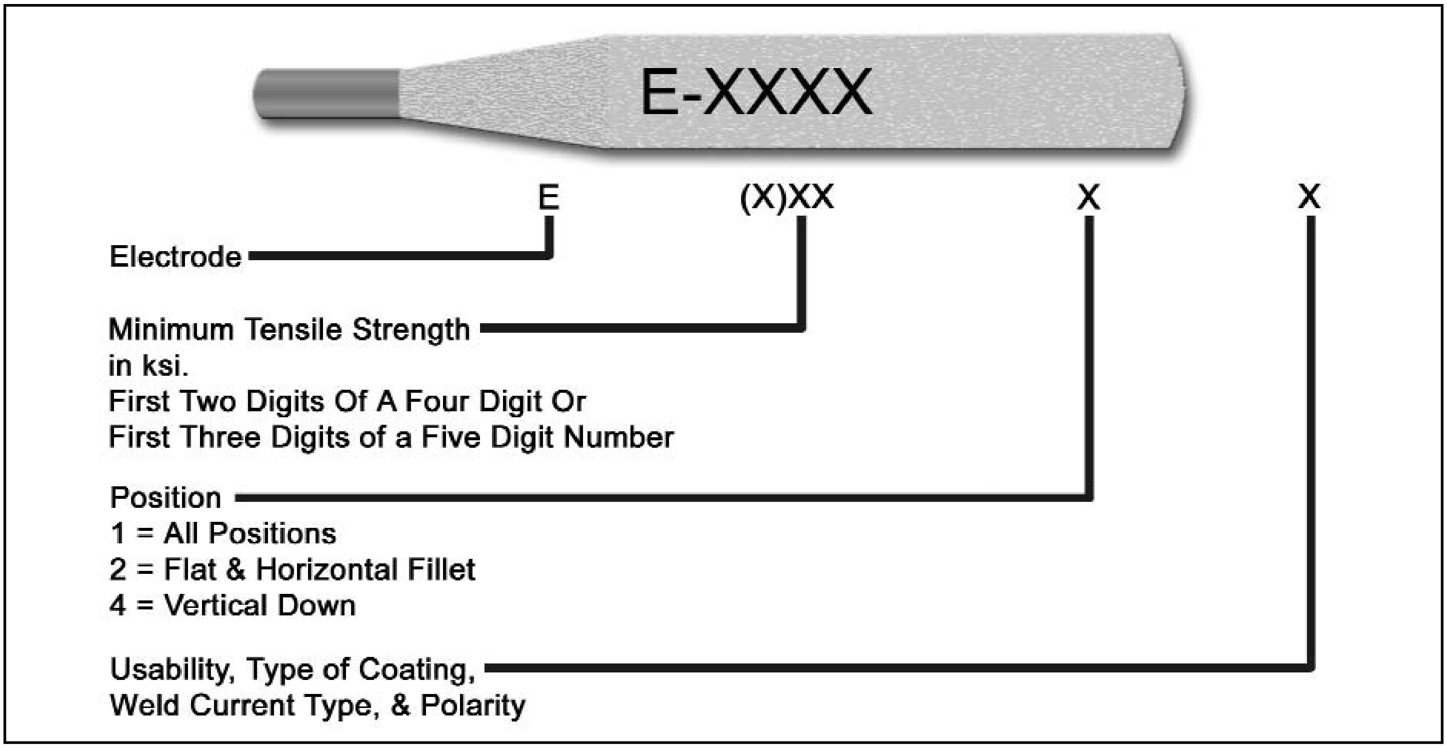
In addition to improving the mechanical properties of the weld metal, electrode coverings can be designed for welding with alternating current (ac). With ac, the welding arc goes out and is restablished each time the current reverses its direction. For good arc stability, it is necessary to have a gas in the arc stream that will remain ionized during each reversal of the current. This ionized gas makes possible the reignition of the arc. Gases that readily ionize are available from a variety of compounds, including those that contain potassium. It is the incorporation of these compounds in the electrode covering that enables the electrode to operate on ac.

To increase the deposition rate, the coverings of some carbon and low alloy steel electrodes contain iron powder. The iron powder is another source of metal available for deposition, in addition to that obtained from the core of the electrode. The presence of iron powder in the covering also makes more efficient use of the arc energy. Metal powders other than iron are frequently used to alter the mechanical properties of the weld metal.

The thick coverings on electrodes with relatively large amounts of iron powder increase the depth of the crucible at the tip of the electrode. This deep crucible helps to contain and direct the heat of the arc and permits the use of the drag technique (described in the next paragraph) to maintain a constant arc length. When iron or other metal powders are added in relatively large amounts, the deposition rate and welding speed usually increase.

Iron powder electrodes with thick coverings reduce the level of skill needed to weld. The tip of the electrode can be dragged along the surface of the work while maintaining a welding arc. For this reason, heavy iron powder electrodes frequently are called drag electrodes. Deposition rates are high, but, because slag solidification is slow, these electrodes are not suitable for out-of-position use.

SMAW electrodes are available to weld carbon and low alloy steels, stainless steels, cast irons, copper, and nickel and their alloys, and for some aluminum applications. Low melting metals, such as lead, tin, and zinc, and their alloys, are not welded with SMAW because the intense heat of the arc is too high for them. SMAW is not suitable for reactive metals such as titanium, zirconium, tantalum, and columbium because the shielding provided is inadequate to prevent oxygen contamination of the weld.



AWS Shielded Metal Arc Covered Electrode Classification System

LAST DIGIT	0	1	2	3	4	5	6	7	8	9
Power source	(a)	AC or DC electrode positive	AC or DC	AC or DC	AC or DC	DC electrode positive	AC or DC electrode positive	AC or DC	AC or DC electrode positive	AC or DC
Type of coating	(b)	Organic	Rutile*	Rutile*	Rutile*	Low Hydrogen	Low Hydrogen	Mineral	Low Hydrogen	Rutile*
Type of arc	Digging	Digging	Medium	Soft	Soft	Medium	Medium	Soft	Medium	Medium
Penetration	(c)	Deep	Medium	Light	Light	Medium	Medium	Medium	Medium	Medium
Iron Powder in Coating	0-10%	None	0-10%	0-10%	30-50%	None	None	50%	30-50%	0-10%

Notes: (a) E-6010 is DC electrode positive; E-6020 is AC or DC
(b) E-6010 is organic, E-6020 is mineral
(c) E-6010 is deep penetration; E-6020 is medium penetration

*A hard titanium dioxide coating.

Interpretation Of Last Digit In AWS Electrode Classification

AWS Class	Type of Coating	Capable of Producing Satisfactory Welds In Positions[a]	Type of Current[b]
E-60 Series — Miniumum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 PSI			
E-6010	High cellulose sodium	F,V,OH,H	DC, Reverse polarity
E-6011	High cellulose potassium	F,V,OH,H	AC or DC, Electrode Positive
E-6012	High titania sodium	F,V,OH,H	AC or DC, Electrode Negative
E-6013	High titania potassium	F,V,OH,H	AC or DC, Either Polarity
E-6019	Iron oxide titania potassium	F,V,OH,H	AC or DC, Either Polarity
E-6020	High iron oxide	H-Fillets, F	AC or DC, Electrode Negative
E-6022[c]	High iron oxide	H-Fillets, F	AC or DC, Either Polarity
E-6027	Iron powder, iron oxide	H-Fillets, F	AC or DC, Electrode Negative
E-70 Series — Minimum Tensile Strength of Deposited Metal in As-Welded Condition 70,000 PSI			
E-7014	Iron powder, titania	F,V,OH,H	AC or DC, Either Polarity
E-7015	Low hydrogen sodium	F,V,OH,H	DC, Electrode Positive
E-7016	Low hydrogen potassium	F,V,OH,H	AC or DC, Electrode Positive
E-7018	Iron powder, low hydrogen	F,V,OH,H	AC or DC, Electrode Positive
E-7024	Iron powder, titania	H-Fillets, F	AC or DC, Either Polarity
E-7027	High iron oxide, iron powder	H-Fillets, F	AC or DC, Electrode Negative
E-7028	Iron powder, low hydrogen	H-Fillets, F	AC or DC, Electrode Positive
E-7048	Low hydrogen potassium, iron powder	F,OH,H,V-down	AC or DC, Electrode Positive

a. The abbreviations are as follows: F–Flat; H–Horizontal; H-Fillets–Horizontal Fillets; V-down–Vertical down; OH–Overhead; V–Vertical (For electrodes 3/16” and under, except 5/32” and under for classifications E-7014, E-7015, E-7016 and E-7018).

b. Electrodes of the E-6022 classification are for single-pass welds only.

Covered electrodes are produced in lengths of 9 to 18 in. (230 to 460 mm). As the arc is first struck, the current flows the entire length of the electrode. The amount of current that can be used, therefore, is limited by the electrical resistance of the core wire. Excessive amperage overheats the electrode and breaks down the flux-covering. This in turn changes the arc characteristics and the shielding that is obtained.

This is because electrodes can be consumed only to some certain minimum length. When that length has been reached, the welder must discard the unconsumed electrode stub and insert a new electrode into the holder. In addition, slag usually must be removed at starts and stops and before depositing a weld bead next to or onto a previously deposited bead.

Because of this limitation, operator duty cycle and overall deposition rates are generally lower than with a continuous electrode process such as Gas Metal Arc Welding (GMAW) or Flux Cored Arc Welding (FCAW).

STRIKING THE SMAW ARC