Welding Process and Filler Metals Training Series:

Welcome to the Welding Process and Filler Metals Training Series. This training series was developed for the purpose of providing a basic set of educational materials that can be used individually or in a classroom setting.

The topics covered in the series are:

Welding Processes

- Topic 1. Introduction To Welding
- Topic 2. Welding Safety
- Topic 3. Basic Electricity For Welding
- Topic 4. Welding Power Source Design
- Topic 5. Engine Driven Power Sources
- Topic 6. Shielded Metal Arc Welding
- Topic 7. Gas Tungsten Arc Welding
- Topic 8. Gas Metal Arc Welding
- Topic 9. Flux Cored Arc Welding
- Topic 10. Metal Cutting
- Topic 11. Troubleshooting Welding Processes
- Topic 12. Submerged Arc Welding

Filler Metals

- Topic A. Introduction To Metals
- Topic B. Tubular Wires
- Topic C. Low Alloy Steel
- Topic D. Stainless Steel
- Topic E. Aluminum
- Topic F. Hard Surfacing

Please note, this series was not developed to teach the skill of welding or cutting, but rather to provide a foundation of general knowledge about the various processes and related topics.

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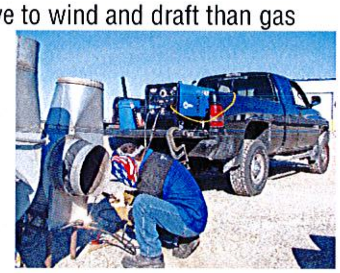
Definition And General Description

Shielded Metal Arc Welding (SMAW) is defined by the American Welding Society (AWS) as an arc welding process with an arc between a covered electrode and the weld pool. The process uses a disposable electrode with a flux coating. As the weld is made the flux burns off to provide shielding for the weld while the electrode provides the filler metal.

Shielded Metal Arc Welding, also called Stick Welding, is one of the most widely used processes, particularly for short welds in production, maintenance and repair work, and for field construction. The process has many advantages:

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



Principles of Operation

Shielded Metal Arc Welding occurs when a constant current,high amperage, low voltage welding power supply generates an electric arc between an electrode and the workpiece. Using a welding power supply that generates a constant current high amperage low voltage welding arc. Figure 1 shows the basic components needed for the welding process:

- Constant current welding power source
- Welding and work cables (electrode and work leads)
- Work clamp
- Electrode holder
- Covered welding electrodes

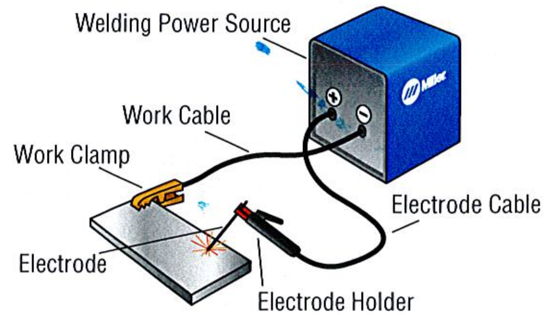


Figure 1 – SMAW System

As illustrated in Figure 2, the arc is generated between the base metal and the core wire that makes up the electrode. This electric arc produces enough heat, about 9000° F (5000° C), to melt both the base metal and electrode forming a weld pool. Small droplets of the core wire melt and transfer to the weld pool providing additional metal to the weld pool. As the electrode covering is heated and melted, it produces gasses that protect the molten puddle from atmospheric contamination. The electrode covering also contains elements that help to stabilize the welding arc, clean the base metal, and provide a protective slag coating that helps form the weld bead as well as protect it from the atmosphere.

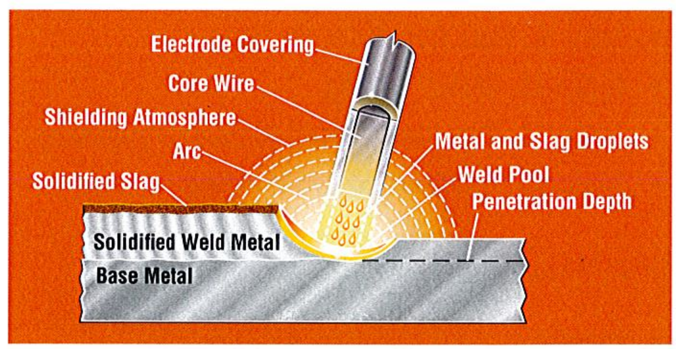


Figure 2 – SMAW Arc

SMAW Equipment

Power Source

There are two types of welding power sources used for the electric arc welding processes: constant current and constant voltage. The Shielded Metal Arc Welding process requires a constant current welding power source. This type of welding power source requires the operator to set welding amperage. The source may be any of the types: transformer, transformer -rectifier, inverter, or engine-driven.

With the many types of power sources available, some criteria are necessary in selecting the right one for the job. One consideration is current type - AC or DC. The light duty power sources found in many small repair shops, on the farm, and around the home, are usually AC machines. They are inexpensive to purchase, very simple to operate, and can usually be operated from residential type electrical service. They provide the necessary power for use with electrodes designed for alternating current.

Figure 3 – An Inverter Welding Power Source

AC power sources are generally used to eliminate arc blow. Arc blow occurs with direct current because of magnetic fields set up by a steady current flow in one direction. Arc blow is most severe when welding in tight fillet corners or box sections. The arc will wander from its intended path and molten metal droplets are expelled as spatter. Arc blow can cause welding defects in the form of undercut and unfilled weld craters, plus excessive spatter. Arc blow is most severe when using large electrodes at high amperages.

Figure 4 – An AC/DC Transformer-Rectifier Welding Power Source

Direct current machines are selected when the application calls for an electrode that operates from direct current. DC is normally preferred for out-of-position work and for use with stainless steel or non-ferrous electrodes. DC is usually preferred for pressure vessels, pipelines, and other critical weldments because of the arc characteristics it provides with the low alloy electrodes frequently used for these applications. Direct current welding power sources offer extra versatility because of polarity selection. Nearly all electrodes can be used with direct current.

In some shops it is desirable to have available both AC and DC power sources. Transformer rectifier-type welding power sources can provide both AC and DC power. The operator can easily select alternating current or direct current from this type of power source.

The duty cycle of the welding power source is another consideration. Analyzing the amperage needs and selecting a power source which will provide the required output within the duty cycle rating is important. A welding power source can be overloaded for a short period of time, but continuous overloading will cause damage to the unit.

Figure 5 – An AC/DC Transformer-Rectifier Engine-Driven Welding Power Source

Physical size can be another issue when selecting a welding power source. Inverter power sources offer exceptional arc characteristics in all processes and are considerably smaller in size than conventional power sources. Inverter power sources are also more electrically efficient than conventional welding power sources.

The primary power available must be considered when selecting a welding power source. Primary power is normally available at 208 volts, 230 volts, 460 volts, or 575 volts. Some welding power sources may operate from only one primary voltage while others can be connected for several primary voltages. AC and AC/DC power sources require single-phase power while DC power sources normally require three-phase primary power. In rural and residential areas, single-phase power is common and three-phase power would require special wiring. Most industrial locations have three-phase power available since it is required by many electric motors and other electrical equipment.

Engine-driven power sources are used on construction sites, mines, cross country pipelines and in remote areas where mobility is a factor and welding utility power is not readily available. Air and liquid-cooled engines are available in gasoline or diesel versions for this type of power source.

Regardless of the type of input voltage, whether they are AC or DC, static equipment or engine-driven, a welding power source has one function: to provide electrical energy at the arc. Amperage demands for welding may vary from a few amperes to over 1000 amperes. Welding power sources are available in many sizes and types to fill the needs of the application.

Welding Current

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

Direct Current

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 SMAC process. These advantages include fewer arc outages, less spatter, easier arc starting, less sticking, and better control in out-of-position welds.

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 positive output connection and the work cable is connected to the negative output connection this is Direct Current Electrode Positive (DCEP).This connection is also referred to as reverse polarity (Figure 6). When the electrode cable is connected to the negative output connection and the work cable is connected to the positive output connection this is Direct Current Electrode Negative (DCEN). This is also referred to as straight polarity (Figure 7).

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

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 hard surfacing electrodes.

Alternating Current

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. This current reversal occurs at regular intervals. The AC sine wave represents the current flow as it builds in amount over time in the positive direction and then decreases in value before reaching zero. The current then reverses direction and polarity, reaching a maximum negative amperage value before returning to the zero value. This alternating repeats as long as the current is flowing.

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.

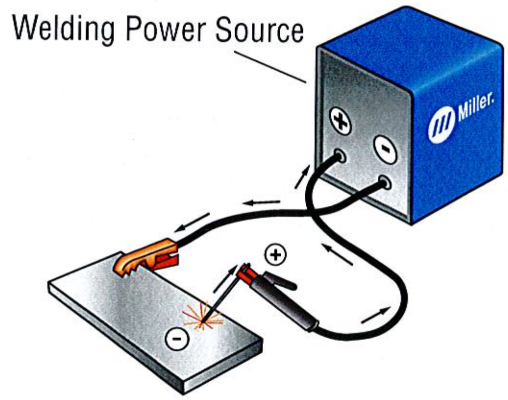


Figure 6 – Direct Current Electrode Positive (DCEP)

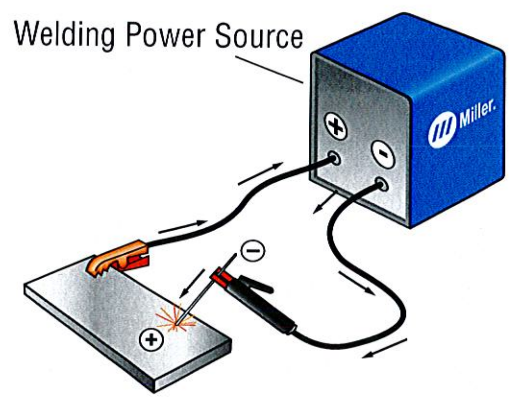


Figure 7 – Direct Current Electrode Negative (DCEN)

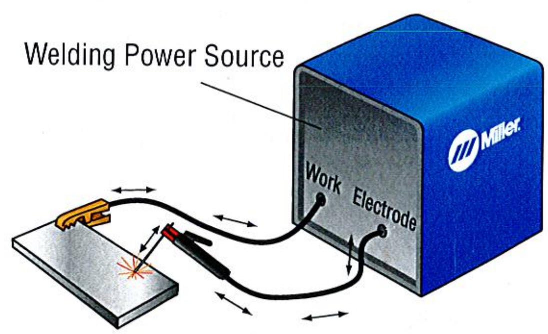


Figure 8 – AC Weld Circuit

Arc Blow

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 occurs in some types of direct current welding operations because 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 creates instability of the arc and it may also be responsible for lack of fusion, porosity, undercut, underfill, and an unevenly welded joint. It is normally not experienced in alternating current arc welding. Methods to eliminate or reduce arc blow include manipulation of the electrode, moving the work clamp location, or using AC weld current.

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, and electrode type and diameter. With experience, the operator is able to determine how much current is needed 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 look at the diameter of the electrode (Figure 9), 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 in. is 0.125 in. The amperage starting point for an 1/8 in 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 general starting point. As with all electrodes, reference to the manufacturers specification sheet is important to be sure that you are using the electrode within its designed and tested parameters.

Figure 9 – SMAW Electrode Core Diameter

On some welding power sources, there will be a chart that shows the amperage ranges for different diameters and types of electrodes. Figure 10 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 polarity needed for DC operation. This chart is also a general guide to establish a starting point for the SMAW electrode.

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	MED	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)

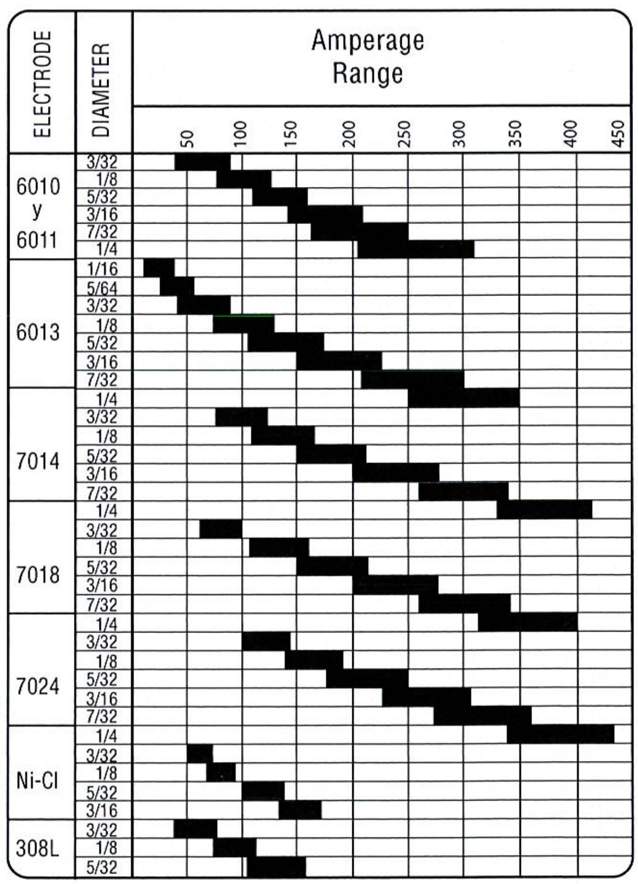


Figure 10 – Electrode/Amperage Selector Chart

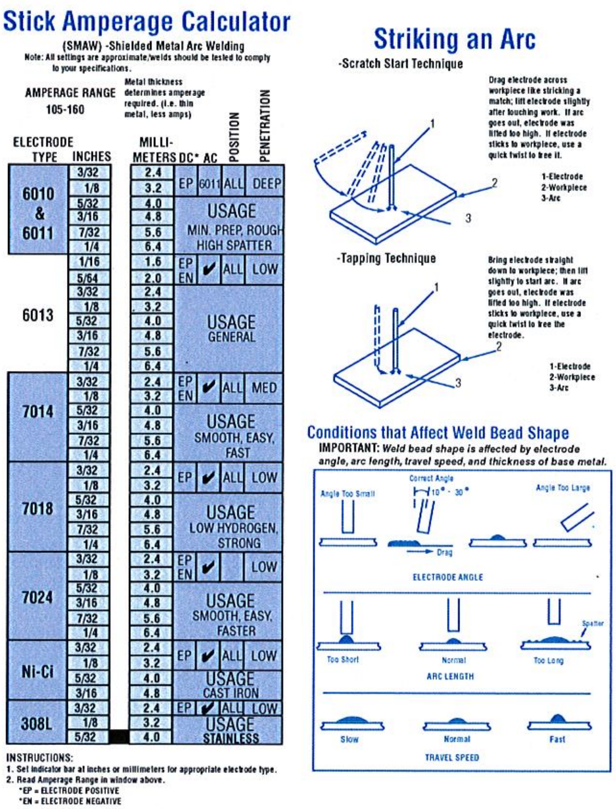


Figure 11 – SMAW Amperage Calculator

Another tool for determining the amount of amperage needed is a calculator such as the one shown Figure 11. This calculator contains the same type of information as the chart shown in Figure 10.

Arc Control, Arc Force, Dig, and Hot Start

Many of Miller Electric's power sources that have constant current output are equipped with an adjustment labeled Arc Force, Dig or Arc Control. Equipment manufacturers over history have used the terms Arc Force, Dig, and Arc Control interchangeably as an output adjustment for the welding power supply. The design of the power supply will dictate the use of each term.

Arc Control

Arc control is a term found on welding power supplies that have both constant current (CC) and a constant voltage (CV) output capabilities. Arc control adjusts Dig during constant current output. Arc control adjusts inductance during the constant voltage output of the welding power supply.

Dig

To understand Dig, 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. Arc length is directly proportional to arc voltage (Figure 12). 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.

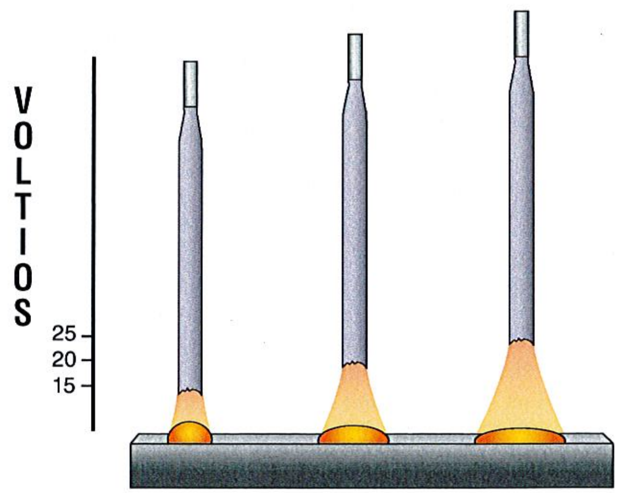


Figure 12 – Arc Length/Voltage

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 amperage 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 over the amount of heat going into the workpiece and is illustrated by the volt/amp curve of the power source (Figure 13).

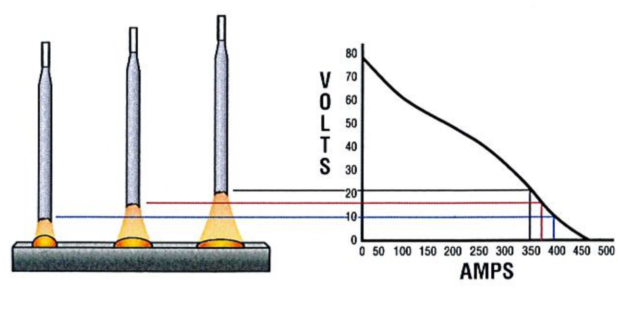


Figure 13 – Traditional Welding Power Source

Without Dig 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 (Figure 14).

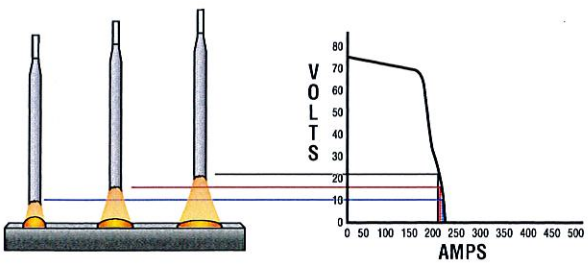


Figure 14 – Without Dig

When Dig is added to the circuit, the power source will deliver more amperage to the arc whenever the load voltage goes below 20 volts (Figure 15).

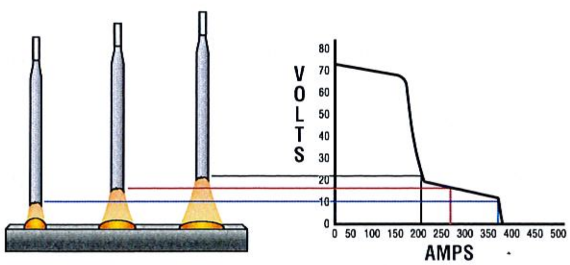


Figure 15 – Dig Added to the Circuit

These welding power sources worked well for SMAC, but were limited with the GTAW process because the GTAW process is best performed if the amperage does not change as arc length changes.

Power sources equipped with Dig allow the operator to change the shape of the volt/amp curve to suit the needs of the application being performed (Figure 16, Figure 17 and Figure 18). Dig 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.

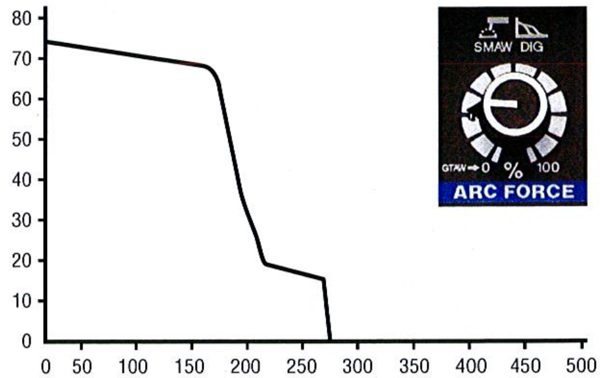


Figure 16 – Volt-Ampere Curve With Dig at 25%

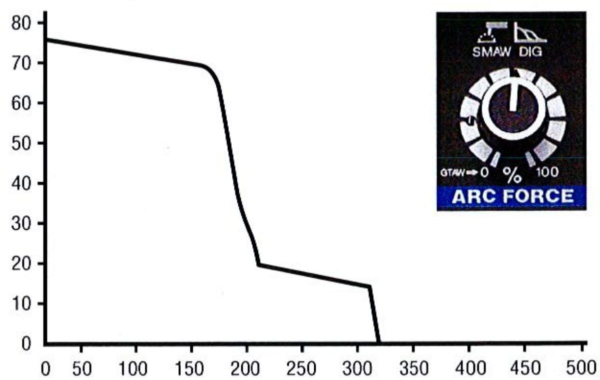


Figure 17 – Volt-Ampere Curve With Dig at 50%

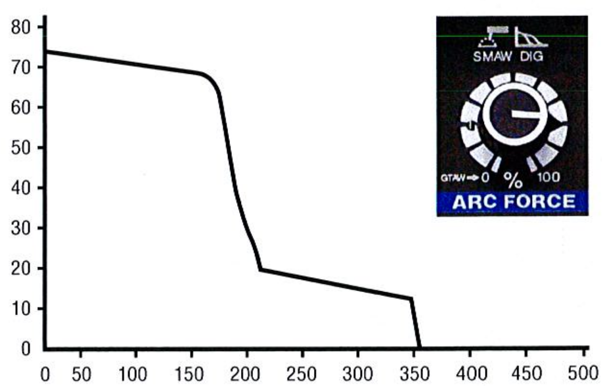


Figure 18 – Volt-Ampere Curve With Dig at 75%

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

- 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 Dig 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 Dig control to the point where the electrodes don't stick at the start or while welding.
- For carbon arc gouging, setting Dig towards maximum will reduce stubbing or arc outages.
- When using voltage sensing wire feeders on CC machines for flux cored wires (FCAW), increasing Dig control can provide improved starts, however, it can also affect the arc length therefore affecting the deposited weld metal chemistry. Using CC for FCAW wires can fall outside of welding code requirements and should be used only in non-critical welding situations.
- 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, Dig should be set at zero or switched "off." If Dig control is set above zero, the Dig 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 or decreased as the actual arc length is changed. Most power supplies today will eliminate this capability when the TIG process is selected.

In summary, Dig control (to the level set) only comes into the welding circuit when load voltage is below 20 volts. Dig can keep electrodes from sticking, can increase penetration, and can eliminate operator frustration.

Arc-Drive™

Arc-Drive™ is a nonadjustable form of Dig found on certain Miller engine drives. Arc-Drive™ automatically enhances the stick welding arc, especially on pipe, by focusing the arc and preventing arc outages (Figure 19 and Figure 20).

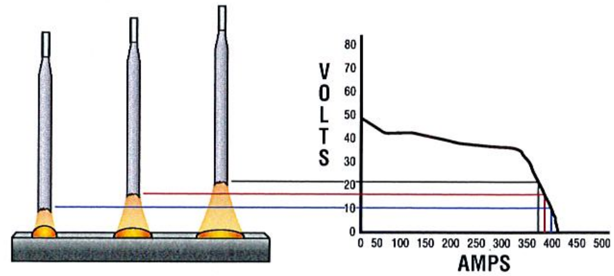


Figure 19 – Without Arc-Drive™

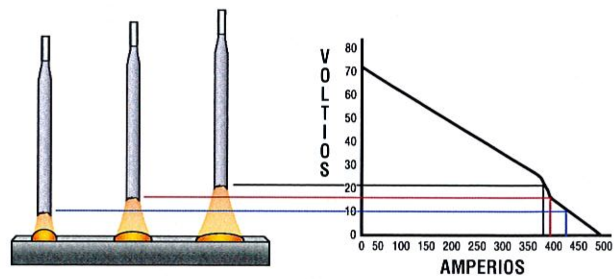


Figure 20 – With Arc-Drive™

Hot Start™

Hot Start™ is a feature that can be activated by the operator when needed. It is typically activated by a switch.

When Hot Start™ is not in use, the amperage for welding will be the same from the start to the end of the weld (Figure 21).

When Hot Start™ is selected, 70 to 100 additional amps are automatically provided for 1/10th second at the start of the weld. This provides a higher starting amperage than the set amperage value and is in addition to the amperage provided by Dig or Arc-Drive™.

Hot Start™ is used for Shielded Metal Arc Welding and Air Carbon Arc Cutting and 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.

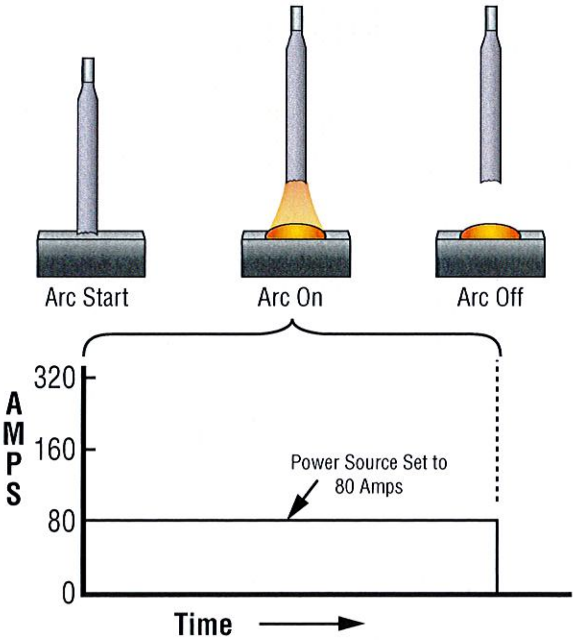


Figure 21 – No Hot Start

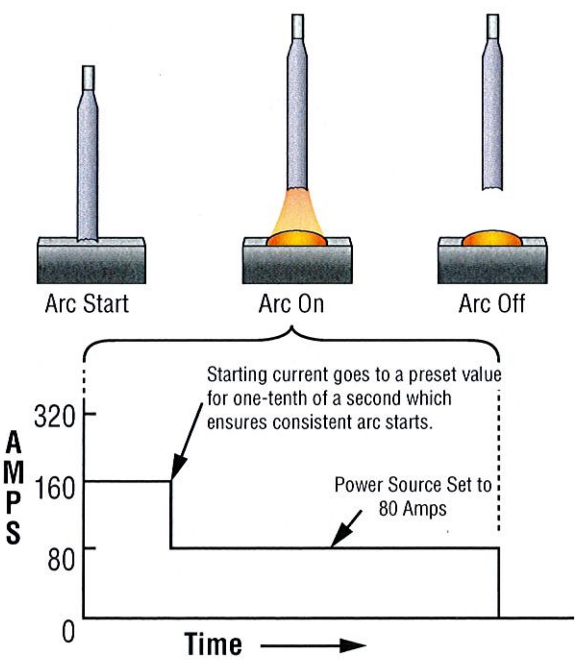


Figure 22 – Hot Start Activated

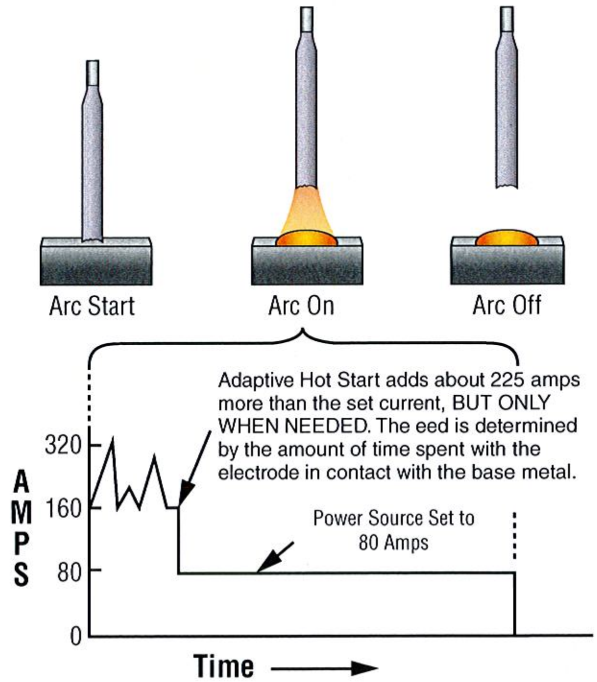


Figure 23 – Adaptive Hot Start

Adaptive Hot Start™

Another form of hot start, called Adaptive Hot Start™, is found on many Miller inverter power sources. Adaptive Hot Start™ automatically increases the output amperage at the start of a weld, should the start require it.

The amount of additional amperage supplied at the start of the arc is based on the amount of time the electrode is in contact with the workpiece. The longer the electrode is in contact with the workpiece the more additional starting amperage is supplied (Figure 23).

Welding Accessories

In addition to the personal protective equipment a welder uses, there are other necessary items of equipment. Each piece of equipment contributes to the overall success an operator has with the arc welding process.

Remote Controls

In some applications the SMAW system may also have a remote amperage control hooked up to the power source. For applications where the welder is working some distance from the power source, these controls allow the operator to adjust the amperage setting from the work site rather than going back to the welding power source.

Typically, the operator sets a maximum amperage setting on the welding power source. This setting becomes the maximum amount available when the remote is turned all the way up. The operator can control the amperage by turning the dial on the remote control.

Figure 24 – Wireless Hand Control

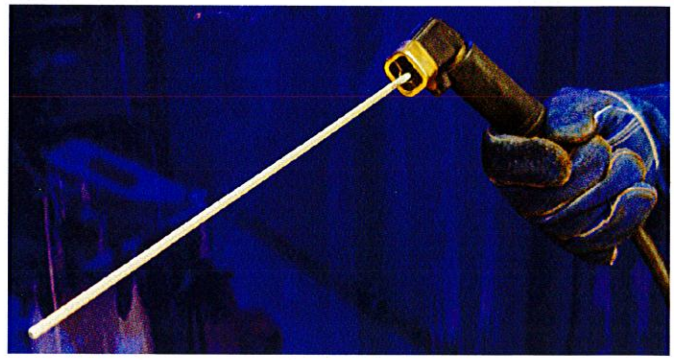


Figure 26 – Bernard Shortstub®/Twist-Type Electrode Holder

The jaws of clamp type electrode holders normally have several grooves which allow the electrode to be positioned at a comfortable angle for welding. The Bernard Shortstub® or twist type holders require the operator to bend the electrode to the desired angle.

Electrode Holder

Part of the basic welding circuit is the electrode holder. It is basically a clamping device for holding the electrode with an insulated handle for the operator to grasp. Figure 25 and Figure 26 show the two main types of electrode holders.

Electrode holders are rated according to their current capacities. Ratings of 150 amps through 600 amps are commonly available. Each electrode holder will accommodate cable sizes appropriate for its rated capacity. The holder should be as light-weight as possible and be well balanced to provide the operator good manipulative control.

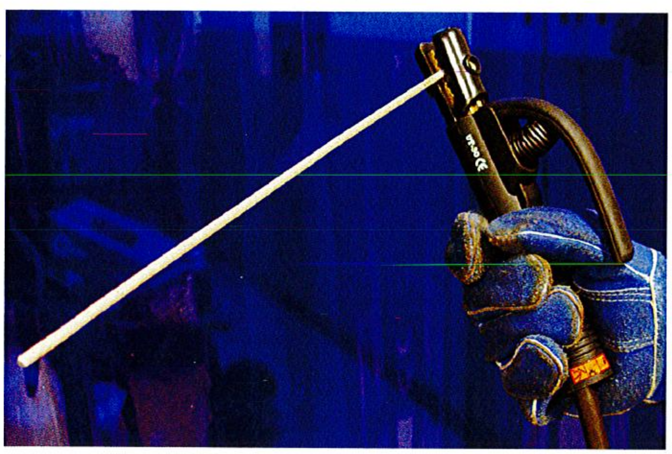


Figure 25 – Clamp Style Electrode Holder

Work Clamps

The work clamp is a fundamental part of the welding circuit. A connection must be made from the work cable to the work. Different types of work clamps are shown in Figure 27. Like the electrode holder, the work clamps are rated in amperage capacity.

Another method of work connection is to secure the cable lug to the workpiece or workbench. The lug can be bolted or securely clamped to the workpiece or table.

Regardless of the method used to make the work connection, it is very important that there is a good firm contact. Many welding problems are related to a poor welding circuit caused by poor contact surfaces or a weakened clamp spring.

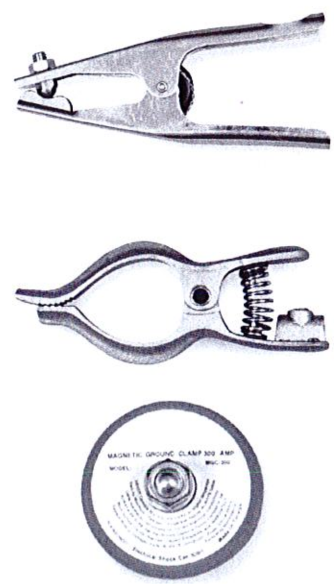


Figure 27 – Various Work Clamp Styles

There is a simple method of checking for a poor circuit. After welding for a period of time, shut off the welding power source and carefully inspect both cables from the power source to the electrode holder and work connection. If a "hot spot" is detected, which is hotter than the rest of the cable, it is probably due to resistance heating in that section. If the hot section is near a mechanical connection such as the power source terminals, electrode holder, or work clamp, you should suspect that a poor connection exists. If the hot spot is in one section of the cable, suspect that some of the strands are broken. If the entire cable is hot, the cable is probably undersized for the current being used.

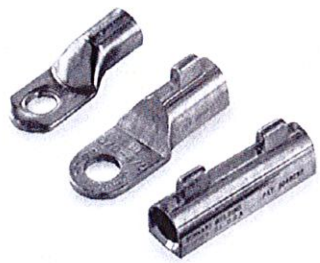


Figure 28 – Lug Connectors

Chipping Hammers and Wire Brushes

The welder needs to remove slag from tack welds and weld beads and clean the material. A chipping hammer and wire brush are essential tools (Figure 29).

Attention given to proper cleaning of the work prior to welding is very important. Rust, scale, paint, coatings, and oily materials should be removed. All of these materials are contaminants and the heat of the arc vaporize them causing gas bubbles. These gas bubbles, if trapped during welding, result in porosity. Once a porous weld is made, the only method of repair is to remove the weld metal completely and deposit another weld bead. Slag from previous welds and tacks must be removed prior to depositing another weld or slag entrapment will result. Trapped slag weakens the weld joint and can lead to weld failure.

Figure 29 – Chipping Hammer, Wire Brush, and a Combination

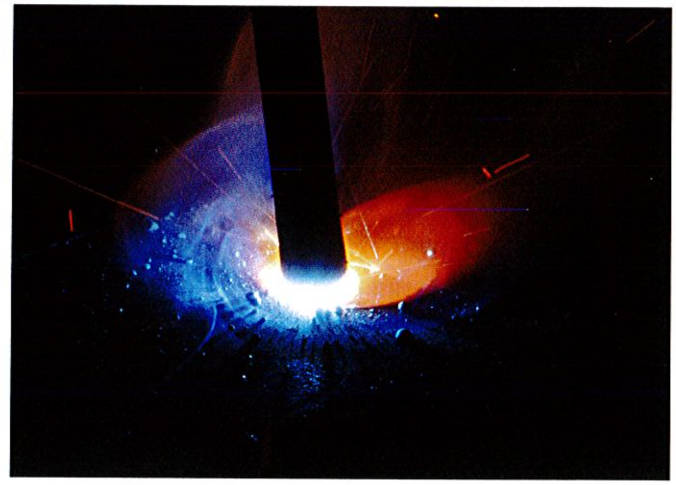


Figure 30 – SMAW Arc

SMAW Electrodes

The electrode is often called a "rod" or "stick," therefore, the term "stick electrode" came into being in everyday shop talk. The correct term is electrode because it is used with an electric arc process. "Rod" means an uncoated or bare filler metal used with the Oxy-Acetylene and Gas Tungsten Arc Welding processes.

A successful welder understands the electrode, its action, selection, and use. There are many types of electrodes made according to standards established by the American Welding Society. All electrodes are labeled in some manner and consist of a metal core wire or rod coated with a baked flux of various materials.

Purpose of Electrode Coatings

The core wire conducts current to the arc from the electrode holder and is melted in arc to become the reinforcing filler metal. The flux serves several functions which can be grouped into four areas:

- Provide an atmospheric shield
- Direct and stabilize the arc
- Provide slag, deoxidizers, and scavengers
- Add elements that affect the deposited weld chemistry

The atmospheric shield prevents contamination of the molten metal. Whenever metal is molten during a welding process it must be protected from the atmosphere (which is largely nitrogen and oxygen). Molten metal, together with these elements, will form oxides and nitrides which result in a brittle weld. Prior to the development of flux coated electrodes, bare rods were used for arc welding. One of the big problems cause by bare rods was brittle weld metal and the associated weld failures. Arc welding received a bad name because of some of the disastrous results of these weld defects. Coated electrodes were developed during the 1920s to overcome this problem and later refined to the state we know them today.

During welding, the core wire burns back inside the flux a short distance providing a "funnel effect" to direct the molten metal and arc toward the workpiece. Certain elements added to the electrode coating serve as "arc stabilizers." Arc stabilizers promote electrical conditions which aid in a steady and smooth current flow.

Elements are also added to the coating to produce a slag blanket over the hot molten metal and the solidified weld metal until it cools. Part of the action in the puddle area is provided by elements added as "scavengers" and "deoxidizers."

These scavengers and deoxidizers mix with undesirable elements in the puddle area and are floated out in the form of slag or are vaporized out because of the intense heat of the arc. The removal of these bad elements refines the grain structure of the weld metal and improves mechanical and chemical properties.

In addition to these three main purposes of fluxes on covered electrodes there are other factors of arc welding operation which may be controlled by the flux on the electrode.

Electrode manufacturers may add alloying elements to the flux to provide certain properties to the weld metal. Also, by changing the ingredients of the flux, different arc features may be provided. For example, some electrodes operate with alternating current, some with direct current, and some work equally well with AC or DC. In some cases, the transfer of molten metal from the electrode to the work is a spray of tiny droplets. In other cases the transfer is in large globules. The molten weld metal from some electrodes will solidify or "freeze" rapidly, while from another electrode the molten puddle will be more liquid and tend to "run" or "sag" when used out of position. All of these features are influenced to a large degree by the ingredients in the coating.

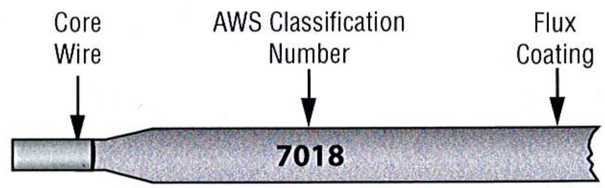


Figure 31 – SMAW Electrode Components

AWS Classification System For Mild Steel SMAW Electrodes

With the large number of electrode types available, some system of classification and identification is necessary. Originally a color code system was developed by the National Electrical Manufacturer's Association (NEMA) and the American Welding Society to identify the electrodes' classification. Some electrodes may still be found with the color marking system. However, since about 1964 the new marking system of imprinting the AWS number on each electrode has been widely used.

The AWS classification system for steel electrodes is based on three main facts about the electrode:

- The as-welded strength of the deposited weld metal
- The position the electrode is designed to be used in while welding
- The type of material used to make the flux coating and operating welding current

Figure 32 shows the chart used to show this information for the most common SMAW electrodes. All mild-steel covered electrodes are classified with a four or five digit number prefixed by the letter "E".

Example: E-7018-1 H4R

The letter "E" stands for coated arc welding electrode.

The next two or three digits, such as "70" in the example, stand for the minimum tensile strength of the deposited weld of the electrode in thousands of pounds per square (psi). This number may be 60, 70, 80, or even as high as 120. In all cases, it still indicates the tensile strength of the electrode.

The third or fourth digit such as "1" in the example, indicates the position of the weld that the electrode was designed to handle. This number is usually a 1 or a 2.

Number 1 =All position, flat, horizontal, vertical and overhead.

Number 2 =Horizontal and flat positions only

E7018-1 H4R

- Electrode
- Tensile in ksi
- Position
- Type of coating and current
- Meets lower temperature impact requirements
- Hydrogen: H4 = less than 4 ml/100 g, H8 = Less than 8 ml/100 g
- Meets requirements of absorbed moisture test

Position

1 Flat, Horizontal, Vertical, Overhead

2 Flat and Horizontal only

Types of Coating & Current

AWS	Digit	Type Of Coating	Welding Current
6010	0	cellulose sodium	DCEP
6011	1	cellulose potassium	AC or DCEP
6022	2	titania sodium	AC or DCEN
6013	3	titania potassium	AC or DCEP or DCEN
7014	4	iron powder titania	AC or DCEP or DCEN
7018	8	iron powder low hydrogen	AC or DCEP

DCEP-Direct Current Electrode Positive
DCEN-Direct Current Electrode Negative
AC-Alternating Current

Figure 32 – AWS SMAW Steel Electrode Classification System

Figure 33 shows how the different positions are defined by the AWS.

The fourth or last number, such as "8" in the example, stands for type of coating and welding current used with the electrode.

Additional designations may be used such as the "-1" to indicate that the electrode meets low temperature impact requirements. This designation becomes important for critical welding on items like boilers or ships.

The "H4" designation provides an indication of the hydrogen content of the electrode. Again, this becomes important for critical welds. Lastly, the "R" designation indicates that the electrode meets AWS requirements established to indicate how the electrode will absorb moisture.

Electrode Selection- Basic Considerations

Each type of electrode is intended for certain applications. With many choices available the welding operator may ask "How do I know which electrode to use?" There are several points to be considered in selecting an electrode for mild and low alloy steels. Most importunately, the manufacturers specification sheet for each filler metal should be referenced before starting any job and to ensure the filler metal is used within the designed operating parameters. The following factors must be considered.

Base Metal: It is essential that the mechanical properties of the base metal be known. The tensile strength and ductility are very important in making a selection. For Example: If the base metal has a tensile strength of 55,000 psi, then an electrode with a tensile strength at least matching that of the base metal must be used to develop the full strength of the joint. Any E-60xx class electrode would be a likely match to meet this physical requirement.

The chemical make-up of the base metal will also have an effect on selection, particularly if the base metal is in the low alloy classification. Low alloy steels are normally considered to be those steels which have small amounts of a variety of alloy elements added to impart special properties but the total alloy content is less than 2-3% for any one of these elements. The suffix of the electrode classification number should be referred to in order that a match between base metal alloy and electrode alloy can be obtained. The manufacturers documentation should be referenced when making such a selection.

Welding Position: Electrodes are designed to be used in different welding positions. For practical purposes, four basic welding positions are encountered: flat, horizontal, vertical and overhead. The electrode identification number will tell in which welding position the electrode can be used. The skill of the operator also affects how well an electrode works in any welding position, particularly in the more difficult vertical and overhead positions.

1 = Flat, Horizontal, Vertical, and Overhead.
2 = Flat and Horizontal only.

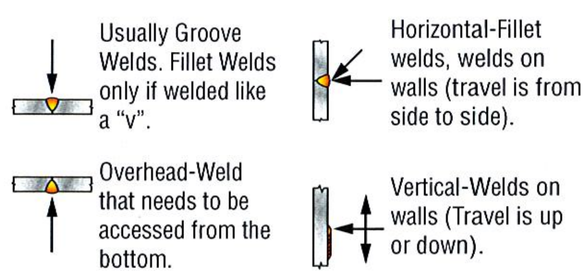


Figure 33 – Welding Positions

Miller

Welding Current: An electrode is designed to operate best with a given type of current. There are three choices of current types available: alternating current (AC), direct current electrode negative (DCEN), or direct current electrode positive (DCEP). Some electrodes will operate satisfactorily on only one current type, while others can be used with any current type. Select an electrode which is right for the type of power source available.

Use of Welded Product: What type of service conditions will the part be subjected to in use? If the weldment is subjected to extreme heat, high pressure, extreme cold, sudden shock, or loading, a filler metal which has the necessary mechanical properties must be selected. Information from the electrode manufacturer will give information about the electrode's suitability for a given service condition.

Codes and Specifications: Weld quality on critical parts has to be of the highest degree possible. Because of the disastrous results which would occur if a critical weldment failed. For example, on jet aircraft, high pressure pipelines, or a cryogenic container, every effort is made to ensure that proper welding procedures are used. The procedure specifies the type of filler metal to very rigid specifications; exact chemical analysis may be specified and records kept on heat and batch numbers of the electrodes.

Joint Design and Fit-Up: Electrodes have different arc characteristics. Some produce a digging, deep-penetrating arc. Other electrodes provide medium penetration and others provide a very light-penetrating soft arc. An electrode giving a deep penetrating arc is best suited for tight fitting joints and heavier material. The opposite situation would be light gauge material and/or poor fit-up where a soft arc would best bridge the gap and prevent too much penetration.

Complexity of Shape and Thickness: Weldments with complex design patterns and varying metal thicknesses must be given special consideration. Because of their complex shape, weld stresses set up during welding and cooling may be severe. To avoid weld cracking, an electrode with maximum ductility should be used. The low hydrogen types are usually selected for these applications.

Production Requirements: The speed of welding and the rate of metal deposition in pounds per hour are sometimes very important. The iron powder-type electrodes provide the highest deposition rates and travel speeds. There are limits on the position in which these electrodes can be used. Other welding conditions will also influence the selection. In some applications the rate of metal deposition may not matter as sometime you can only weld so fast before other problems occur.

The Hydrogen Problem: When low alloy steels and higher tensile strength steels are arc welded, thought must be given to the type of electrode used. One of the major problems with these materials develops because of the presence of hydrogen in the weld area. In the very high temperature of the welding arc, any hydrogen created by the electrode coating may be released. Any moisture picked up by the coating can cause hydrogen to be released. It can be absorbed by the molten metal while hot, but upon cooling the metal's ability to dissolve and hold the hydrogen is greatly reduced.

As the metal solidifies, the gas is forced out into an area where it builds up pressure and causes a crack. The area that normally solidifies last is where the hydrogen collects. Weld metal freezes like an ice cube freezes. That is, the center freezes last. This means that the crack is inside and usually not seen from the surface. This kind of cracking is termed "underbead cracking." The cure is to keep as much hydrogen away from the weld area as possible.

To do this, an electrode must be used that has a coating made of elements that do not form hydrogen. Electrodes with low hydrogen coatings are those with AWS classifications of E-xx15, E-xx16, and E-xx18. In addition, the electrode must be free of moisture from the atmosphere since this is a direct source of hydrogen. For this reason, the electrodes must be properly stored to prevent moisture absorption from the atmosphere.

Storage and Reconditioning of Electrodes

The quality of welds produced by the SMAW process is dependant on the condition of the electrodes used to produce the welds. Therefore, it is important to understand the proper care and storage of the various types of electrodes.

Mild steel and low alloy electrodes may be divided into two groups with regard to care and storage. The first group is made up of electrodes of AWS class E-xx10, E-xxll, E-xxl2, E-xxl3, E-xxl4 and E-xx24 and electrodes where the hydrogen content of the coating is not a major concern. The second group is comprised of electrodes of AWS class E-xxl5, E-xxl6, and E-xxl8; this is the low hydrogen group where hydrogen content is a very important factor in electrode operation and weld quality.

The care and storage of electrodes in the first group is simple. Electrodes are manufactured and packed in various types of containers. The containers may be sealed waterproof tin cans, cardboard waterproofed boxes, or plastic boxes. The storage of unopened containers is the same. They must be stored in a dry area. The area must afford protection against rain or snow and the containers should not be allowed to become wet. After the containers are opened, more care must be exercised to ensure the electrodes are protected from excessive moisture damage.

Damaged cartons permit entry of damp air which may be absorbed by the product and lower its quality. Humidity below 50% should be avoided for XX10, XX11, XX12, and XX13 covered electrodes. At no time should these classes of electrodes be stored in an oven above 130° F (54° C).

Electrodes which have been water damaged tend to be explosive in arc action, and it is not uncommon to see large pieces of flux coating strip off of the electrode and fly into the weld pool while welding. The explosive action plus the loss of flux coating means that the shielding properties of the electrode are being lost during the welding operation. This loss will be reflected by spatter, pin holes, and in some cases, brittle welds. However, this does not mean that these electrodes must be kept in a drying oven. In fact, excessive dryness can be detrimental to the overall arc action of this group of electrodes. Normal atmospheric moisture absorption is permissible with this group.

Figure 34 – Stationary Electrode Storage Oven

Electrodes that fall into group two (low hydrogen) require more careful attention to their storage. Low-hydrogen electrodes should be received from the manufacturer in sealed tin cans. Electrodes received in this type of container may be used "as is" upon opening the can. Once the container is opened the electrodes must be stored in a drying oven at 250° to 300° F (121° to 149° C) to maintain the as-manufactured dryness of the electrodes.

Moisture picked up from the atmosphere can ruin the low hydrogen characteristics as quickly as 30 minutes. The low-hydrogen electrode that has absorbed moisture, either directly from rain or snow, or through atmospheric absorption is no longer usable as a low-hydrogen electrode. The use of a wet low-hydrogen electrode will cause a wild unstable arc, surface pin holes, and underbead cracking. In other words, a welding failure.

Low-hydrogen electrodes that accidently become wet by over-exposure to the atmosphere may be reconditioned to a usable state by rebake. Rebake a low-hydrogen electrode by placing the electrode in a drying oven and maintaining a temperature in excess of 700° F (371° C) for at least one hour. Specific time and temperatures for rebake will depend upon the type of electrode, moisture content, and weld quality involved. Sometimes the welding code being used will specify the rebake time and holding temperature to reclaim wet electrodes. Manufacturers of electrode drying ovens also provide recommendations for electrode drying and storage.

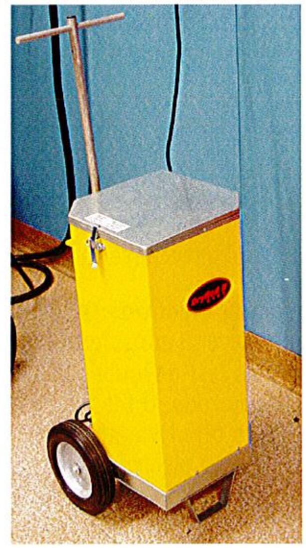


Figure 35 – Portable Electrode Storage Oven

Figure 36 shows the recommended storage conditions, time, and temperature for reconditioning electrodes that have absorbed excessive moisture or have been exposed to the atmosphere for longer than permitted by welding code.

The instruction, "Dry at Room Temperature" in the table signifies that the humidity should be below 70% and the temperature should be within the limits of 40° to 120° F (4° to 49° C).

Over reconditioning can be as damaging as excessive moisture. Low-hydrogen electrodes should not be reconditioned more than one or two times because reconditioning causes a higher moisture absorption rate. The welding code that may be required for a job will also specify the allowable reconditioning of electrodes.

Oven Storage And Reconditioning Of Stick Electrodes

Welding electrodes may be damaged by atmospheric moisture. The following table recommends proper storage conditions, and time and temperature for reconditioning electrodes that have absorbed excess moisture.

Notes for table: Pallets and unopened cartons of electrodes should be stored away from exposure to water in the form of rain, snow, spray, or humidity. Only hermetically sealed cans are safe against these conditions. Damaged cartons permit entry of damp air which may be picked up by the product and lower its quality. Humidity below 50% should be avoided for 6010, 6011, 6012 and 6013 electrodes. At no time should these classes of electrodes be stored in an oven above 130°F.

The instruction, "Dry at Room Temperature" in the table signifies that the humidity should be below 70% and the temperature should be within the limits 40°F to 120°F.

Item Designation	Storage of Contents of Open Cartons*	Reconditioning*
Mild Steel – 6010, 6011	Dry at room temperature	Not recommended
Mild Steel – 6013, 6022, 7014, 7024	100°F - 130°F	250°F - 300°F, 1 hr.
Mild Steel Low Alloy – 7010, 8010, 9010	Dry at room temperature	Not recommended
Mild Steel, Low Alloy, Low Hydrogen – 7018, 8018, 9015, 9018, 10018, 9010 11018, 12018	250°F - 300°F	500°F - 800°F, 102 hrs.
Stainless Steel Stick Electrodes DC Lime (AWS-15) Sterling AP & AC/DC (AWS-16) Smootharc Plus (AWS-16) Sterling (AWS-17)	225°F - 260°F	500°F - 600°F, 1 hr.
Hardalloy® Surfacing	225°F - 260°F	450°F - 600°F, 1 hr.
Special Maintenance GP	225°F - 260°F	500°F, 1 hr.
Cast Iron Electrodes	215°F - 230°F	250°F - 300°F, 1 hr.

* Remove any packaging that may be damaged from oven storage or reconditioning.

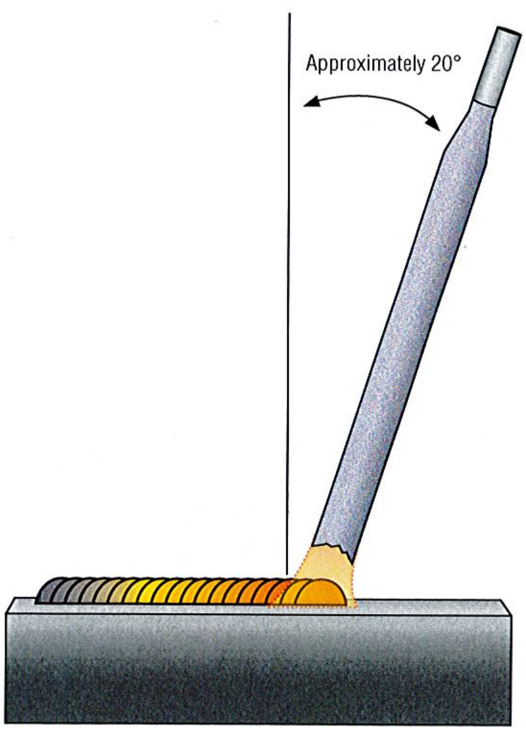
Figure 36 – Storage and Reconditioning of Electrodes

Essentials of Good Welding Technique

Even with the finest equipment available, a few basic essentials must be followed in order to obtain proper weld quality. These essentials are variables a welder must be aware of to control weld quality. These are called variables since they are constantly being changed or altered to suit a specific need. A "rule of thumb" can be applied to each as a starting point in learning control over these variables.

Correct Electrode: When selecting an electrode for a specific job, several considerations are necessary. The previous section of this text describes the items of consideration when selecting an electrode. If the wrong electrode is used, even careful attention to other variables will probably not produce a high quality weld. The electrode must be compatible with the material to be welded and the technique being used.

Correct Electrode Angles: The angle that an electrode is held will vary with different types of joints. Figure 37 shows the two angles that an operator needs to maintain when welding with a SMAW electrode. Simply stated, work angle is the angle of the electrode in relation to the weld joint; travel angle is related to the direction of welding. For example, a common work angle for a fillet weld is shown in Figure 39.



Front View-Travel Angle

Figure 37 – Travel Angles

Correct Arc Length: As a "rule of thumb" the arc length should be about equal to the electrode diameter. Some applications will require a shorter or tighter arc length while a slightly longer arc is required on other applications. If the arc length is too short, arc voltage will be low and the electrode may freeze to the work. If arc length is too long, arc voltage will be high and excessive spatter can result. A long arc length will also cause poor control of the arc as well as porosity (due to a loss of available shielding gas; Figure 38).

Correct Travel Speed: Travel speed is the rate of progression along the joint. Generally, stringer beads produce about one inch of weld for each inch of electrode consumed. A 14 in. electrode will produce about 12 inches of weld if a 2 in. stub is discarded. When the electrode is weaved or a large fillet weld is made, less linear weld is produced.

The shape of the weld ripples and the bead width are good indications of correct travel speed. A bead approximately 1-1/2 times the diameter of the electrode, which shows half moon-shaped ripples, indicates a correct travel speed. A narrow bead with teardrop-shaped ripples indicates a fast travel speed while an excessively wide and tall bead indicates a slow travel speed.

Correct Current: Amperage must be adjusted properly for a given size electrode in order to produce a bead of the proper size, and to ensure that the elements in the electrode coating that contribute to the weld's integrity are properly melted. Depending upon joint design and material thickness, amperage may vary slightly.

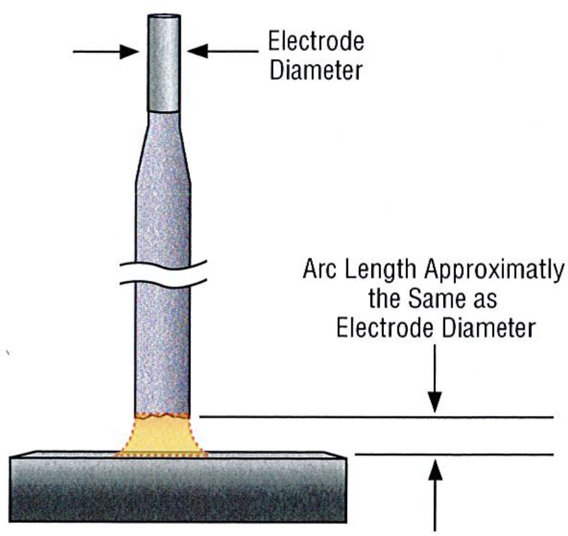


Figure 38 – Arc Length

Work Angles for Fillet Welds

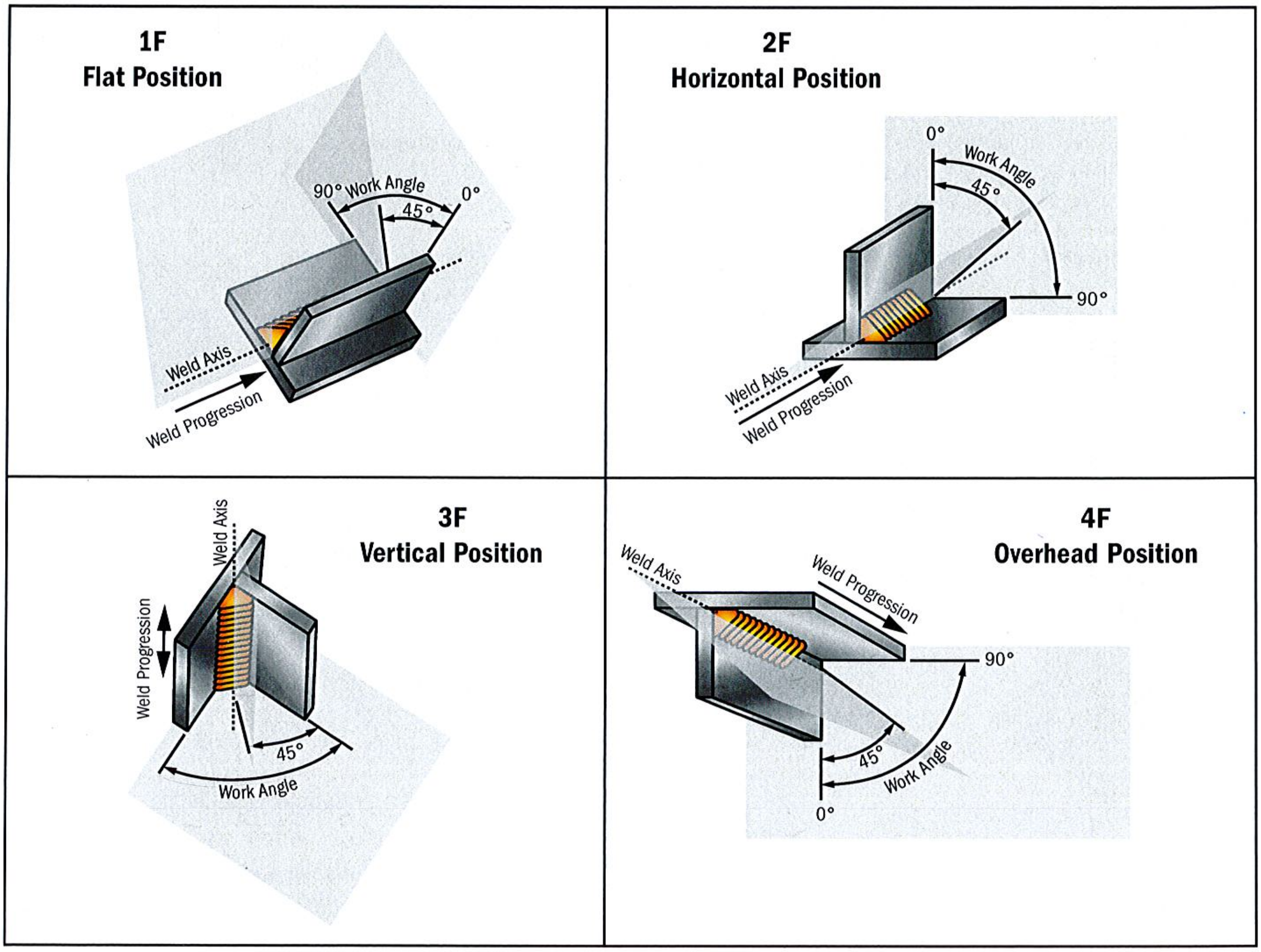


Figure 39 – Electrode Work Angles For Fillet Welds Notice The Angle Is Measured Perpendicular To The Nonbutting Member..

Welding Joint Types

A weld joint is the term used to describe the location where two or more pieces of metal are to be, or have been, joined together. In order to obtain a sound weld, and to ensure the most economical use of filler metal, the joint design must be considered in any type of weldment. This will depend upon several factors including material type, thickness, location, strength required, etc. A proper joint design will provide the required strength that codes and specifications designate. The correct joint design will then need a weld deposited to the highest quality possible at the lowest possible cost. The joint design selected will, of course, dictate what type of weld is to be made.

Edge Joints

Edge joints are often used when the members to be welded will not be subjected to any great stresses. Edge joints are not recommended where impact or any other great stresses may occur to one or both of the welded members. An edge joint occurs where the edges of parallel or nearly parallel members meet and are joined by a weld. Figure 51 shows different types of edge joints. It can be seen from the Figure that the edges can be left square or they can be altered by grinding, cutting or machining the edges into a bevel groove, V-groove, J-groove, or U-groove. The main purpose of these grooves is to allow adequate penetration or depth of fusion. See Figure 52.

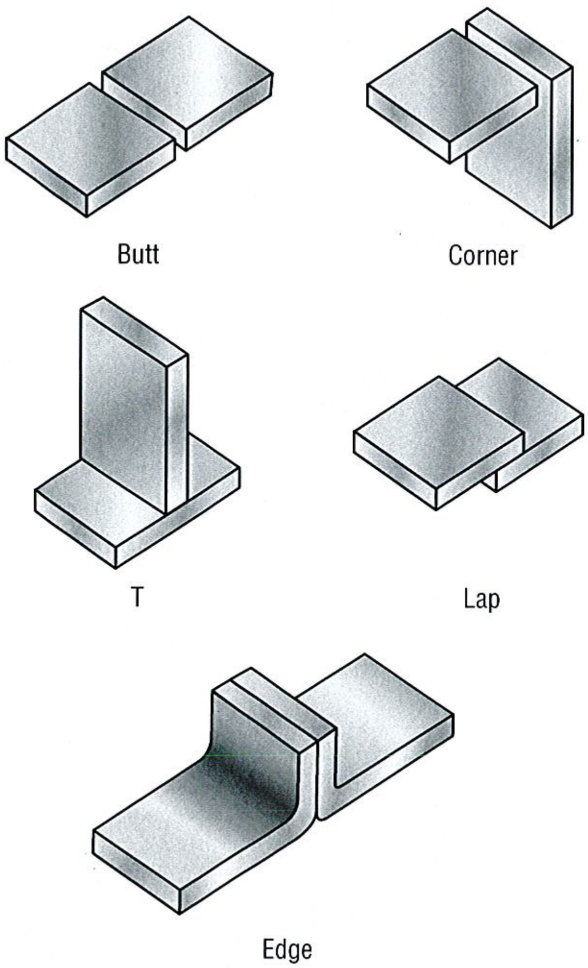


Figure 40 – The Five Basic Joint Designs. (Butt and T joints are the most common)

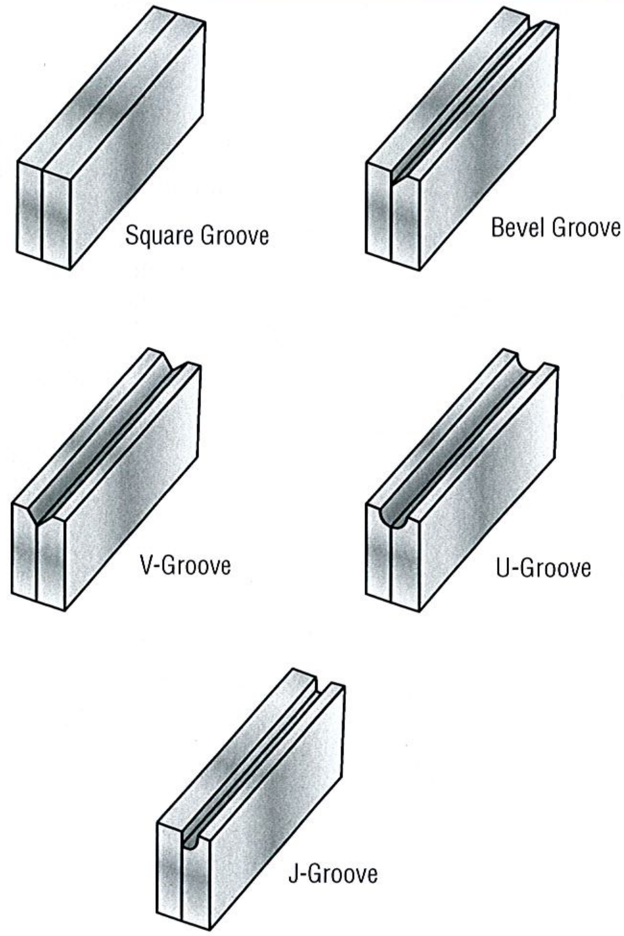


Figure 41 – Various Edge Joints

Butt Joints

A butt joint occurs when the surfaces of the members to be welded are in the same plane with their edges meeting. Figure 53 shows different types of butt joints. Butt joints are often used to join such things as pressure vessels, boilers, tanks, plate, pipe, tubing or any application where a smooth weld face is called for. Groove welds generally require more welding skill than fillet welds. Groove welds can be expensive due to the added cost associated with joint preparation. Distortion and residual stresses can be problems if the butt joints are not properly designed or welded.

Butt joints can be designed in a number of ways. They may be welded with or without a backing material. Backing material can be a piece of metal or ceramic backing the joint, and is usually referred to as a "backing bar" or "backing strip". The edges can be square, beveled, or grooved. Edges may be held tight together or a small gap known as a root opening may be left between the edges. Butt joints have very good mechanical strength when made properly.

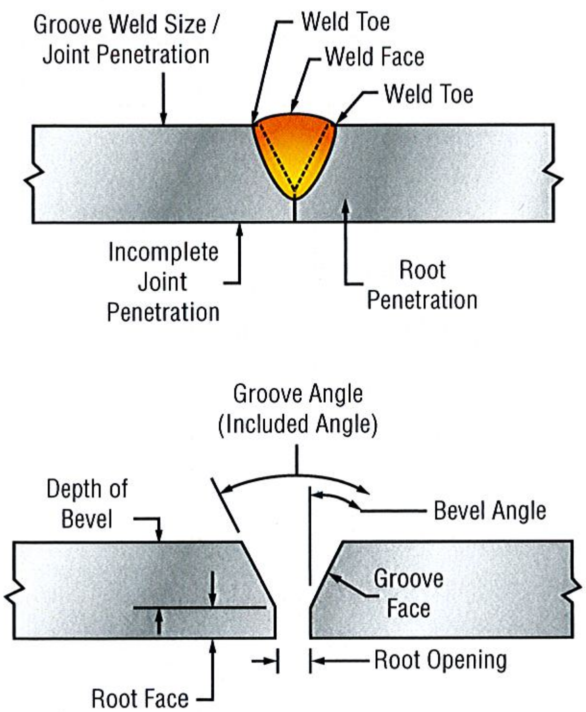


Figure 42 – Groove Weld Terminology

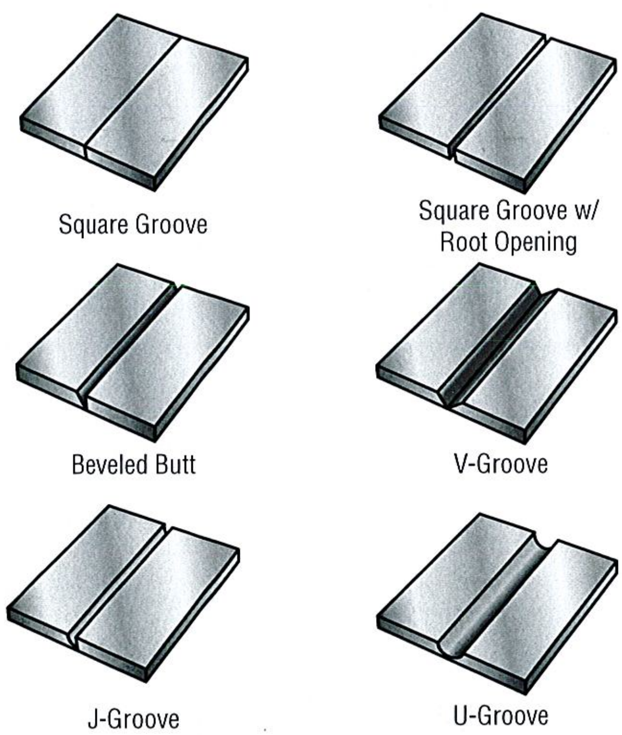


Figure 43 – Various Groove Butt Joints

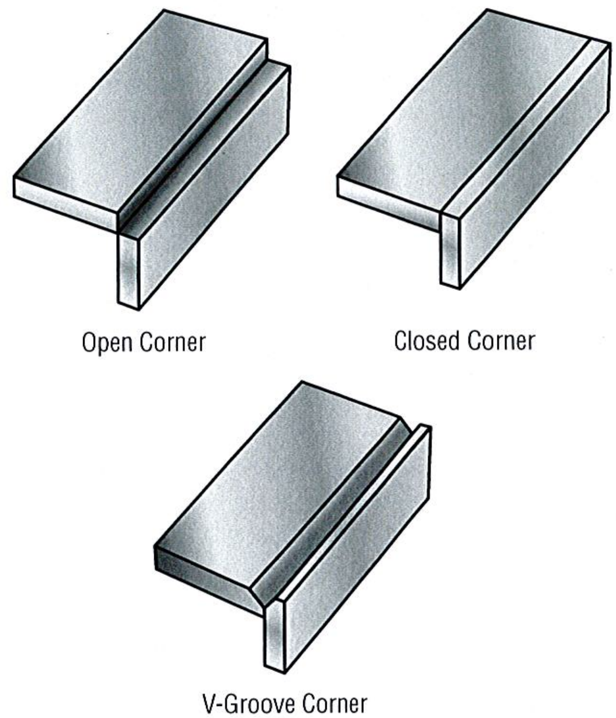


Figure 44 – Various Corner Joints

Lap Joints

Another joint design often used is the lap joint. Lap joints occur when the surfaces of joined members overlap one another. A lap joint has good mechanical properties, especially when welded on both sides. The weld type on a lap joint is generally a fillet weld. The degree of overlap of the members is influenced by the thickness of plate. In other words, the thicker the plate, the more overlap is generally needed.

Corner Joints

When members to be welded come together at about 90 degrees and take the shape of an "L", they are said to form a corner joint. Various types of corner joints are shown in Figure 54. These joints are quite easily assembled and require little if any joint preparation. After welding, the joints are generally finished by grinding to present a smooth attractive appearance. When this is the case, the welder should try to prevent high spots, low spots, undercut, and overlap (weld material rolling outside the toe of the weld onto one of the members). These problems can all mean more work since excessive grinding time, rewelding and re-grinding may be required. There are two main types of corner joints, open corner and closed corner. On lighter gauge material, it may be necessary to increase travel speed, especially on open corner joints where excessive melt through is a possibility.

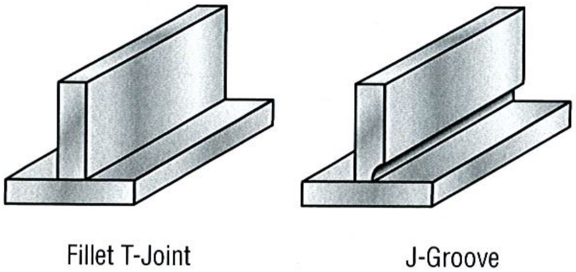


Figure 45 – T-Joints

T-Joints

A T-joint occurs when the surfaces of two members come together at approximately right angles, or 90 degrees, and take the shape of a "T". On this particular type of joint, a fillet weld is usually made.

T-joints possess good mechanical strength, especially when welded from both sides. They generally require little or no joint preparation and are easily welded when the correct parameters are used. The edges of the T-joint may be left square or they may be altered by cutting, machining or grinding.

Weld Types and Positions

Fillet Welds

Fillet welds are approximately triangular in cross sectional shape and are made on members whose surfaces or edges are approximately 90 degrees to each other. Fillet welds can be as strong, or stronger than the base metal if the weld is the correct size and proper welding techniques are used. When discussing the size of the fillet weld, it is generally the length of the leg of the weld that is being referred to when the profile is convex. Figure 56 shows a fillet weld and the basic terms associated with it. Adding 1/16 in. to the leg size of a 1/4 in. fillet weld, to deposit a 5/16 in. fillet weld, will require approximately 35% more filler metal, time, gas etc., so the proper sizing and deposition of a fillet weld is important.

Groove Welds

A groove weld is made in the groove between the work pieces. While there are several different types of grooves(U, J, V, Bevel), the most common is the V-groove. Figure 52 shows the terminology used to describe the different parts of a groove weld. Groove welds can take the shape of all of the joint types. A T-Joint, for example, is often just a simple fillet weld. However, when the top plate is beveled (as opposed to a simple square shape) the weld is then a groove weld. It may even have a fillet weld placed after the groove weld is completed. See (Figure 58).

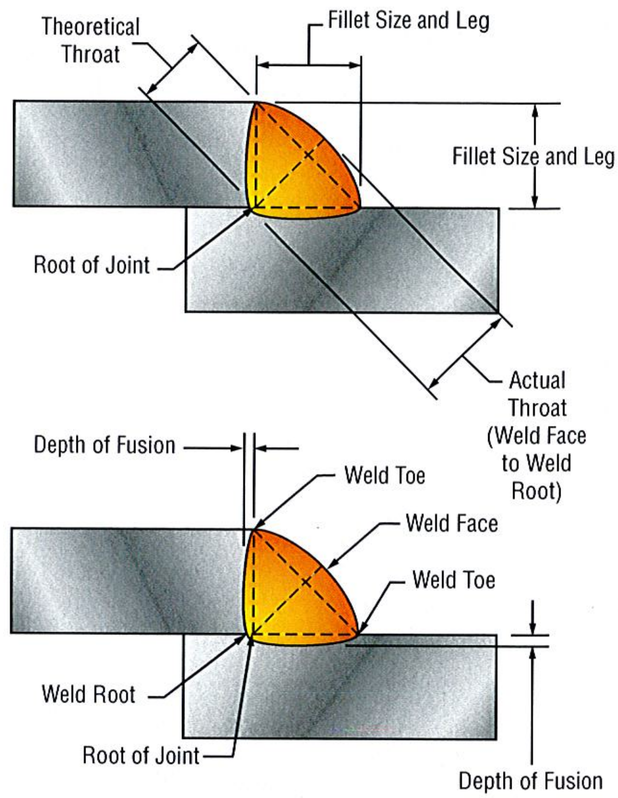


Figure 46 – Convex Weld Terminology

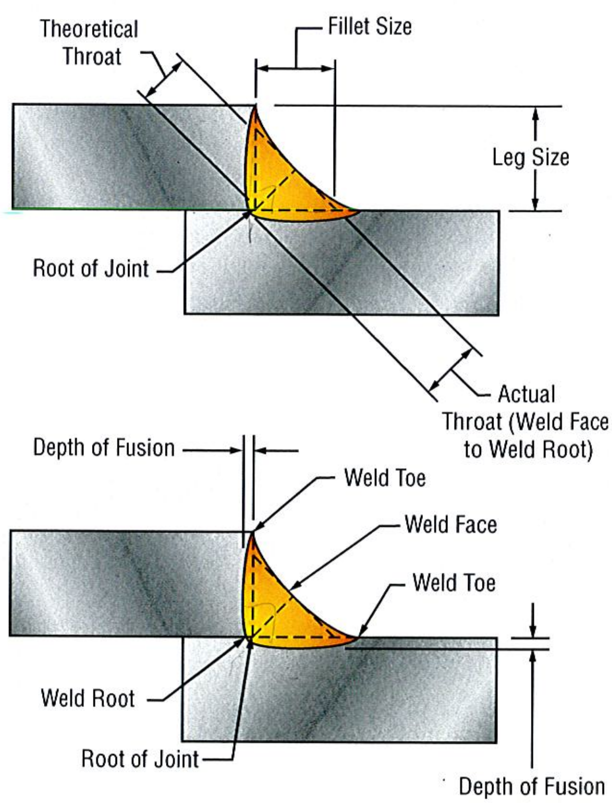


Figure 47 – Concave Fillet Weld Terminology

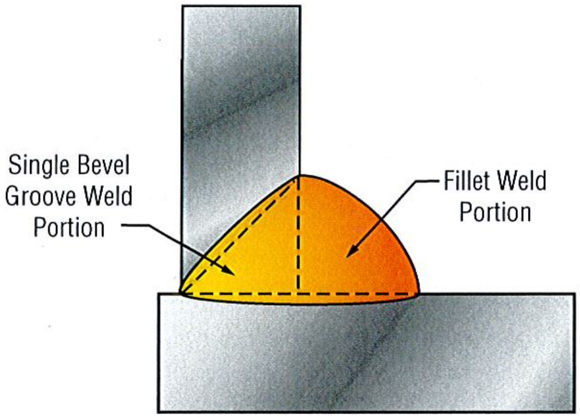
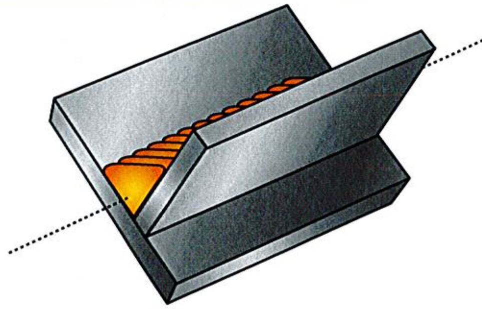


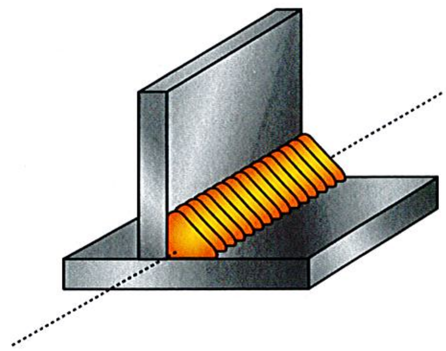
Figure 48 – A Groove Weld (Single Bevel) with a Fillet Weld Adding Additional Reinforcement on a T-Joint.

Weld Positions

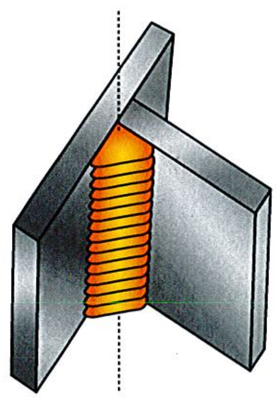
Fillet and groove welds are welded in various positions depending on the location of the weld on the part to be welded. In order to help the welder understand the location of the weld to be made, a number and letter system is used to indicate the type and position of the weld. The illustrations in (Figure 59, Figure 60, and Figure 61 show the different positions for fillet welds, groove welds on plate, and groove welds on pipe.



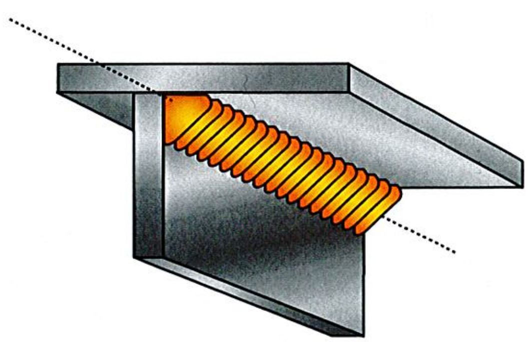
Flat Position 1F



Horizontal Position 2F



Vertical Position 3F



Overhead Position 4F

Figure 49 – Fillet Weld Positions

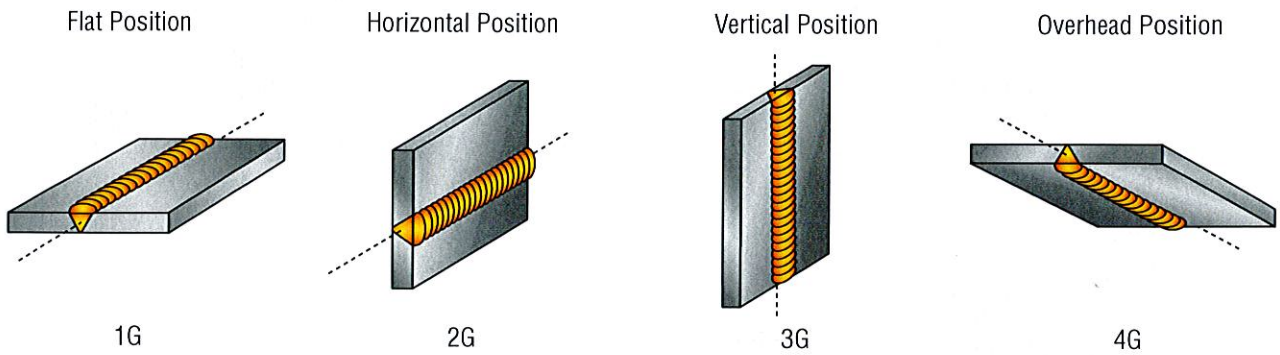


Figure 50 – Groove Weld Positions

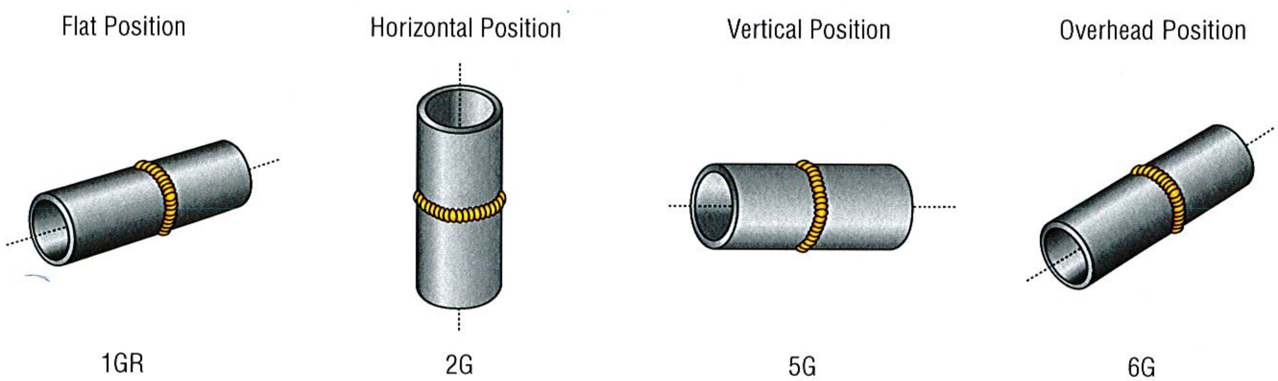


Figure 51 – Pipe Groove Weld Positions

Welding Symbols

Welding symbols are defined by the American Welding Society in ANSI/AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination. This standard should be referenced for all engineering documentation to ensure quality and consistency in manufacturing of welded structures. Many companies use welding symbols incorrectly and do not refer to this standard. This causes confusion and can lead to significant quality problems.

Because welding symbols have an element of interpretation the AWS Standard is very thorough and complete in helping identify the intended weld that the symbols implies. This section is intended to stress the importance of using the AWS standard when using welding symbols. The welding symbols chart, Figure 62, helps identify welding symbols. An excellent resource to learn welding symbols can be purchased from The Hobart Institute of Welding Technology: *Symbols for Welding.* This programmed self-paced course provides a simple yet complete method for students to learn and understand welding symbols.

American Welding Society Welding Symbol Chart for AWS A2.4-98

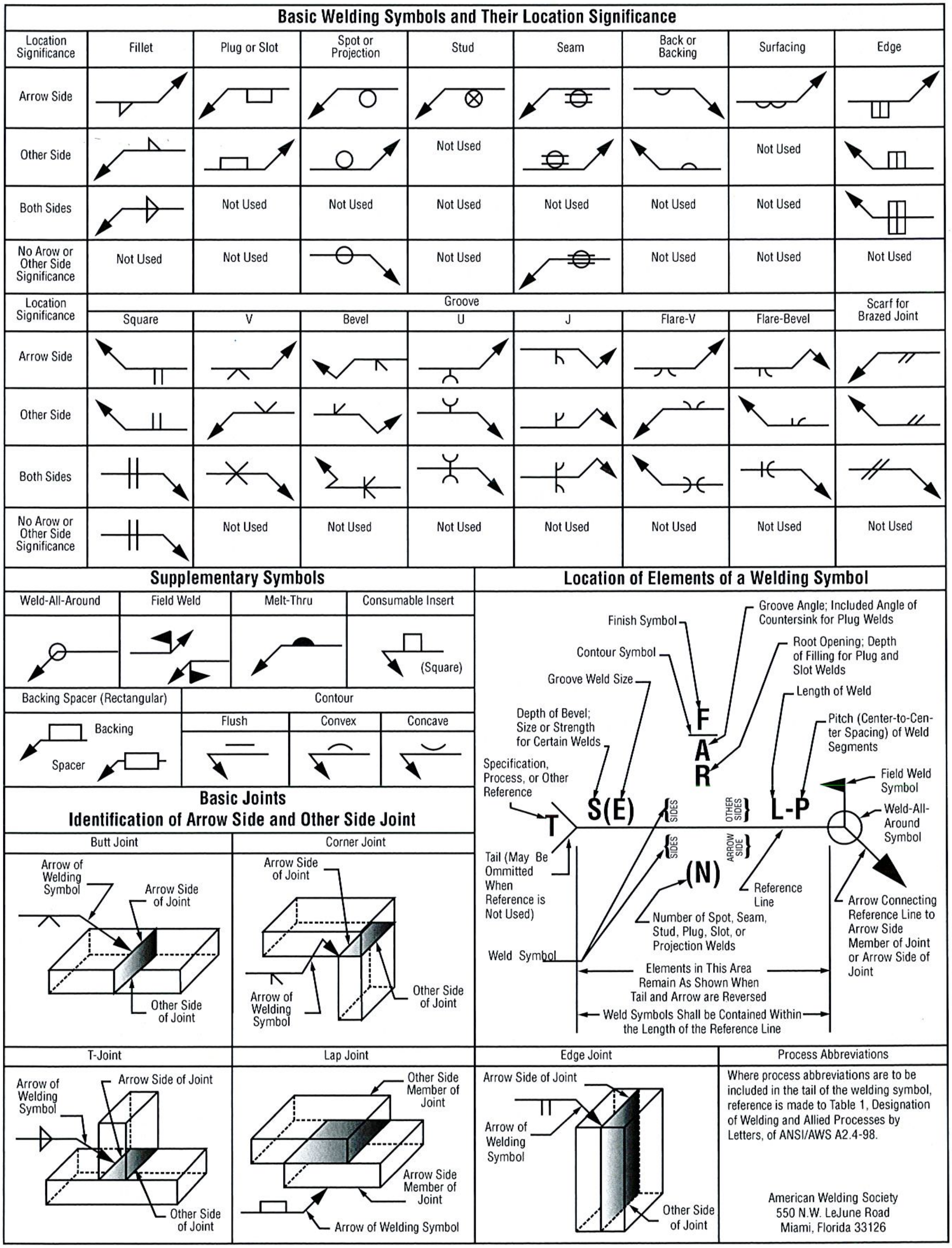


Figure 52 – The American Welding Society Welding Symbol Chart

Terms and Definitions

This section is intended to define the terms used throughout the training series. Many terms (highlighted in blue) are used by Miller Electric Manufacturing and Hobart Brothers and are not necessarily the same as used by the American Welding Society. The American Welding Society Publication A3.0 *Standard Welding Terms and Definitions* should be consulted to ensure the clearest definition of welding terms as they relate to your application. Many of the standard terms in this document are defined using the AWS standard as a reference. Generally, the terms listed in this book are defined to describe the word in the context it is used for this series.

A

Accu-Mate™: Gun/feeder connection on certain wire feeders that use an integrated power pin lock to properly seat the gun for optimal feeding, and uses an all-brass power clamp for improved electrical conduction and durability.

Accu-Pulse®: (GMAW-P) A pulsed GMAW process that delivers precise control of the arc even over tack welds and in tight corners. Provides optimum and precise molten puddle control.

Accu-Rated™ Power: The standard for measuring engine-driven generator power. Guarantees delivery of all power promised. Is measured by the amount of usable peak power at an ambient temperature of 104°F (40°C)

Accu-Set™: Amperage indicator on Thunderbolt® models provides accurate control with infinite amperage control.

Active Arc Stabilizer™: Enhances arc starts and provides a softer arc throughout all ranges with less puddle turbulence and less spatter.

Adaptive Hot Start™: Automatically increases the output amperage at the start of a Stick weld, should the start require it. Helps eliminate sticking of the electrode at arc start.

Adaptive Pulse: Adaptive pulse refers to a pulse control's ability to automatically adjust pulse frequency in order to maintain a constant arc length, regardless of change in welding wire stickout.

Advance Active Field Control Technology™: A simple and reliable way of accurately controlling an engine drive's generator weld output.

Advanced Squarewave: (AC): The advanced AC output available from inverter based power sources. The wave is much more square in shape, and more responsive than the conventional squarewave power source. It also has expanded balance control up to 99% electrode negative (maximum penetration) and the ability to control arc frequency (arc direction). Some welding power sources have the additional ability to adjust the amount of current in the electrode negative and electrode positive cycles independently, providing a fast freezing puddle, deep penetration and fast travel speeds.

Aging (Precipitation Heat Treating): The precipitation of a portion of the elements or compounds from a supersaturated solution to yield desirable properties. Aging at room temperature is termed natural aging; at elevated temperature it is called artificial aging.

Air Carbon Arc Cutting (CACA): A cutting process by which metals are melted by the heat of an arc using a carbon electrode. Molten metal is forced away from the cut by forced air.

All Position Welding: Refers to the ability to weld in the flat, horizontal, vertical, and overhead positions.

Alloy: A metal that has one or more other materials added to it to improve its properties.

Allumination™ Technology: Gives you the ability to use the extended reach of a push-pull system to feed your aluminum wire using a conventional wire feeder instead of a dedicated push-pull wire feed system.

Alternating Current (AC): An electrical current that reverses its direction at regular intervals, such as 60 cycles alternating current (AC), or 60 hertz (Hz).

Aluminum Pulse Hot Start™: Automatically provides more arc power to eliminate a "cold start" that is inherent with aluminum starts.

Amperage: The measurement of the amount of electricity flowing past a given point in a conductor per second. Current is another name for amperage. Amperage has the most effect on the penetration into the base metal.

Annealing: The opposite of hardening. A heat treating process used to soften a metal and relieve internal stresses.

Anodize: To anodize aluminum is to increase the thickness of the natural oxide layer on the metal by either chemical or electrical means. The coating provides improved corrosion and wear resistance. The thickness of this coating depends upon the length of the treatment. This coating is often removed from the area to be welded. Anodizing can be reapplied after welding.

Arc: The "bright light" that occurs when welding. It is the result of controlling the welding machine's electrical output and maintaining arc plasma. This arc plasma is an electrically conductive gas like state of matter that produces heat and rays that can produce burning of the skin.

Arc Blow: Also referred to as magnetic arc blow. When welding with direct current (DC), magnetic forces may cause the arc to be deflected from its normal path.

Arc Column: The part of the welding area containing the ionized gas and the consumable electrode wire. The arc column is protected by shielding gas that has not been ionized by the electric arc.

Arc Control: A term used on the panel of multi process power supplies that produce both Constant Current and Constant Voltage output. On Constant Current it adjusts Dig. On Constant Voltage it adjusts inductance.

Arc-Drive™: Automatically enhances Stick welding, especially on pipe, by focusing the arc and preventing the electrode from going out. It is a feature found on Miller engine drives.

Arc Force: See Dig.

Arc Gouging: An arc cutting process used to provide some type of bevel or groove for welding preparation. Often used to remove defective welds or to prepare for welding a damaged material such as a casting

Arc Length: The Physical distance between the tip of the electrode and the work.

Arc Stabilizer: Filler metal: Materials added to the coating of an SMAW electrode to help maintain the arc. This helps the welder control the arc and makes welding much easier. Power supply: See Stabilizer:

Arc Voltage: Measured across the welding arc between the electrode tip and the surface of the weld pool.

As-Welded: Is the condition of the weld metal, welded joint, and total weldment after welding before any heat treatment, aging, or chemical-mechanical treatment has been applied to it.

Asymmetric Waveform: The output waveform of a welding power source that has the ability to independently modify the amplitude of the positive and negative half cycles of alternating current.

Auto Remote Sense™: Automatically switches machine from panel to remote control with the remote connected. Eliminates confusion and need for a panel/remote switch.

Auto Stop™: Allows a TIG arc to be stopped without the loss of shielding gas.

Auto-Crater™: "Crater-out", allowing time for addition of filler, without the loss of shielding gas. Eliminates the need for a remote control at arc end.

Autogenous Weld: A weld made without the addition of filler metal. Also referred to as a "fusion weld".

Auto-Gun Detect™: Automatically detects and recalls the voltage, wire feed speed, and timer on the active gun - either the MIG gun, spool gun, or push-pull gun.

Auto-Line™: Allows and adjusts for primary input voltage within a large voltage range, single, or three-phase, 50 or 60 hertz. Also adjusts for voltage spikes within the entire range. The specific voltage range that Auto-Line™ functions within is machine specific.

Auto-Link®: Automatically connects to the primary input voltage upon power up. It connects to, single, or three-phase at 50 or 60 hertz. The specific voltage range that Auto-Link™ functions within is machine specific. It is a feature available on inverter based power supplies.

Automatic Start at Idle™: Idles engine immediately when started, extending engine life and reducing fuel consumption and noise.

Automatic Welding: Uses equipment which welds without controls adjusted by the welder or operator requiring minimal observation.

Auto-Refire™: Automatically controls the pilot arc when plasma cutting expanded metal or multiple pieces of metal, without manual triggering.

Auto-Set™: Sets the MIG welder automatically to the proper parameters. Operator only needs to set the wire diameter and material thickness.

Auto-Speed™: On select engine driven power sources the Auto Speed mode of the speed control switch automatically controls the engine speed depending on the total power needed.

Auto-Stop™: Allows a TIG arc to be stopped without the loss of shielding gas.

Axcess® File Management: that turns a standard Palm™ (PDA) handheld into a data card and a remote pendant for all Axcess systems. Allows e-mailing, storage, and transfer of welding programs.

B

Back Gouging: The removal of weld metal and base metal from the other side (root side) of a weld joint; typically used to make a weld that has complete penetration of the weld joint.

Background Current: The lower of the two current levels used for GMAW-P and GTAW-P to produce the pulsing waveform.

Backing: A material used to back up the joint while welding. Its purpose is to aid in getting full penetration without excess melt through.

Balanced Wave (AC): An alternating current waveform that has equal negative and positive polarity, current and time values.

Base Metal: The metal that is being welded.

Bead (Weld Bead): The deposited weld metal after making a single pass. Can either be a stringer or a weave.

Bevel: An angular type of edge preparation used to access the thickness of the base metal to obtain full or deeper penetration.

Bevel Angle: An angle formed between a plane, perpendicular to the surface of the base metal and the prepared edge of the base metal.

Blue Lightning™: High frequency arc starter for non-contact arc initiation on GTAW power supplies. Provides more consistent arc starts compared to traditional HF arc starters.

Brazing: A method of joining material when using a non-ferrous filler metal which melts above 840°F (450°C) but is below the melting point of the base metal. The base metal is not be melted while brazing and the filler material uses capillary action to complete the joint.

Burnback: The degree of electrode melt rate occurring when the electrode wire melts back towards the contact tip at the completion of a weld. If the burnback value is too great, burnback can extend to the front of the contact tip and possibly damage the tip. It prevents freezing of the wire in the puddle for GMAW spot welding and automatic welding.

Butt Joint: A weldment where the material surfaces and joining edges are in or near the same plane.

C

Cap Pass: The visible pass or passes that finish a welded joint.

Capacitance: The ability of a device (capacitor or conductor) to store an electrical charge.

Carbide Precipitation: Occurs when austenitic stainless steel is heated within a temperature range of 800°–1600°F, 427°–870°C for a critical period of time. Carbon moves from a solid solution to grain boundaries and combines with chromium. The metal adjacent to the grain boundaries is left with less chromium and is said to be sensitized. Corrosion resistance is therefore reduced in the grain boundary region.

Carbon Arc Gouging: A cutting process by which metals are melted by the heat of an arc using a carbon electrode. Molten metal is forced away from the cut by a blast of forced air.

Carriage: The device on a manipulator which moves the welding gun or cutting torch.

Cast: The diameter of a loose ring of wire, laid flat and not restrained. The wire should be cut off from the spool or other wire package, with enough wire cut off to form a loop, or a maximum of 10 ft. For steel 4 in. spools, 0.045 in. diameter and less, cast should be from 4 in. to 9 in.. For steel spools larger than 4 in., and for wires 0.030 in. in diameter and smaller, cast should be at least 12 in.. For steel spools larger than 4 in., and for wires 0.035 in. and larger, cast should be at least 15 in.. For stainless steel 12 in. spools, cast should be 15 in. to 50 in..

Casting Alloys: A component which has been formed by pouring or injecting molten metal into a mold and allowing it to solidify and take the shape of the mold. Alloys having compositions suitable for this method of fabrication are termed casting alloys.

Ceriated Tungsten (EWCe)**:** An electrode used for GTAW welding. It is made from tungsten with a small amount of nonradioactive cerium added. Improves arc starting and provides for use of wider current ranges for both AC and DC welding. It is identified by a grey band (formerly orange).

Characteristics: A special quality or property. FIller Metal: Electrode coatings have special qualities or properties that allow them to be used with certain current types, weld in certain positions, and operate with various techniques. Power Supply: Some welding machines have certain characteristics which allow a welder to perform more welding applications than with other welding machines.

Circuit: The complete path or route traveled by the electric current including the power source, weld cables, electrode holder, work clamp, electrode, base metal and arc.

Coalescence: Means that two pieces of metal are joined into one. The methods of achieving this are varied but, nevertheless, if there is an atomic bond between two pieces of metal they are said to be coalesced.

Cold Lap: See Incomplete Fusion.

Concave Root Surface: A root surface (underside of weld bead) which is concave. Often referred to as "suckback".

Conductor: A material that allows current to flow through it easily. This means the conductor has low resistance. Most metals are good electrical conductors. Copper and Aluminum are most commonly used for electric components.

Constant Current (CC) Welding Machine: These welding machines have limited maximum short circuit current. They have a negative volt-amp curve and are often referred to as "droopers". The voltage will change with different arc lengths while only slightly varying the amperage, thus the name Constant Current or variable voltage. CC machines are commonly used for SMAW, GTAW, and SAW.

Constant-Speed Wire Feeder: A wire feeder where the motor produces a constant wire feed speed and does not vary regardless of weld voltage.

Constant Voltage (CV), Constant Potential (CP) Welding Machine: "Potential" and "voltage" have basically the same meaning. This type of welding machine maintains a relatively stable, consistent voltage regardless of the amperage output. It results in a relatively flat volt-amp curve as opposed to the drooping volt-amp curve of a typical Constant Current (CC) welding machine. Constant Voltage power supplies are used for GMAW, FCAW, and can also be used for SAW.

Consumable Insert: Filler metal that is usually shaped specifically for the weld to be made and it is completely fused into the joint and becomes part of the weld.

Contact Tip: A copper or copper alloy tube at the end the GMAW or FCAW gun that guides the continuous electrode wire and transfers welding current to it.

Contactor: An electrical switch that is used to energize or de-energize output terminals of a welding machine. In some types of welding machines they can be of solid state design, with no moving parts and thus no arcing of contact points. In some cases such as Auto-Link™ a contactor is used to supply the primary input power to a welding machine.

Contraction: The shortening and thickening of a metal as it cools off after welding or being heated. This shortening and thickening of the metal usually results in the metal binding, buckling or distorting.

Corner Joint: Produced when the weld members meet at approximately 90° to each other in the shape of an "L".

Corrosion Resistance: The ability of a metal to resist attack by other elements and chemicals.

Covered Electrode: Used with the SMAW process, it is a solid core wire which has a coating of flux on the outside to shield the arc from the atmosphere, act as a deoxidizer, stabilize the arc, produce slag, and can carry alloying elements. This is most commonly referred to as a "stick" electrode.

Crater: A depression at the end of a weld bead caused during the solidification of the metal at the end of the weld.

Crater Crack: A crack in the depression at the end of a weld bead caused by rapid solidification of the metal at the end of the weld.

Critical Temperature: Is the temperature a metal must be heated to before a molecular change will take place. In steel this temperature is 1333° F (722° C).

Current: See Amperage.

Current Density: The amount of current per square inch of cross-sectional area in an electrode. For any electrode diameter, find the current density by dividing the current value by the electrode cross-sectional area in square inches.

Cycle: One cycle equals 360 electrical degrees. For alternating current, current flow is in one direction through a circuit for 180° and in the opposite direction for the other 180°. For 60 cycle power, a cycle is repeated 60 times per second. Some welding machines, especially outside the United States, require 50 cycle (hertz) power. Hertz stands for cycles per second.

D

Defect: One or more discontinuities that exceed the acceptance criteria as specified for a weld.

Deformation: Is to alter the form or shape of a weldment due to the contracting forces of the cooling metal.

Deoxidizer: An element added to the coating of electrodes for the purpose of removing oxygen and its resulting by-products such as porosity.

Deposition Efficiency: The percentage that represents the amount of filler metal that gets deposited into the finished weld. For each welding process the amount of filler metal that is lost due to vaporization, spatter, flux, or stub loss can vary greatly.

Deposition Rate: The amount (weight) of weld metal deposited in a given time period. Deposition rate directly relates to wire feed speed for FCAW and GMAW welding. This rate is usually given in pounds per hour (lb/h), or kilograms per hour (Kg/h). Deposition rate is determined for SMAW electrodes by the welding amperage.

Dig: Sometimes referred to as Arc Control and formerly referred to as Arc Force. It is an adjustment on an welding power supply that gives a power source variable additional amperage during low voltage (short arc length) conditions while SMAW welding. Helps avoid "sticking" stick electrodes when a short arc length is used or to provide additional amperage as the operator sees the need for it in tight fit up conditions. See Arc Control.

Dilution: The change in chemical composition of deposited filler metal caused by the admixture of the base metal or previous weld metal in the weld bead.

Diodes: See Rectifier

Direct Current (DC): Flows in one direction and does not reverse its direction of flow as does alternating current.

Direct Current Electrode Negative (DCEN): The specific direction of current flow through a welding circuit when the electrode lead is connected to the negative terminal and the work lead is connected to the positive terminal of a DC welding machine.

Direct Current Electrode Positive (DCEP): The specific direction of current flow through a welding circuit when the electrode lead is connected to a positive terminal and the work lead is connected to a negative terminal of a DC welding machine.

Discontinuity: Any change in a metal's typical structure. It is the lack of consistency in mechanical, metallurgical or physical characteristics. Discontinuities are found in all metals and welds because they have some degree of inconsistency in them. However, this is acceptable as long as the discontinuities do not exceed the acceptance criteria of the weld or metal in question. If a discontinuity exceeds the acceptance criteria, they are defects and must be repaired.

Distortion: The warpage of a metal due to the internal residual stresses remaining after welding. Distortion results from metal expansion (during heating), and contraction (during cooling).

Drag Angle: The travel angle when the electrode is pointed back away from the direction of travel. Sometimes referred to as backhand welding.

Dual Power Option™: Gives the option on some engine driven welders to use 230 volt single - or three-phase electric input power which reduces engine wear, noise and emissions, as well as fuel costs.

Ductility: The ability of a metal to bend or twist without cracking or breaking.

Duty Cycle: The number of minutes out of a 10-minute time period an arc welding machine can be operated at maximum rated output. An example would be 60% duty cycle at 300 amps/32 volts. This would mean that while welding at 300 amps/32 volts the welding machine can be used for 6 minutes and then must be allowed to cool for 4 minutes. During cooling on some power supplies the fan may or may not be running. (Some imported welding machines are based on a 5-minute cycle).

E

Edge Joint: A joint that occurs when the surfaces of the two pieces of metal to be joined are parallel or nearly parallel, and the weld is made along their edges.

Elasticity: The ability a metal has to return to its original shape after it has been bent.

Electrode: Filler Metal: Is the conductor between the electrode holder and the arc. For SMAW it is usually coated with a flux. The electrode melts and fuses with the base metal to produce a weld bead. Power Supply: The component of an electric arc where the electrons are carried between it and the workpiece.

Electrode Cable: The conductor that is attached to the power source terminal and electrode holder.

Electrode Extension: The length of electrode extending beyond the end of the contact tip or the contact point that holds the electrode.

Electrode Holder: A device used to clamp and hold the SMAW electrode in place. They are rated in amperage for size and should be properly insulated from accidental arc strikes outside of the electrode.

Electrolyte: A solution which is capable of conducting an electrical current. A typical electrolyte is water to which salt has been added. Electrolytes are a major factor in the corrosion of metals.

Electron: A very small atomic particle which carries a negative electrical charge. Electrons can move from one place to another in atomic structures. It is electrons that move when electrical current flows in an electrical conductor.

Elongation: To lengthen a piece of metal by subjecting it to stress. It is usually expressed as a % of an original length.

Engine Save Start™: Idles engine 3–4 seconds after starting to help extend engine life and reduce fuel consumption.

Etching: When a weld specimen is cut through a weld, an acid or similar solution can be applied to the weld area to bring out the features of the weld. These includes the deposited weld metal, heat affected zone, penetration and weld profile. Many different etching solutions and techniques exist for the various kinds of metals.

Excessive Melt-Through: A weld defect occurring in a weld joint when weld metal falls through the weld joint or "burns through". Also referred to as excess penetration.

Expansion: Increase in size and volume by heating. When welding, the heat from the arc causes the metal to expand. When the metal starts to cool, it shrinks or contracts.

Extended AC Balance™: (30–99%) Controls the amount of time the AC welding current spends on the Electrode Negative half of the AC GTAW welding cycle. This helps to maximize the energy delivered to the part to melt it and minimizing the oxide removal that takes place during the electrode positive half of the cycle, and improving aluminum weld quality and productivity.

EZ-Access™: Consumable compartment and parameter chart in flip-down compartment on the front of select Millermatic® series power supplies.

EZ-Change™: Low cylinder rack allows operators to easily roll cylinders on and off of rack.

F

Face: The surface of the weld as seen from the side of the joint on which the weld was made.

Fan-On-Demand™: Internal power source cooling system that only works when the power source is hot enough to need it, keeping internal components cleaner and functioning efficiently.

FasTip™ Contact Tip: A simple contact tip design that only needs a single-turn for quick change—no tools needed!

Fatigue: A condition where the metal, although it may not have stressed beyond its yield strength or ultimate tensile strength, starts to come apart when loaded cyclically.

Ferrous: Refers to a metal that contains primarily iron, such as steel, stainless steel and cast iron.

Fill Pass (intermediate weld bead): Weld pass(es) made to fill a joint after the root pass and before the cover pass.

Filler Metal: The reinforcing metal added when making a welded, brazed, or soldered joint.

Fillet Weld: A weld that is used to join base metal surfaces that are approximately 90° to each other, as used on a T-joint, corner joint or lap joint. The cross sectional shape of a fillet weld is triangular in shape.

Fit-Up: Often used to refer to the manner in which two members are brought together to be welded, such as the actual space or any clearance or alignment between two members to be welded. Proper fit-up is important if a good weld is to be made. Tacking, clamping or fixturing is often done to ensure proper fit-up. Where it applies, base metal must be beveled correctly and consistently. Also, any root openings or joint angles must be consistent for the entire length of a joint. An example of poor fit-up can be too large of a root opening in a V-groove butt joint.

Fixed Automation: A dedicated machine specifically designed for arc welding the same specific parts on a continuous production basis. Usually performed around a part (circumferential) or on a straight line (longitudinal) weld.

Flat Position: When welding is done from the top side of a joint, it is in the flat position if the face of the weld is approximately horizontal. Sometimes referred to as downhand welding. The axis angle can be from 0°–15° in either direction from a horizontal surface. Face rotation can be from 150°–210° with 180° for a flat table.

Flexible Automation: A variation on the Fixed Automation but allows for some part variation such as a diameter change on a circumferential weld or a length adaptation on a longitudinal weld.

Flux: Material used in the coating of an SMAW electrode, the core material of a FCAW electrode, or in granular form for SAW to help remove, dissolve, and prevent oxides and other harmful materials from forming in the weld metal and base metal.

Flux Cored Arc Welding (FCAW): An arc welding process which melts and joins metals by heating them with an arc between a continuous, consumable tubular electrode wire (consumable) and the workpiece. Shielding is obtained from a flux contained within the electrode's tubular core. Depending upon the type of flux-cored wire, added shielding may (FCAW-G) or may not (FCAW-S) be provided from externally supplied gas or gas mixture.

Freeze Lines: The lines formed across a weld bead. They are the result of the weld pool freezing. In appearance they sometimes look as if one tiny weld was continuously laid upon another.

Frequency: The number of times per second an alternating current goes through a complete cycle. Usually referred to as "hertz" or "cycles per second". In the united States, the frequency of alternating current is usually 60 hertz. Some Advanced Squarewave power sources allow the AC welding arc frequency to be adjusted to provide stability and directional control that focuses the arc.

Fusion: Occurs when two or more pieces of metal are molten or liquid and join together.

G

Gas Cup: That part of the GTAW torch that directs the shielding gas flow over the weld area. Made of ceramic, glass, or metal in various styles.

Gas Metal Arc Welding (GMAW): An arc welding process which joins metals by heating them with an arc. The arc is between a continuously fed solid filler wire (consumable) electrode and the workpiece. Externally supplied gas or gas mixtures provide shielding for GMAW. Sometimes called MIG welding (Metal Inert Gas) or MAG welding (Metal Active Gas).

Gas Tungsten Arc Welding (GTAW): Often called TIG welding (Tungsten Inert Gas), it is a welding process which joins metals by heating them with a tungsten electrode which should not become part of the completed weld. Filler metal is sometimes used and argon inert gas or inert gas mixtures are used for shielding.

Gaseous Shield: The heat from the arc causes the flux coating on the SMAW electrode to produce a gas. This gas covers the arc and molten metal around the arc and acts as a shield to prevent atmospheric air from coming into contact with the arc and molten metal. For other processes this is the envelope of externally supplied shielding gas.

Glass: Term often used with GMAW to refer to small islands of residue left on top of a weld bead, usually made up of silicates. Sometimes referred to as glossy, glass-like islands, and slag.

Globular Transfer: A non-axial directed transfer between a short circuit and a spray arc transfer. This process is generally undesirable and produces excessive spatter.

GMA Spot Welding: An arc process where the gun is not moved. Two pieces of material can be joined by completely penetrating the top piece and melting into the bottom piece. Standard GMAW equipment is used along with a special timer control and an engineered nozzle used on the end of the GMAW torch.

Groove Angle: When a groove is made between two materials to be joined together, the groove angle represents the total size of the angle between the two beveled edges and denotes the amount of material that is to be removed. Also referred to as the included angle.

Ground Connection: A safety connection from a welding machine frame to the earth. Often used for grounding an engine driven welding machine where a cable is connected from a grounding stud on the welding machine to a metal stake placed in the ground. See Work Connection.

Ground Lead: See Work Lead.

Gun-On-Demand™: Allows you to use either a standard gun or a Spoolmatic® gun without flipping a switch. The machine senses which gun you are using when you pull the trigger.

Gun Technique: Refers to the position of the gun as it progresses along the weld joint. A perpendicular technique would have the wire being fed 90° into the weld. A drag technique has the gun pointed back at the weld as the gun is "dragged" away from the deposited weld metal. The drag technique is sometimes also referred to as the pull technique. A push technique has the gun pointed away from the weld as the gun is "pushed" away from the weld.

H

Hard Facing: A type of surfacing where a layer of metal or type of coating is applied to a base metal for the purpose of reducing wear or loss of base metal by impact, abrasion, or erosion.

Hardness: The resistance a material has to being penetrated.

Heat Affected Zone (HAZ): The portion of a weldment that has not melted, but has changed due to the heat of welding. The HAZ is between the weld deposit and the unaffected base metal. The physical makeup or mechanical properties of this zone are different than the rest of the weld or base metal and represent a very thin transition between the base metal and the weld metal.

Heat Sink: A good weld needs a certain amount of base metal to absorb the high heat input from the welding arc area. The more base metal, or the thicker the base metal, the better heat sink effect. If this heat sink is not present, too much heat will stay in the weld area, and defects can occur.

Helix: The distance in height between one end of a looped wire and the other end. The wire should be laid flat and not restrained. The wire should be cut off to form one loop, or a maximum of 10 ft. For steel 4 in. spools, 0.045 in. diameter and less, helix should be 1/2 in. maximum. For steel spools larger than 4 in. and for wires 0.030 in. in diameter and smaller, helix should be 1 in. maximum. For steel spools larger than 4 in., and for wires 0.035 in. and larger, helix should be 1 in. maximum. For stainless steel 12 in. spools, helix should be 1 in. maximum.

Hertz: Hertz is often referred to as "cycles per second". In the United States, the frequency or directional change of alternating current is usually 60 hertz.

High Crown: Excess build up on the face of a weld bead.

High Frequency: Covers the entire frequency spectrum above 50,000 Hz. Used in GTAW welding for arc ignition and stabilization.

High-Low: See Mismatch.

Horizontal Position: The face of the weld is against a vertical surface and the weld axis is horizontal.

Hot Start™: A timed function used on some Stick (SMAW) machines to make it easier to start difficult-to-start electrodes by providing additional welding amperage for 1/10 of a second. Used for arc starting only.

I

Impedance: Impedance will slow down, but not stop, amperage flowing in an electrical circuit. It is the resistance in an alternating current circuit. Impedance is the combination of the natural resistance to current flow in any conductor and the inductive or capacitive reactance in an electric circuit. It is brought about by the building and collapsing field of alternating current. This building and collapsing induces a counter electro-motive force (CEMF) (voltage) that holds back, but does not stop, current flow.

Included Groove Angle: See Groove Angle.

Inclusions: Are usually non-metal pieces such as slag that are trapped in the weld metal. They are usually considered a discontinuity until they are large enough in size or number to be considered as a defect in the weld.

Incomplete Fusion: Molten filler metal rolling over a weld edge but failing to fuse to the base metal. Also referred to as cold lap or overlap.

Inductance: Inductance (an inductor) will slow down the changes in current, as if the electrons were sluggish. This only works in short circuit gas metal arc welding (GMAW). When this setting is increased there is slightly more arc "on" time than arc "off" time causing the puddle to "wet out" more. This adjustment is used to "soften" the arc on a high setting and "stiffen" the arc on a low setting.

Inductor (Stabilizer): For GMAW and related processes, an inductor changes the welding machine's rate of response and number of short circuits per second. An inductor limits the amount of spatter and generally improves wetting out of the puddle.

Inert Gas: A gas that will not combine with any known element. At present 6 are known; argon, helium, xenon, radon, neon, and krypton. Only argon and helium are used as shielding gases for welding.

Infrared: Invisible electromagnetic energy radiating from a welding arc. It produces a sensation of heat and can cause a condition known as arc burn (similar to sunburn).

Inverter: Welding power source which increases the frequency of the incoming primary power, thus providing for a smaller size machine and improved electrical characteristics for welding. It offers faster response time and more control for wave shaping and pulse welding. Components in an inverter are smaller because the higher operating frequency generates less heat. This reduced heat helps to make inverters more electrically efficient and lighter weight.

J

Joint Design: The cross-sectional shape and measurements for a particular weld. Generally includes bevel angles, root opening dimension, root face dimension , and the preparation shape (V, J, U, etc.).

Joint Root: That part of a joint that comes closest together where the weld is to be made. This may be an area of the joint or just a line or point of that joint.

K

Kerf: The space from which base metal has been removed due to a cutting process such as oxy-acetylene or plasma arc cutting.

KVA: Kilovolt-amperes or volts times amps divided by 1,000. The power demanded by a welding power source from the primary power furnished by the utility company.

KW: Kilowatts. Primary kW is the actual power used by the power source when it is producing its rated output. Secondary kW is the actual power output of the welding power source. Kilowatts are determined by multiplying volts times amps and dividing by 1,000 and taking into account any power factor.

L

Lack of Fill: Insufficient fill in a joint to meet specified requirements or specified strength requirements.

Land: See Root Face.

Lanthanum Tungsten (EWLa): An electrode used for GTAW welding. It is made from tungsten with a small amount of lanthanum added. Improves arc starting and provides for use of wider current ranges for both AC and DC welding. It is identified by a yellow/Gold band for the most common 1.5% La Tungsten.

Lap Joint: A joint that is produced when two or more members of a weldment overlap one another.

Leg: Is measured from the toe of the fillet weld to the root of the joint.

Lift-Arc™: This feature allows TIG arc starting without high frequency. Starts the arc at any amperage without contaminating the weld with tungsten.

Liquidus: The temperature at which all constituents in an alloy have reached their melting point.

Load Voltage: Measured at the output terminals of a welding machine while welding. It includes the arc voltage (measured while welding), and the voltage drop through the welding arc, weld cables, and cable connections.

Longitudinal: Generally refers to the measured length of a weld.

Low OCV Stick™: Reduces OCV when the power source is not in use, eliminating the need for add-on voltage reducers.

LVC™ (Line Voltage Compensation): Keeps the output of a power source constant, regardless of minor fluctuations in input power.

M

Machine Welding: (Mechanized Welding) Uses equipment which welds by an operator manually adjusting and setting mechanical controls to complete the weld.

MAG: The abbreviation for Metal Active Gas. A shop term used mostly in Europe for the Gas Metal Arc Welding process.

Mechanical Properties: Properties that relate to how a metal will withstand various stresses placed on it.

Melt-through: Visible root reinforcement produced in a joint welded from one side.

Metal Cored Composite Electrodes: Made up of alloying materials encased in a metal sheathing. Arc stabilizers or fluxes may be included, and external shielding is usually required. This type of electrode wire is normally used for depositing more metal with no additional heat in less time than solid wires. Metal Cored wire do not produce any slag and are classified the same as a Solid wire electrode.

Metal: Any of a class of chemical elements such as iron, copper, etc., that have luster, are ductile, malleable and can conduct heat and electricity.

Metallurgy: Originally used to describe the work which had to be done to release metal from the ores in which they are found. Its application has expanded to include a wide range of aspects concerning metals, including their weldability.

Microprocessor: Integrated circuits that contain a processor that can be programmed with stored instructions to perform a variety of arithmetic and logical functions.

MIG: The abbreviation for Metal Inert Gas. A shop term for the Gas Metal Arc Welding process.

Mismatch (Weld Joint Mismatch): Misalignment of the weld joint pieces. When pipes are out of round or egg-shaped, their butting surfaces will not match up if the pipe ends are brought together. Also referred to as High-Low.

Molten Metal: Metal that is at a temperature above its molten or liquid state. Metal must be in its liquid state for fusion to take place.

Multiple Pass: More than one pass required to complete a joint, passes could be stringer or weave beads.

MVP™ (Multi-Voltage Plug): Allows connection to 115 or 230 - volt receptacles without tools— just choose the plug that fits the receptacle.

N

Nonferrous: Refers to a metal that contains no iron, such as aluminum, copper, bronze, brass, tin, lead, gold, silver, etc.

O

Open Circuit Voltage (OCV): As the name implies, no current is flowing in the circuit because the circuit is open. The voltage is impressed upon the circuit, however, when the circuit is completed; the current will flow immediately. For example, a welding machine that has the output turned on but is not being used for welding at the moment will have an open circuit voltage applied to the output terminals of the welding machine.

Oscillator: Device that can provide a side-to-side motion of the welding gun to produce a programmed weave.

Output Control: An electrical switch that is used to energize or de-energize output terminals of a welding machine. In some types of welding machines they can be of solid state design, with no moving parts and thus no arcing of contact points.

Overaging: The precipitation and growth of a greater than normal amount of the elements or compounds from a supersaturated solution. The result in some circumstances can be reduced strength and corrosion resistance but in other circumstances can result in improved corrosion resistance and other properties.

Overhead Position: When welding is performed on the bottom of the joint. For example: the letter "T" illustrates an overhead double sided fillet weld.

Overlap: The protrusion of weld metal beyond the weld toe or weld root.

P

Palm OS Compatibility: Replaces the need for data cards and remote control pendants on Axcess® models.

Parameters: The welding settings on a welding machine such as voltage and amperage and normally read on a voltmeter and an ammeter. Parameters may also include things as travel speed, electrode size, torch angle, electrode extension, weld joint position and preparation, and other documented variables to produce a weld.

Parent Metal: Another name for base metal. The metal that is being welded or cut.

Peak Amperage: The higher of the two currents in the GMAW-P or GTAW-P pulsing waveform.

Penetration: The nonstandard term used to describe the following:

- **Depth of Fusion:** The distance from the surface melted during welding to the extent of the fusion into the base metal or previous weld bead.
- **Joint Penetration:** The depth that a weld extends from the weld face into the joint, minus reinforcement. Joint penetration may include root penetration.
- **Root Penetration:** The depth that a weld extends into the root of a joint.
- **Complete Joint Penetration:** Occurs when the "filler" metal completely fills the groove, and good fusion to the base metal is present.
- **Incomplete Joint Penetration:** A condition in the root of a groove weld when the weld metal does not extend through the joint thickness. This is generally considered a defect when the joint by design was to have complete joint penetration.
- **Partial Joint Penetration:** A condition in the root of a groove weld when the weld metal does not extend through the joint thickness. By design this may be acceptable and not a defect because it will carry the load for which it was intended.

Phase: For welding, phase refers to what type of AC power is provided to the welding machine by way of primary line voltage. Welding machines usually require either single- or three-phase power.

PhaseShift Technology™: In multiple-torch SAW operations, PhaseShift Technology™ allows the AC welding power source to guarantee arc stability by enabling the welding machines to communicate and coordinate sine wave polarities and phase delays.

Physical Properties: Properties of a metal that deal with factors other than strength. Physical properties include a metal's weight and its ability to resist rusting and to conduct electricity.

Plasma: The electrically charged, heated ionized gas which conducts welding current in a welding arc.

Plasma Arc Cutting (PAC): An arc cutting process which severs metal by using a constricted arc to melt a small area of the work. This process can cut all metals that conduct electricity.

Plasma Arc Gouging (PAG): An electric arc process that produces a groove in the metal being gouged. This process is used to remove defective welds or defects in the base metal as well as for weld joint preparation.

Plug Welding: A weld made by filling (or partially filling) a hole in one member of a joint, fusing that member to another member.

Polarity: Refers to the direction of current flow such as electrode positive or negative. Is primarily concerned with direct current since DC flows in one direction only.

Porosity: A void in a weld caused by trapped gases. They are usually round in shape and can be on or under the surface of the weld.

Positioner: A device which moves the weldment when a stationary arc is used. Positioners include turning rolls, head and tail stocks, and turntables.

Pounds Per Square Inch (psi): Mass or weight measured in pounds applied to one square inch of surface area.

Power Efficiency: How well an electrical machine uses the incoming or primary electrical power.

Power Factor Correction (PFC): Normally used on single-phase, constant current power sources to reduce the amount of peak primary amperage demanded from the power company while welding. To reduce the power used while welding vs. a non-PFC machine, the PFC machine will draw more power during the non welding time and will actually use more electricity overall than a non-PFC machine.

Primary Power: Often referred to as the input line voltage and amperage available to the welding machine from the shop's main power line. Primary input power is a high voltage and low amperage, single-phase or three-phase, AC power. Welding machines with the capability of accepting more than one primary input voltage and amperage must be properly connected or linked for the incoming primary power being used. See auto-link.

Pro-Pulse™: An easier-to-use pulse welding method than conventional pulse for pipe welding applications. Offers precise arc and puddle control even in narrow weld joints, providing optimum molten puddle control for out-of-position welding.

Profile Pulse™: Pulsed MIG process which produces a stacked dime bead profile without the operator having to manually manipulate his welding torch to do so. Appearance is similar to an aluminum TIG weld.

Puddle: See Weld Pool.

Pulse Frequency (PPS): The number of peak current pulses which occur in one second of time.

Pulse Width: Duration of the peak current level, measured in milliseconds.

Pulsed MIG (GMAW-P): A modified spray transfer process that produces no spatter because the wire does not touch the weld puddle. A microprocessor controls the pulsing variables and essentially changes the current levels between a peak current and a low current anywhere from .01 to hundreds of pulses per second. Applications best suited for pulsed MIG are those currently using the short circuit transfer method for welding steel, 14 gauge (1.8 mm) and up, to increase travel speeds and deposition rates.

Pulsed TIG (GTAW-P): A modified TIG process appropriate for welding thinner materials. It alternates the current between a high level (peak amperage) and a low level (background amperage) for a determined number of pulses per second (PPS). This results in a lower average heat input as well as puddle agitation, and a more constrictive or shaped arc.

Pulsing: Varying the current from a high peak amperage level to a lower background amperage level at regular intervals. Pulse controls also adjust for the number of pulses per second and the percent of time spent at the peak amperage level. Pulsing is used to control heat input and allow for improved weld profile.

Pure Tungsten (EWP): An electrode used for GTAW welding. It is made from pure tungsten with no added elements. Used for AC welding with non-inverter AC welding power supplies. It is identified by a green band.

Purging: Cleaning, purifying or removing something from a container.

Push Angle: The travel angle when the electrode is pointed forward toward the direction of travel. Sometimes referred to as forehand welding.

Q

Quenching: The dipping of a heated metal into water, oil or other liquid to cool a metal to obtain necessary hardness.

R

Rapid Set: Electrodes which produce a molten puddle that quickly solidifies after heat of the arc is removed.

Rated Load/Rated Output: The amperage and voltage the welding power source is designed to produce for a given specific duty cycle period. For example, 300 amps, 32 load volts, at 60% duty cycle.

Reactor: For welding purposes, a reactor is a device within the welding machine which allows a welder some degree of slope control. For example, a 14-turn slope reactor would have 14 wraps of wire around the reactor iron core. See Slope.

Rectifier: An electrical device that allows the flow of electricity in basically only one direction. Its purpose is to change alternating current (AC) to direct current (DC). Rectifiers are usually made up of diodes.

Reduction of Area: The difference between finished area and the original cross section area, when expressed as a percentage of the original area,

Residual Stress: The stress remaining in a metal resulting from thermal or mechanical treatment, or both. When welding, stress results when the melted material expands and then cools and contracts. Residual stresses can cause distortion as well as premature weld failures.

Resistance: The opposition to the flow of electrical current. This opposition to electric flow changes electric energy into heat energy.

Resistance Grid: A device containing resistive coils, and put into a welding circuit between the welding machine and stick electrode cable and holder. Its function is to put resistance into the welding circuit and change the shape of the volt-amp curve to provide "droop". A resistance grid lowers the effective short circuiting amperage value and allows SMAW to be done from a CV welding machine. Resistance grids are also used on a special type of welding machine where one welding machine alone supplies power for many welding arcs.

Resistance Spot Welding (RSW): A process in which two pieces of metal are joined by passing current between electrodes positioned on opposite sides of the pieces to be welded. There is no arc with this process, and it is the resistance of the metal to the current flow that causes the fusion. This process has four main variables: squeeze force, time, tip shape, and amperage.

Response Time: The time it takes for a welding machine to go from OCV to a short circuit, and then to a welding voltage and amperage.

Reverse Polarity: A nonstandard term denoting electron flow from the workpiece to the electrode. Direct Current Electrode Positive (DCEP) is the terminology used to clearly identify this direct current polarity.

Ripple: The pattern seen in the face of a weld and caused by the freezing of the molten metal as the arc moves out of the area. Ripple also refers to the DC weld output oscilloscope reading to indicate how smooth it is. A DC current with a lot of ripple does not produce a smooth welding arc.

RMD™ (Regulated Metal Deposition): A welding process that produces a precisely controlled short-circuit transfer. It is a method of detecting when the short is going to clear and then rapidly reacting to this data by changing the current (amperage) levels.

RMS (Root Mean Square): The "effective" values of measured AC voltage or amperage. RMS equals 0.707 times the maximum, or peak value.

Robotic Welding (Programmable Automation): Automation that is completely controlled and performed by machinery (such as a robot) and has the capacity to be reprogrammed to perform another task.

Root: The deepest point of fusion in a weld bead, or on a joint where the joint members are in the closest point of contact in the weld area.

Root Face: That portion of the groove face adjacent to the root of the joint, also referred to as the land.

Root Opening: The separation of the members of a joint. The purpose is to allow better fusion and penetration to take place. Often referred to as the "gap".

Root Pass: The first weld bead placed into a joint. This pass must fuse both members together with adequate fusion and penetration.

S

Scavenger: The material placed in the coating of electrode for the purpose of removing impurities in the weld metal and base metal.

Schedule No.: These numbers refer to the wall thickness of the pipe. The larger the number, the heavier the wall thickness.

SCR: Silicon Controlled Rectifier. Often used to change AC current to DC. It also functions as an output control device for regulating the current/voltage and arc off-on ability.

Secondary Power: Refers to the actual power output of a welding machine. This includes the load voltage while welding (measured at the output terminals) and the current (amperage) flowing in the circuit outside the welding machine. Secondary amperage can be measured at any point along the secondary circuit.

Semiautomatic Welding (SA): Equipment that is both manually and automatically controlled where one or more of the welding variables is automatic and the others are performed by hand.

Sensitization: The changing of a stainless steel's physical properties when exposed to a temperature range of 800° to 1600° F (426° to 871° C) for a critical period of time. See also Carbide Precipitation.

Sequencing: The control over all aspects of the weld. This would include the pre-flow, weld start, initial current, initial current time, upslope time, weld current level, weld current time, final slope, final current level, final current time and post-flow.

SharpArc®: Optimizes the size and shape of the arc cone, bead width and appearance, and puddle fluidity.

Shielded Metal Arc Welding (SMAW): An arc welding process which melts and joins metals by heating them with an electric arc created between a covered metal electrode and the work. Shielding gas is obtained from the electrode outer coating, often called flux. Filler metal is primarily obtained from the electrode core. This process is commonly referred to as Stick Welding.

Shielding Gas: Protective gas used to prevent atmospheric contamination of the weld pool.

Short Circuit Transfer (SCMT or GMAW-S): Short Circuit Gas Metal Arc Welding. A method of GMAW arc transfer in which metal is deposited only when the wire actually touches the work. No metal is transferred across the open arc.

Sine Wave: A traditional AC welding arc cycle shape common in equipment produced before 1976. It was the foundation to build the Squarewave AC arc primary power is delivered using a sine wave profile. Used as a choice in inverters for welders that like a traditional arc (quiet with good puddle fluidity).

Single Phase: When an electrical circuit produces only one alternating cycle within a 360 degree time span. This circuit will have two primary voltage wires and one earth ground wire.

Slag: The covering left on a weld bead after welding with coated electrodes. The slag contains the impurities from the weld metal and base metal along with the unburned coating residue. If this material becomes trapped in the weld, it is referred to as an inclusion.

Slope: Slope refers to the shape of the volt-amp curve. By varying the amount of slope in the welding circuit, a welder can change the amount of short circuit current and, in some cases, the welding machine's rate of response.

Slot Welding: A weld made by filling (or partially filling) an external hole (slot) in one member of a joint, fusing that member to another member. The hole (slot) may be completely enclosed, or it may be open at one end.

Smart Fuel Tank: Tank's design minimizes chance of fuel backflow when refueling.

Smooth Start™: Provides a smooth, spatter free start to the MIG weld.

Soft Squarewave: A modified AC waveform that allows an inverter AC welding arc to have an arc similar to a standard Squarewave AC weld profile (Syncrowave series power supplies). It is used to create a soft, buttery arc with maximum puddle control and good wetting action.

Solder: A non-ferrous filler metal that has a melting point below 800°F (427°C). Usually used for electrical connections.

Solenoid: An electrical device which either stops or permits the flow of water used to cool a welding gun or the flow of gas used to shield the weld puddle and arc.

Solid Solubility: When an alloy consisting of two metals is heated to an elevated temperature, but below the melting point, the amount of one metal in solution in the other is said to be its solid solubility. For example, solid aluminum can, if the temperature is high enough, dissolve copper up to 5.6% of its weight, which is termed its solid solubility limit.

Solidus: The temperature at which all the constituents in an alloy have solidified.

Spatter: Molten metal particles thrown out of the arc which do not become part of the weld bead. This loss contributes to the deposition rate of a welding process and the deposition efficiency of a wire

Spot Welding: Usually made on materials having some type of overlapping joint design. Can refer to resistance, MIG, or TIG spot welding. Resistance spot welds are made from electrodes on both sides of the joint, while TIG and MIG spots are made from one side only.

Spray Transfer: Movement of a stream of tiny molten droplets across the arc from the electrode to the weld puddle.

Squarewave AC: The AC output of a power source that has the ability to rapidly switch between the positive and negative half cycles of alternating current that are square in shape when observed on an oscilloscope. Advanced squarewave is an enhanced version of this output waveform.

Stabilizer: Power Supply: A coil with an iron core, used in a DC welding machine to smooth or "stabilize" the welding arc. (See Inductor). High frequency is also referred to as a stabilizer (see High Frequency) Filler metal: See Arc Stabilizer

Stick Welding: A nonstandard term for the Shielded Metal Arc Welding process.

Stitch: A manipulation technique used to help control the molten puddle and penetration.

Straight Polarity: A nonstandard term denoting electron flow from the electrode to the workpiece. Direct Current Electrode Negative (DCEN) is the terminology used to clearly identify this direct current polarity.

Strain: The change in shape of metal caused by an internal or external force acting upon it.

Strain Hardening: A method of increasing the strength of a metal by cold-working it. Alloys which respond to cold-working are said to be strain-hardenable.

Stress: Is the force acting upon a metal. It can be an internal force or an external force.

Stress Relief Heat Treatment: The heating of a structure or a portion of a structure to a particular temperature. This is to relieve the majority of residual stresses, and is followed by the uniform cooling of the structure or structure portion.

Stringer Bead: A weld bead that is deposited without any side to side motion of the electrode as it is moved along the metal.

Stripper Pass: A nonstandard term used to describe fill passes that fill a pipe joint to a near flush contour before a cover pass is applied. Most often used when using a vertical down technique.

Submerged Arc Welding (SAW): A process by which metals are joined by an arc or arcs between a bare metal electrode or electrodes and the work. Shielding is supplied by a granular, fusible material usually brought to the work from a flux hopper. Filler metal comes from the electrode and sometimes from a second filler rod.

Suck Back: The same as a concave root surface, caused by excess heat, improper joint design, and improper welding techniques.

SunVision™: Allows easy reading of digital meters in direct sunlight or shade.

SureStart™: Provides consistent arc starts by precisely controlling power levels for specific wire and gas combinations.

Surfacing: Depositing filler metal on base metal in order to obtain certain metal properties or specific dimensions.

Syncro Start™: Allows selectable customized arc starts on Syncrowave® series power supplies.

Synergic: Synergic refers to the unit's ability to use pre-programmed pulse parameters in order to determine the actual pulse settings of peak amperage, background amperage, pulse frequency, and pulse width at any specific wire feed speed setting.

T

Tee Joint: When two members are located approximately 90° to each other in the form of a "T."

Tempering: A heat treatment process that "toughens" the metal. It is the balance of strength and ductility.

Tensile Strength: Is the resistance a metal has to being pulled apart.

Thermal Conductivity: The property a material has that allows heat to pass through it. A good heat conducting metal would be one that allows heat to pass through it very rapidly.

Thermal Expansion: The comparison of expansion and contraction of metals.

Thoriated Tungsten (EWTh 1, 2): An electrode used for GTAW welding. It is made from tungsten with a small amount of thorium added. Improves arc starting and provides for use of wider current ranges for DC welding. It is identified by a red band.

Three Phase: When an electrical circuit delivers three cycles within a 360 degree time span, and the cycles are 120 electrical degrees apart. A three-phase circuit has three primary voltage wires and one earth ground wire.

Tie-ins: The location where one weld bead attaches to another.

TIG: The abbreviation for Tungsten Inert Gas. An industry accepted term for Gas Tungsten Arc Welding.

Tip Saver Short Circuit Protection™: Shuts down output when the MIG contact tip is shorted to the work. Extends contact tip life and protects the machine. Trigger reset permits quick reset at the gun rather than at machine.

Toe: The point where the face of the weld and the base metal meet.

Torch: A device used in the GTAW process to control the position of the electrode, to transfer current to the arc, and to direct the flow of shielding gas. A GMAW Gun is also referred to as a torch.

Torch Detection™: A circuit that enables some power supplies to detect if a GTAW torch is water- or air-cooled.

Touch Start: See Lift-Arc™

Toughness: The energy or stress that can be absorbed by a material (the area under the entire stress-strain diagram) up to the point of fracture

Transformer: A device that changes AC voltage from one magnitude to another. Typically used to reduce high primary voltages to lower welding voltages.

Transitional Parameters: A transition point occurs when metal transfer changes, such as when a short circuit transfer becomes a globular transfer or a globular transfer becomes a spray transfer. This can happen when the voltage and amperage settings are too high for a short circuit transfer, or too low for a spray transfer.

Transverse: A measurement made across an object, or basically at or near a right angle to a longitudinal measurement.

Travel Angle: The angle at which the gun is positioned from perpendicular as the weld progresses. Travel angles are usually 5 to 15°.

Triangular wave: A triangular shaped AC wave from an inverter power supply that reduces the heat input and is good on thin aluminum. It produces fast travel speeds.

Tri-Cor™ Technology: A welding arc stabilizer design that delivers smoother welds and decreases spatter with E-7018 electrodes without sacrificing performance with E-6010 electrodes.

Tungsten: Rare metallic element with an extremely high melting point of 6,000°F (3410°C). Used in manufacturing GTAW electrodes.

U

Ultra-Quick Connect™: Offers the fastest plasma torch and work cable connection and removal in the industry.

Ultra-Violet: Invisible rays given off by a welding arc. There is no easy way to detect their presence as with the heat from infrared rays, but they can produce a very damaging effect on the eyes if proper eye protection is not worn.

Undercut: A groove melted into the base metal usually along the toes or root of the weld. Since this is a weak spot in the weld, if too large it may be considered a defect and must be corrected.

V

Vertical Position: When the axis of the weld is vertical and the weld face is also vertically placed up or down.

Voltage: The pressure or force that pushes the electricity through a conductor. Voltage does not flow but causes amperage or current to flow. Voltage is sometimes termed Electro Motive Force (EMF) or difference in potential. Voltage has the most effect on the height and width of the weld bead.

Voltage-Sensing Wire Feeder: A wire feeder that operates from the arc voltage generated by the welding power source.

Volt/Amp Curve: Graph that shows the output characteristics of a welding power source. Shows voltage and amperage capabilities of a specific machine.

W

Wagon Tracks: Defect within a weld resulting in an inclusion or a void along both toes of a bead in a weld.

WaveWriter™ File Management: Includes all Axcess™ File Management functions, plus a simple, graphical wave-shaping program for the most demanding GMAW applications.

Weave Bead: The side to side motion or oscillation of the electrode while traveling along a joint. The purpose of a weave is to increase the volume of the weld bead.

Weld at Idle™: Allows certain engine drives to automatically weld at a quieter, lower RPM, using less fuel. When more output is required, the machine goes to high speed without a change in the arc.

Weld Axis: An imaginary line that runs lengthwise through the geometric center of a welds cross section.

Weld Metal: The electrode and base metal that was melted while welding which forms the welding bead.

Weld Pool: The liquid state of a weld prior to its becoming solid weld metal.

Weld Root: When looking at the weld profile or cross section, it is the deepest point or points the weld fused into the joint root.

Weld Transfer: Method by which metal is transferred from the wire to the molten puddle. There are several methods used in GMAW; they include short circuit transfer, spray arc transfer, globular transfer, and pulsed arc transfer.

Weldability: A qualitative evaluation of the ease with which a metal or alloy can be welded to produce sound joints with desirable properties.

Welder: Used to describe a welding machine or a person who performs manual or semiautomatic welding. The term "weldor" is now rarely used to describe the person performing the weld.

Welder Certification: The actual written words or a document given to a person who has passed a weld test.

Welder Performance Qualification (WPQ): The actual taking of a test by welding with a particular process. Also, the passing or failing of such a test according to specific standards. Often referred to as a welder qualification test.

Welding Operator: A person who operates machine or automatic welding equipment.

Welding Procedure: Written instructions to assure quality welds. This includes the details for welding a particular joint—details such as materials to be used, process, methods and specific welding symbols.

Welding Procedure Specification (WPS): A list of detailed guidelines that must be followed when welding specific material or parts to meet requirements established by welding codes.

Welding Symbol Bracket: Consists of a reference line, arrow, and sometimes a tail for identifying specific process information.

Weldment: Refers to the finished assembly when two or more pieces of material are joined by welding.

Wet Out: Flattening out of a weld deposit due to the heat generated in the arc area.

Whip or Whip and Pause: A welding technique often referred to as stitch welding which is a uniform shortening and lengthening of the arc at the same time moving the arc ahead of and then back into the puddle. Its purpose is to allow the puddle to cool and give the welder more control over penetration and fusion. A whip is also a non-standard term for an SMAW Electrode holder and lead.

Wind Tunnel Technology™: Internal air flow on many Miller inverters, that protects electrical components and PC boards from contamination, significantly improving reliability.

Wire Feed Speed (WFS): Expressed in meters per minute or inches per minute, and refers to the speed and amount of filler metal fed into a weld. Generally speaking, the higher the wire feed speed, the higher the amperage.

Work Angle: The angle between the workpiece and the centerline of the electrode. On a flat plate square butt weld, a normal work angle would be 90° to the work surface.

Work Cable (Work Lead): The conductor cable or electrical conductor between the arc welding machine's output terminal and the work.

Work Connection: A means to fasten the work lead (work cable) to the work (metal to be welded on). Also, the point at which this connection is made. The quality of this connection will have an affect on the welding machine's ability to transfer the arc.

Wrought Alloys: Alloys which are suitable for service when the final form is to be achieved by a process of shaping such as rolling, extruding, or forging.

X

X-ray: A non-destructive weld inspection method using x-rays to view the inside of a weld without damaging the weld.

Y

Yield Point: See Yield Strength.

Yield Strength: The stress required to produce a permanent strain or change in shape after the load is removed.

Z

Zirconiated Tungsten (EWZr 2): An electrode used for GTAW welding. It is made from tungsten with a small amount of zirconium added. It combines the desirable effects of pure tungsten and provides wider current ranges for AC welding. It is identified by a brown band.