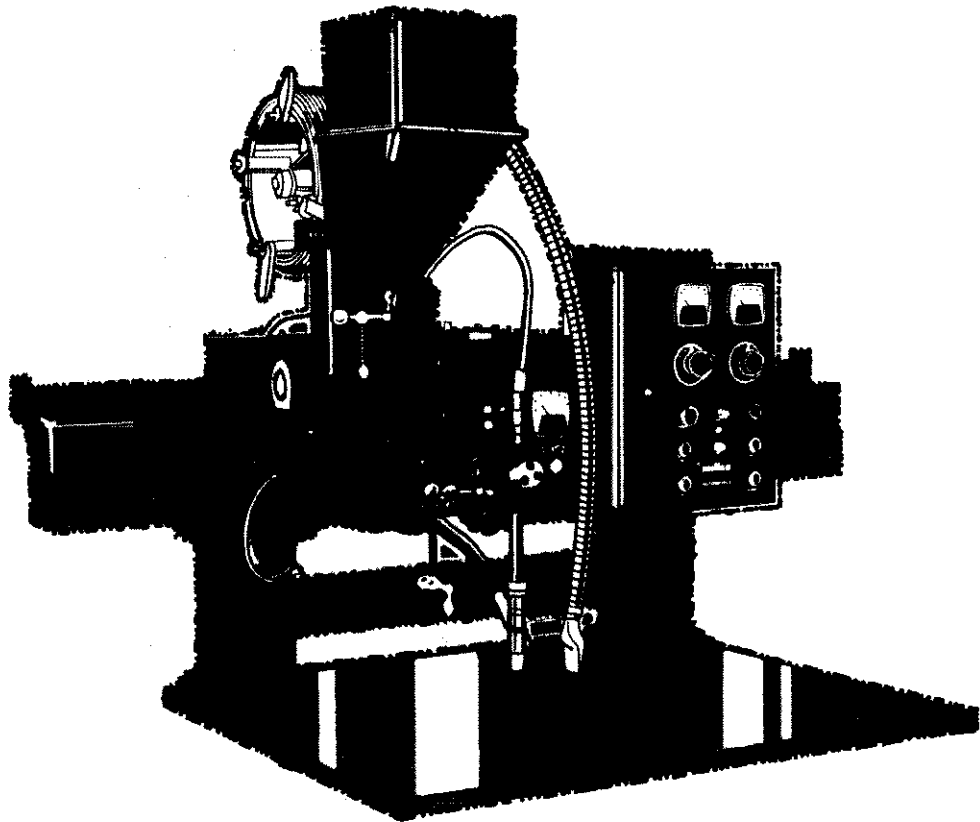


**Miller**®

# SUBMERGED ARC WELDING



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## PREFACE

The material contained within is current technical information on the application of the Submerged Arc Welding (SAW) process. It goes without saying that new, up-to-date technical data is changing continuously. However, basic information is always beneficial, and it is hoped that this book will be helpful in that respect. All recommendations in this book are approximate values. We suggest that any welds or weldments be tested to assure that all codes and specifications are met.

MILLER Electric Mfg. Co.

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# SUBMERGED ARC WELDING

## GENERAL

Submerged Arc Welding (SAW), or Sub Arc as it's generally referred to, is a unique welding process because there is no visible evidence that a weld is being made. The welding zone is completely shielded by a blanket of granular flux. Exposed arc eye protection is not normally used since the arc should be completely covered. The welding operator must, however, employ good safety practices to assure protection of the eyes and face. By contacting the American Welding Society (AWS), 550 NW LeJeune Road, P.O. Box 351040, Miami, Florida 33135. Safety Manual Z49.1 *Safety in Welding and Cutting* can be obtained.

Any arc welding process can produce fumes and gases that could be harmful to health. Always maintain good ventilation in welding areas. Use special care in confined spaces.

The American Welding Society (AWS) defines Submerged Arc Welding (SAW) as follows:

*"An arc welding process which produces coalescence of metals by heating them with an arc or arcs between a bare metal electrode or electrodes and the work. The arc and molten metal are shielded by a blanket of granular, fusible material on the work. Pressure is not used, and filler metal is obtained from the electrodes and sometimes from a supplemental source (welding rod, flux or metal granules)."*

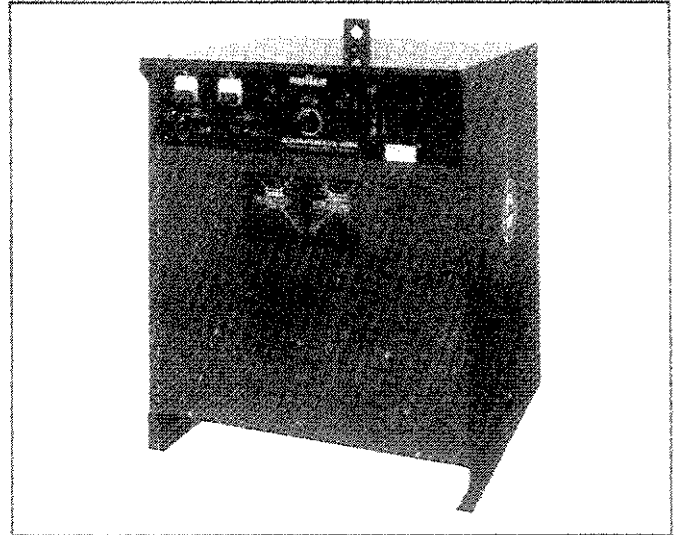
This process has been used successfully for years to produce high quality welds in compliance with such code agencies as: ASME, AWS, API and the American Bureau of Shipping. Submerged Arc Welding has found usage in nearly all industries.

Semiautomatic and Automatic Sub Arc have some advantages, such as:

1. Higher deposition enhances welding speed or production.
2. Deep penetration in some cases may eliminate joint preparation.
3. Excellent mechanical properties for high quality code and X ray requirements.
4. Improves welding operator comfort and appeal.

## EQUIPMENT

The basic welding equipment requirements for the process include a power source, wire feed control and drive assembly, a welding gun, a flux delivery system and fixturing.



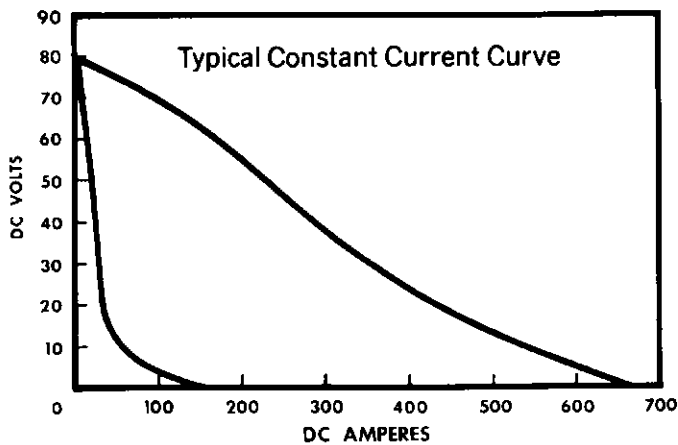
*Submerged Arc Welding Power Source*

## POWER SOURCES

The POWER SOURCE is usually the first piece of equipment selected. Because the process is often fully automated, the power source must be capable of an output and of a duty cycle to match the operation. The thickness of the material to be welded will dictate the amperage requirements. Light gauge material may require as few as 300 amps, while heavy material can require 1,000 amps or more.

### Constant Current

With a CONSTANT CURRENT POWER SOURCE (this type is characterized by the relatively steep downward slope of the volt/amp curve), a voltage sensing wire feeder is sometimes used. The voltage sensing feeder is designed to increase the speed of the wire feed motor when the arc voltage increases and reduces the speed of the wire feed motor when the voltage decreases. This maintains a fairly constant arc voltage and arc length, but does not give a consistent deposition rate.

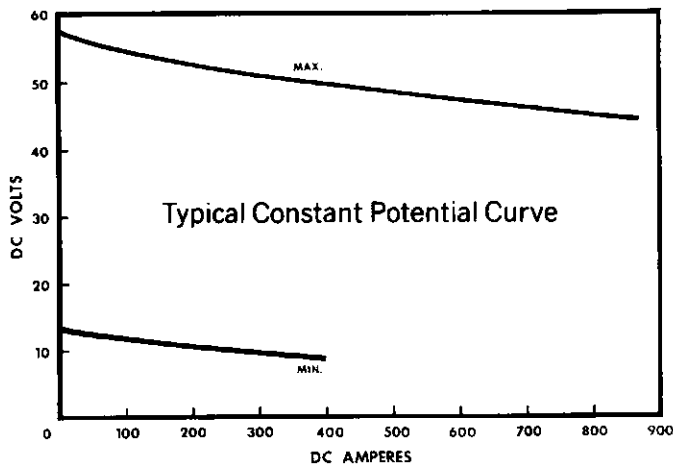


The constant current power source and voltage sensing feeder is more difficult to set because the adjustments of either the power source or the feeder can cause a change in the other.

## Constant Potential

It is more common, however, for a constant potential power source to be used. The CP power source has an almost flat, or horizontal volt/amp curve. The voltage is held relatively constant by the power source and the amperage is determined by the speed of the electrode.

As the wire feed speed is increased, more amperage is required to burn off the wire. Conversely, when the wire feed speed is decreased, less amperage is required. The voltage is set on the power source. This system simplifies the adjustment of the equipment settings because of this tendency for self-regulation.



## AC Power Supplies

Alternating Current (AC) square wave, constant potential (CP) power sources have been a major advancement over conventional AC/CC power supplies with the submerged arc process. The designated application of these power supplies is to deep groove joints, preferably straight butt, 2 degree included angle. This reduces joint preparation and weld time considerably, sometimes as much as 50 percent. The ability to weld joints in thick material (2 to 8") with 1/2" root openings, good sidewall

fusion, no slag entrapment and considerable savings in both wire and weld time are some of the benefits now realized with this process. Sometimes a square butt is not practical, however, experience has shown that the Square Wave power source will allow a reduction in the included angle of most joint designs.

Because of the shape of the sine wave output on conventional AC power sources, there is a tendency for the arc to go out as the current passes through the zero point. During reignition of the arc, the electrode may stub which can cause a defect in the weld. The Square Wave power source output, with extremely rapid transitions through zero, reduces the problems associated with arc outages. This feature greatly reduces arc starting difficulties.

One problem often encountered with DC Sub Arc is magnetic arc blow. With arc blow, there is a tendency for the arc to "wander" to one side of the groove as it is affected by the magnetic field produced by DC current. Because the Square Wave 1000 power source is an AC power source, this problem is virtually eliminated.

The alternating pass concept, one toward each sidewall, is recommended. One bridging pass from wall to wall promotes centerline cracking and slag entrapment, and is not normally recommended.

The Square Wave power sources are also applied to lead or trailing arc applications used in combination with DC power sources.

The Square Wave power source has been proven to work well with most AC fluxes and some DC fluxes. If you contemplate a change from conventional AC or DC power supplies (CC) to the square wave (CP) concept, your application should allow a change of flux, joint design and weld parameters compatible with the Square Wave power source's performance.

Because this power source is a constant potential, not a constant current unit, the weld parameters (voltage or amperage) are easier to set. Constant speed wire feeding equipment designed for SAW, GMAW or FCAW can also be used. Remote control capabilities are easily accomplished because of the solid state design.

In all cases, before an AC power supply can be recommended for the semiautomatic process, it should be investigated to see that the unit has the proper remote capabilities, OCV and amperage capacity, etc. for the application.

## WIRE FEEDING

Virtually any wire feeder used in the Gas Metal Arc or Flux Cored Arc Welding processes can be used for the Sub Arc process provided it will feed the required wire size at the right speed. For a semi-automatic sub arc system, a standard wire feeder is normally used. If using a constant current type power source, special wire feeders that change feed rates in response to the arc voltage changes are sometimes used.

When automated equipment and large wires are used, it is advantageous to have "run in" wire speed control to assist with arc starts. "Crater fill" features are sometimes

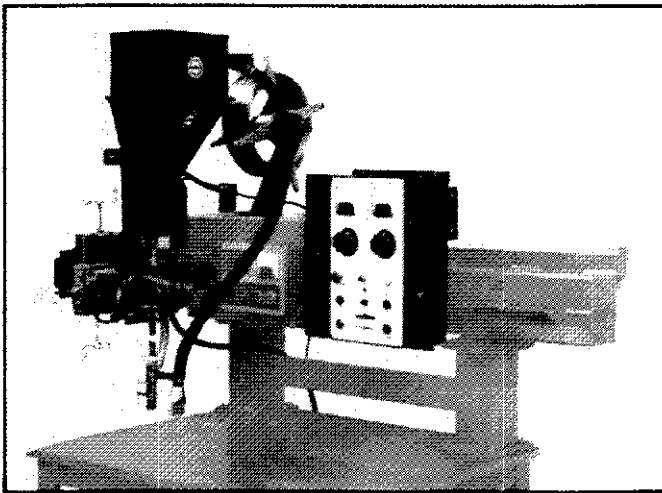
used to minimize the weld crater at the finish of the weld.

A burnback control is beneficial to both semi-automatic and automatic systems to prevent the wire from sticking to the weld puddle at the end of a weld.

When electric flux feeding equipment is used, a preflow/preflux circuit is advantageous.

When all these features are required, automatic equipment is normally used. However in both cases, semi-automatic or automatic, it is important to check the feeder features and speed range to assure the proper IPM can be maintained for the size wire to be used.

AC or DC power sources may be used with a wire feeding system. However, some units have meters and controls which must be properly coordinated for AC or DC operation.

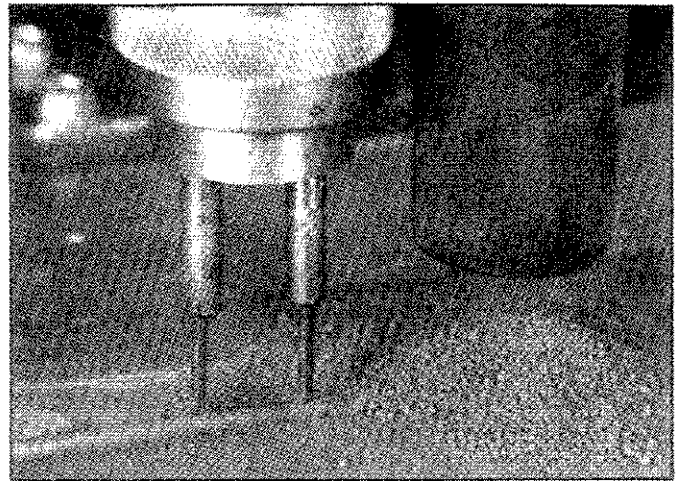


**Automatic wire feeding equipment with side beam.**

DUAL WIRE feeding systems have special drive head assemblies and guns. Two wires of the same size are fed together using a common power supply, control panel, wire drive assembly and gun into one weld metal deposit. The gun is constructed to allow the two wires to be run lead/trail, side by side or staggered to adapt to different joint designs.

Although this system is not used extensively, some of its advantages are higher deposition and travel speed. When this system is employed, usually only wire sizes from .045" to 3/32" are used—most commonly .045" and 1/16".

Either constant current or constant voltage power sources can be used with this feeding system, however, the self-regulating characteristic of constant voltage is desired.



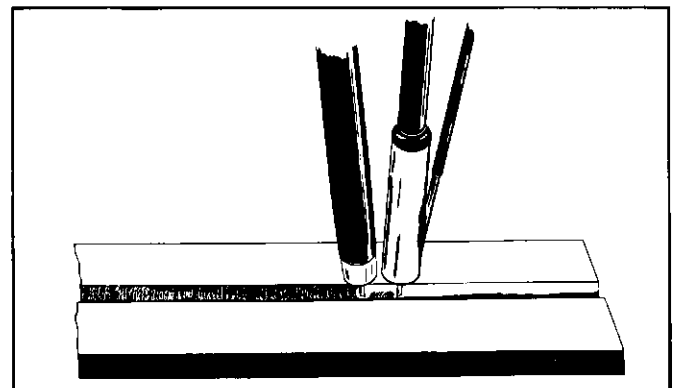
**Dual Wire**

TANDEM WIRE systems require two power supplies, two control panels, two wire drive assemblies and two guns mounted lead/trail so both wires are fed into a common puddle, but only the lead gun requires a flux delivery system. The gun spacing on this system must be close enough to allow the second wire (trail arc) to pass through the molten (unsolidified) flux. The spacing required depends on the application, current, travel speed, flux, polarity, fixturing, workpiece, etc. In the majority of cases, a gun spacing of 5/8" to 1" spacing is used to produce narrower beads with deeper penetration. Wider gun spacing increases bead width, reduces penetration and arc stability.

Wire sizes of 3/32" and larger are usually used with this system to take advantage of higher deposition and travel speeds. There is, of course, the possibility of using 3 or 4 wires to try to maximize these advantages, however, the equipment mass required becomes a detriment and operator problems are often encountered.

Another side effect of these systems that could be undesirable is the fact that arc blow or arc interaction is usually severe. It is normally required to mix AC and DC power sources (AC - DC), (DC - AC - DC) properly to minimize this arc interaction.

The multi-wire systems are used in most cases where the welds are very large and/or long. These systems help to minimize the additional setup and/or weld time required.

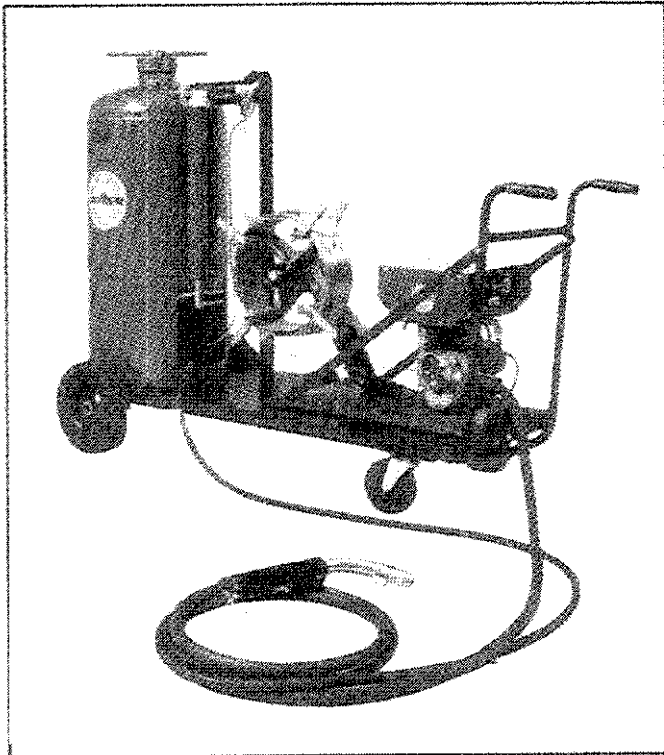


**Tandem Wire Systems**

## SEMI AUTOMATIC SUBMERGED ARC

In many ways, semiautomatic hand held Sub Arc is identical to automatic Sub Arc. Some hand held Sub Arc arrangements have easily been converted to automatic by tooling and fixturing.

Hand held Sub Arc most commonly utilizes 1/16", 5/64" and 3/32" wire diameters. Its main advantage is its portability and the deep penetration common to Sub Arc. This process lends itself well to thick material applications of easy access. Semiautomatic applications are usually limited to fillet welds or grooved butt joints where the gun nozzle can be dragged along the joint for a guide.



**Semiautomatic Equipment**

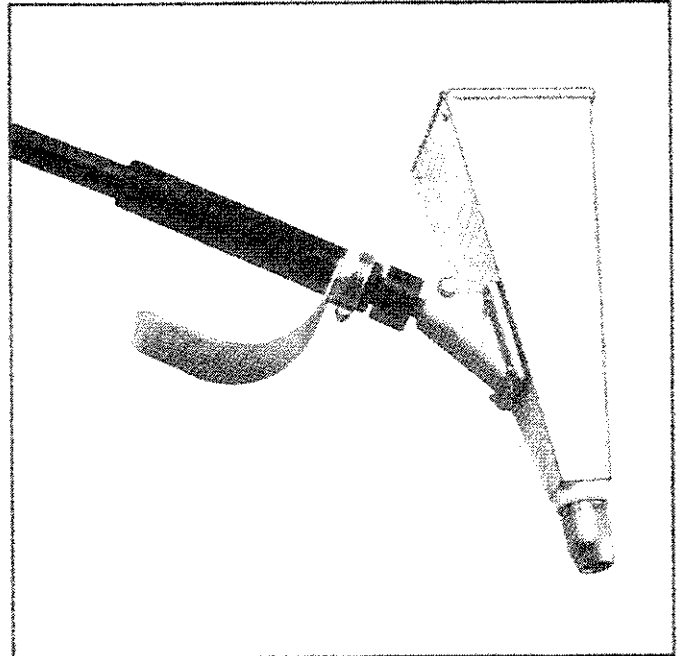
Disadvantages may be the lack of adaptability to thin materials as welding operators find it difficult to travel fast and steady enough to avoid melt-thru. The flux pile has a tendency to hide the weld joint making it difficult for the welding operator to follow the joint. Another disadvantage may be the difficulty in recovering unfused flux for reuse.

Although automatic and semiautomatic Sub Arc are similar in many areas, there are some differences in semiautomatic that need describing: 1) flux feeding, 2) arc starting, 3) gun positions and 4) extensions.

### Flux Feeding

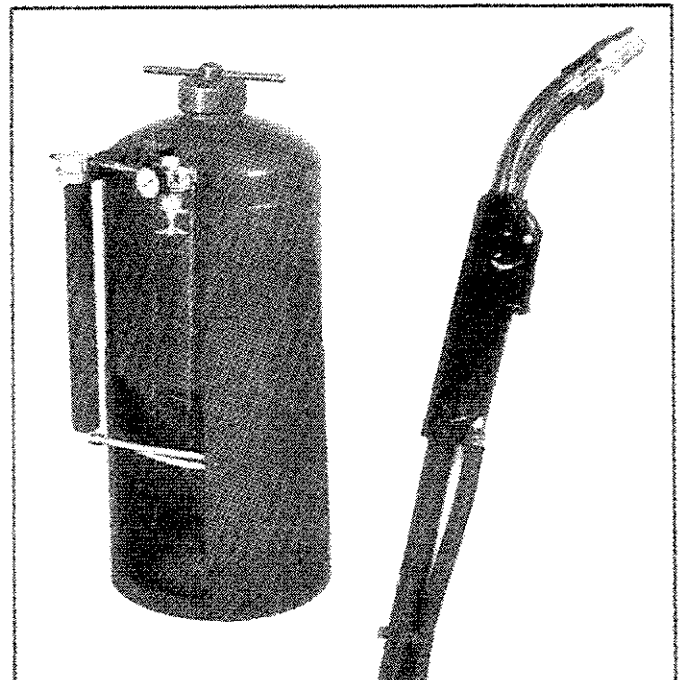
Flux feeding can be done by two methods: 1) gravity feed and 2) forced air feed. Gravity fed hand held Sub Arc is

limited by the amount of flux (2 to 3 pounds) that the welding operator can handle in the gun/flux cannister. Thus, it is only designed for short duration welds with good accessibility.



**Gravity fed semiautomatic flux equipment**

The forced air flux feeding system is the most convenient to use of the semiautomatic systems. A conventional wire feeding unit feeds the wire. A pressure vessel type storage tank is capable of holding approximately 100 pounds of flux. A hand held gun that is fed air pressure forced flux completes the package.

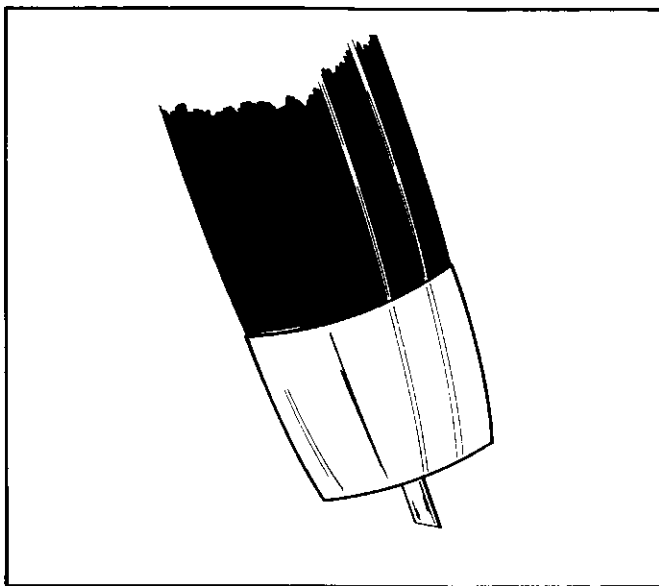


**Forced air semiautomatic flux equipment**

An outside air supply (filtered to trap line moisture) is attached to the flux storage tank. This tank has a regulator which adjusts the pressure feeding the flux through a small diameter tubing to the gun. Under normal conditions with a 15-foot gun, 30 psi pressure is adequate. As the length of the flux tubing increases, so must the pressure supplying the flux. In some cases fine fluxes require less pressure or cannot be used at all because of their packing characteristics. The system must have a safety release in case over pressure is supplied. An opening at the bottom of the tank allows draining to change fluxes. A large cap on the top, followed by a mesh filter allows filling the tank and cleaning large debris from the flux being added. Line moisture is also trapped by a filter on the storage tank itself but should not be relied upon to do the complete job of eliminating incoming air line moisture. Porosity caused by wet flux can create weld rejects.

## Arc Starting

The wire should be clipped to a sharp point as close to the flux cone as possible. Improper or no clipping can result in poor starts or arcing of or to the contact tip. After setting voltage and amperage/wire feed speed, position the gun over the joint. Allow enough flux to gather (1/2" to 3/4" depending on wire size) to prevent arc flash. Then strike the wire on the metal by lightly scratching through the flux at the same time the trigger is depressed and travel begun.

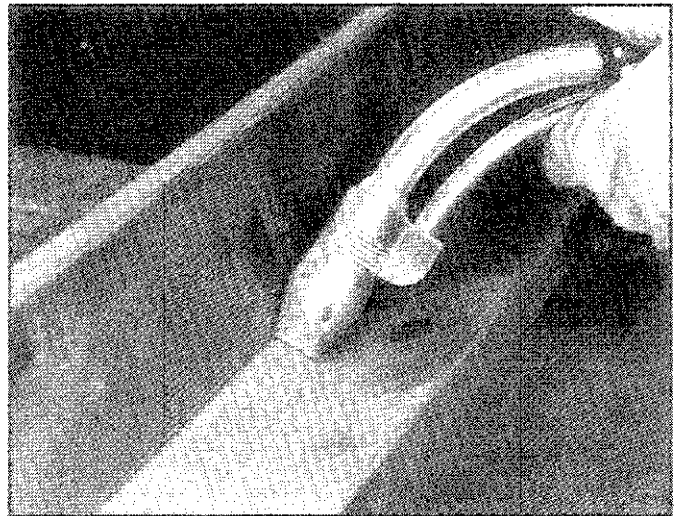


**Wire clipped at angle**

If the electrode does not establish an arc and pushes the gun away from the work, immediately release the trigger, raise the gun and shut off the flux flow. Some guns may need to be nozzle up to stop the flux flow. On other guns, the trigger release automatically shuts off the flux flow. This stubbing problem may be caused by 1) mill scale, rust or dirt on the workpiece surface, 2) loose electrical connections, too low volt and amp (WFS) settings, damaged cables, etc., 3) slag or flux between the wire and work. After checking these points and cleaning the base metal starting point, clip the wire and proceed again.

## Gun Positions

Hold the gun parallel with the joint and 45 degrees or less from the vertical. Lightly touch the flux cone to the workpiece, being sure to cover the arc area adequately with flux. Activate the trigger and begin welding, lightly dragging the flux cone along the workpiece. The trigger may be manually held or a trigger lock used to maintain the arc throughout the weld operation.



**Correct gun position**

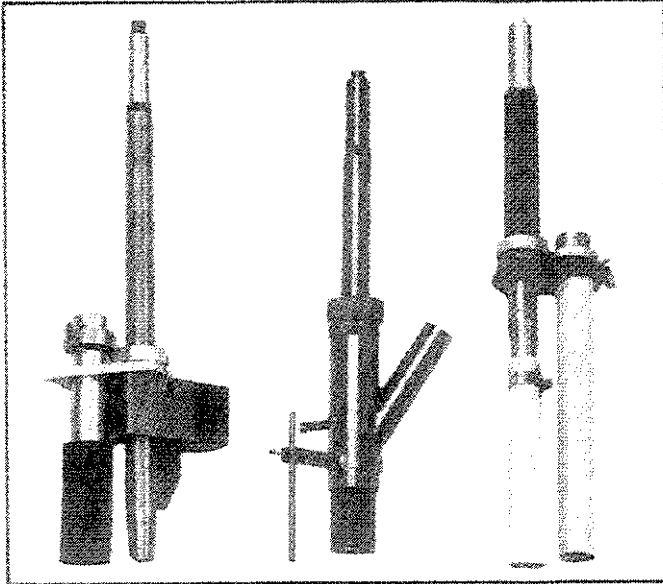
## Electrical Extensions

Electrical extension guides are available to increase the deposition rates by preheating the wire. Inspect the manufacturer's literature for various sizes and types available.

## AUTOMATIC SUBMERGED ARC

### Guns and Flux Systems

There are basically three types of guns used for single wire Sub Arc usage—the side flux delivery, the concentric flux delivery (flux deposited around the wire) and the deep groove type of gun.



*Guns for automatic applications*

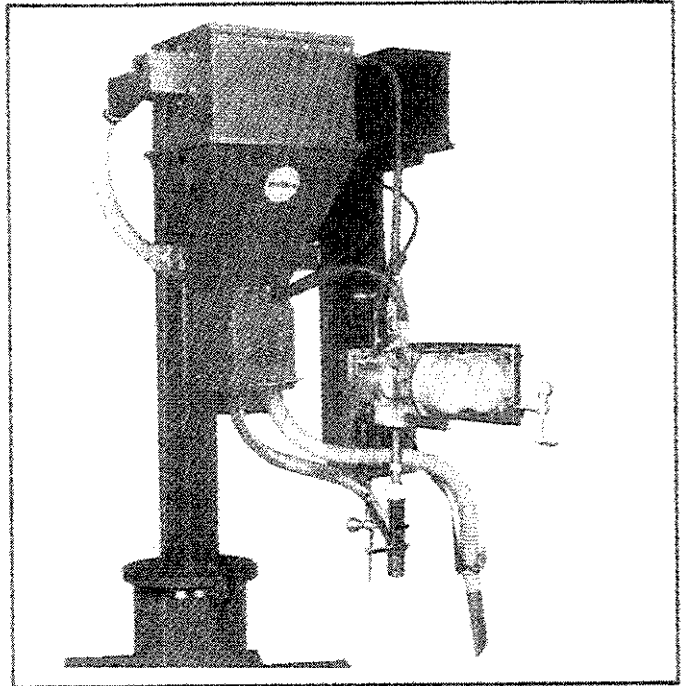
The joint design and sometimes welding operator preference will determine the type of gun required. The flux shut-off should be available on the gun itself for welding operator access, and to prevent a large volume of flux running out at the end of the weld. This deposit is caused by the emptying of the flux hose between the shut off and the arc. In cases where electric or manual shut-offs are used on the flux hoppers, it is difficult to control flux run out at the end of the weld, depending on flux hopper location and flux hose length.

When the side delivery flux gun or deep groove gun is used, the flux is fed from an overhead gravity hopper to the flux shut-off assembly on the gun. The flux is deposited in front of the wire normally to a depth sufficient to prevent visible arcing or flashing. Flux depth also depends on choice of weld current (AC or DC), size of wire, polarity, amperage being used, type of flux and joint design. The flux characteristics, delivery and control would be the same for multi-wire applications.

Flux can be a messy or undesirable aspect in the Sub Arc process, and in many cases the process is not used because of it. While it would often be easier to just discard old flux, it is generally practical to recover and reuse the unfused portion. The unfused flux is abrasive and dusty. In most cases, the flux is recovered 4 to 6" behind the weld and is still very hot. Occasionally the solidified flux is ground and mixed with new flux for reuse.

There are several manufacturers of flux recovery equipment, both the electric (vacuum cleaner type) or air operated (siphon/venturi type) on the market. The venturi system recycles the unused flux back into the hopper

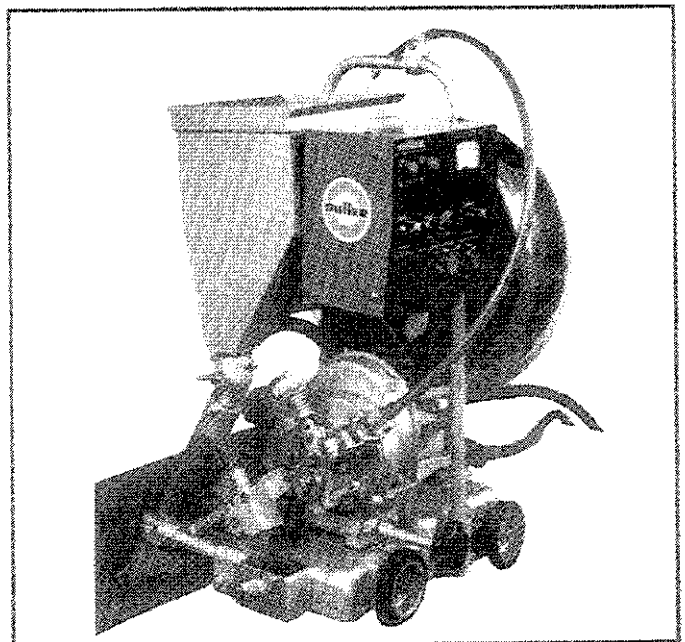
and can be used while feeding flux. Also the venturi system, by retrieving hot flux produces a drying effect on the flux in the hopper, reducing weld porosity that can be caused by damp flux.



*Electrically/manually operated flux systems with siphon type recovery unit.*

### FIXTURES

Submerged Arc welding can be accomplished automatically or semi automatically. Automatic submerged arc welding can be the result of moving the workpiece under the weld head or moving the weld head over the stationary work. An automatic setup can even be made using semi automatic equipment with a tractor arrangement on long structural weldments or plates.



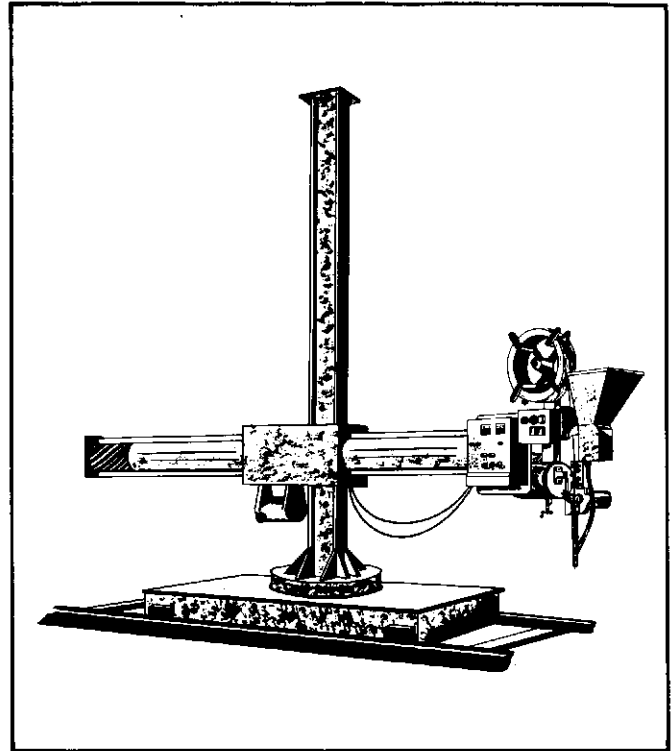
*Tractor and Welding Equipment*



Gun or workpiece movement is often the most difficult part of the sub arc process. Movement has to be steady and precise. Adjustable fixtures can be used to hold the piece(s), but parts and applications vary in some ways that tend to make each fixture special. Many times extensive clamping is required to minimize distortion created by welding.

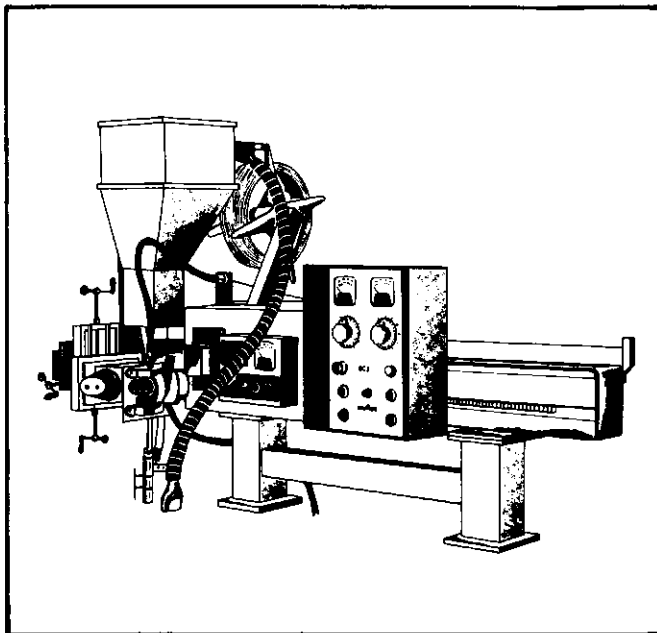
Most automatic welding control panels have the necessary circuits required to start and stop movement for fully automated systems. In some cases, this will allow one welding operator to operate more than one system.

Some of the most popular fixtures are the SIDE BEAM CARRIAGES which are stationary, normally moving the welding equipment over the part to be welded, such as I Beams, etc.

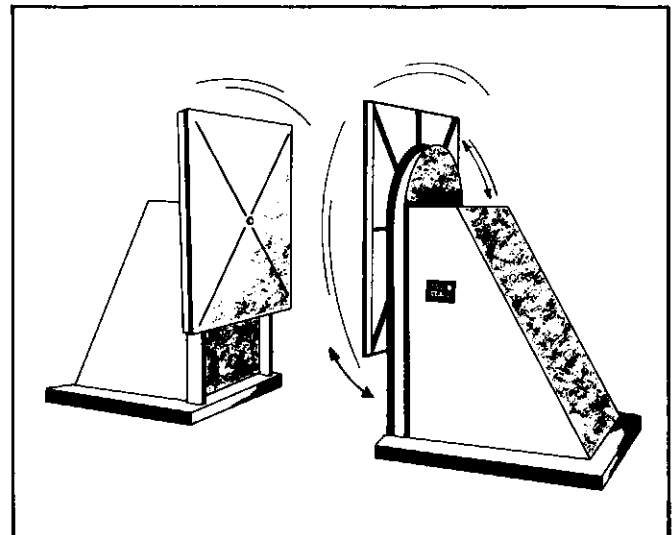


**Manipulator with welding equipment**

MANIPULATORS which also move the welding equipment over, around or through the work (normally pipe applications) have the ability to swivel, traverse in and out, up and down and move back and forth on rails. POSITIONER, and HEAD and TAILSTOCK assemblies are usually stationary and grasp the part (pipe fittings, wheels, rollers, etc.) in some fashion with the ability to turn and tilt the part at the proper speed for welding.

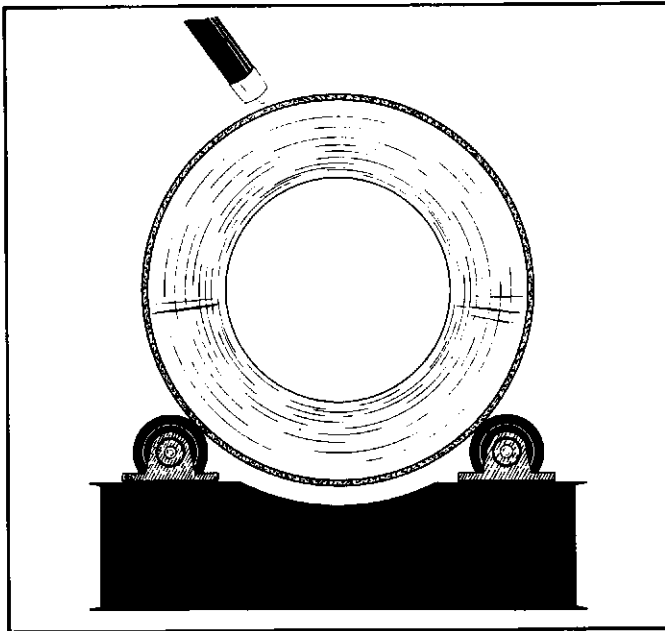


**Sidebeam with welding equipment**



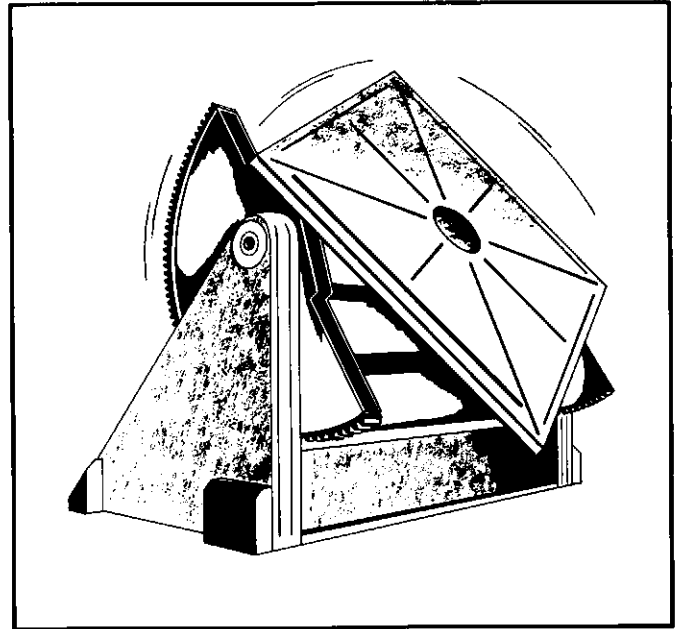
**Positioner head and tail stock**

**TURNING ROLLS** are used to turn pressure vessels, large diameter and lengths of pipe, etc.



*Turning rolls*

**TURN TABLES** come in a variety of sizes; the part is mounted or merely placed on it and rotated for welding. Some models also have the ability to tilt the part.



*Turntable*

## **CONSUMABLES**

### **FLUXES**

The unique feature of Submerged Arc Welding (SAW) is the granular material that covers the welding area. This material will be referred to as flux even though it performs other functions in addition to those associated with a fluxing agent. The process derives its name from the fact that the arc is hidden (submerged) beneath a flux blanket and is not visible to the welding operator. The flux is often instrumental in achieving high deposition rates and producing the type of weld quality that characterizes the submerged arc welding process.

The Sub Arc process is not as versatile as some of the more common processes, such as Shielded Metal Arc, Gas Metal Arc or Gas Tungsten Arc Welding. A reason for this non-versatility is the effect of gravity on the flux feeding into the weld area and on the molten weld pool. This limits the process to flat and horizontal fillet positions only, except for special cases of vertical and horizontal welds with special equipment, such as belts or shoes which are required to hold the flux in position.

Fluxes perform many functions in Submerged Arc Welding. They shield the molten puddle by covering it with molten slag, clean the molten puddle, influence the chemical composition of the weld metal, weld bead shape and the mechanical properties of the weld. The

granular flux also acts as a barrier preventing the heat from escaping, and concentrates the heat into the weld area promoting deep penetration.

Fluxes differ by the various methods used to manufacture them. These manufacturers should be contacted as to the type of flux recommended for a particular application. The different types by manufacturing methods are: fused, bonded, agglomerated and mechanically mixed.

### **Fused Fluxes**

Fused fluxes are made by dry mixing the raw materials, melting (fusion) in a furnace, and cooling which is accomplished by using large chill blocks or a stream of water. The glassy flux material is then crushed, screened for particle sizing and packaged for shipment.

Fused fluxes offer these advantages: 1) Less moisture pickup than other flux manufacturing methods and 2) Recycling through flux recovery systems without losing particle sizing or composition. A disadvantage of fused fluxes is the difficulty in adding deoxidizers and alloys during manufacture. This problem stems from the high temperature used during manufacture.

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## Bonded Fluxes

Bonded fluxes are made from raw materials that are powdered, dry mixed and bonded together with either a potassium silicate or sodium silicate binder or a combination of both. The wet bonded mix is pelletized and baked at low temperature. When drying is complete, the pellets are broken up, screened for particle sizing and packaged for shipment.

Bonded fluxes offer these advantages: 1) Easy addition of deoxidizers and alloying elements (fused fluxes achieve this with great difficulty because of separation or loss), 2) Allows a thicker flux layer when welding and 3) Can be identified by color. The disadvantages of bonded fluxes are that they absorb moisture like Shielded Metal Arc electrode coatings and they can change in flux composition from segregation or loss of fine particle size.

## Agglomerated Fluxes

Agglomerated fluxes are produced similar to bonded fluxes with these exceptions: A ceramic binder is used. A higher drying temperature is also used which limits the use of deoxidizers and alloy elements similar to the fused fluxes. Advantages and disadvantages are similar to those of bonded fluxes.

## Mechanically Mixed Fluxes

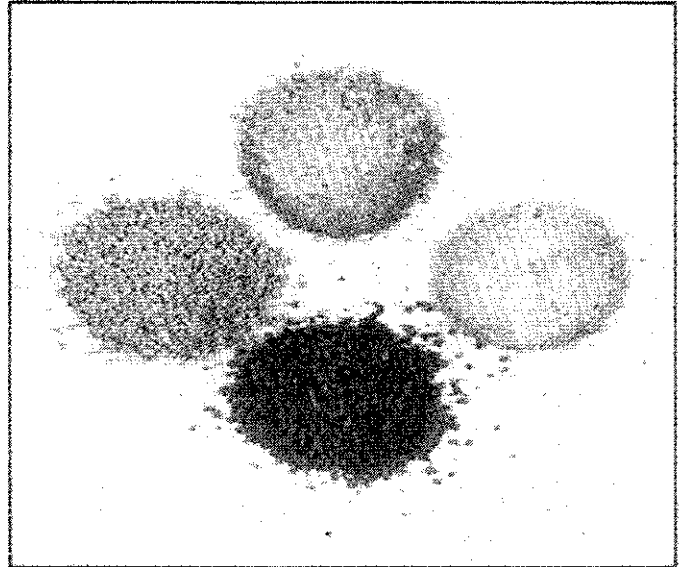
A mechanically mixed flux is achieved by mixing two or more fluxes, bonded or agglomerated fluxes to get the desired properties. These mixed fluxes have the advantage of using readily available commercial fluxes for mixture in higher critical weld situations. Disadvantages of mixed fluxes are: Segregation during shipping, storage and handling, segregation in flux feeding and recovery systems, and inconsistent mixtures from one mix to the next.

## Particle Size

Flux particle sizes are important because they influence flux feeding, recovery, weld bead shape, appearance and weld current levels. As amperage is increased, the average flux particle size should decrease. Some flux manufacturers provide literature giving the mesh sizing along with the amperage suitable for that mesh sizing.

Too high a current for a particle flux size will cause an unstable arc with ragged, uneven bead edges. However, coarser sized flux particles are needed for rusty plate to allow gases to escape easily.

Manufacturers label their flux containers with mesh sizing information using two numbers (20 x 200, for example).



*Various particle sizes*

The numbers represent the largest and smallest particle sizes in evidence when standard mesh screens are used for measuring. The first number indicates the mesh through which all the particles will fall. The second number tells the mesh through which none of the particles will fall. The sizing numbers do not indicate how great a percentage of coarses or fines are within that mesh sizing. This can only be achieved by sample screening at various mesh sizes and checking the weight of each screening against the weight of the total sample.

Flux feeding systems sometimes limit the ability to handle fine fluxes. Separation of coarses and fines occur as well as plugging (packing) in the hopper and hoses.

A constant effort should be made to keep fluxes dry. Bonded fluxes hold surface moisture easier than fused but precautions should be taken with all fluxes. Manufacturers should be consulted as to specific baking procedures when fluxes do need drying.

When flux is recovered, it must be mixed with new flux before it is reused. It may otherwise lose its manufactured properties and be detrimental to the weld quality desired. Consult the flux manufacturer for proper proportions. A rule of thumb often used is three parts new to one part recovered.

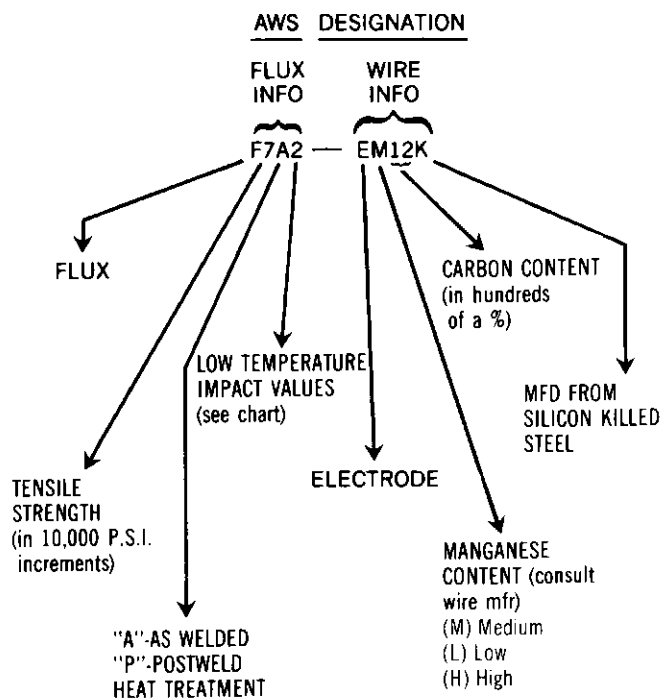
Fluxes are generally classified as basic, acidic or neutral. The basity or acidity of a flux is the ease with which the oxides in the flux ingredients break up. Oxides which break up easily are called basic. Basic fluxes are used to resist brittle fracture in welding. Acidic oxides break up only to a small degree. Neutral fluxes do not oxidize alloying elements or add alloying elements to the weld, thus the term "neutral flux."

The neutrality, acidity, or basicity of a flux is generally referring to its ratio of calcium oxide or manganese oxide to its silicon dioxide. Ratios greater than 1:1 are basic, near 1:1 are neutral and less than 1:1 are acidic.

The choice of a flux can be complex when confronted by all the different types of fluxes. This is compounded by the consideration of wire in combination with a flux and base metal. The safest route to take when in doubt is to consult the flux and wire manufacturer for their recommendation.

## Wire and Flux Identification

Each flux manufacturer provides various AWS weld metal analysis information on the flux bag. A particular flux can be used in combination with many different classes of wire but with differing deposited analysis.



## Impact Values at 20 Ft-Lbs

<u>NUMBER</u>	<u>TEMPERATURE F°</u>
Z	no impact required
0	0
2	-20
4	-40
5	-50
6	-60
8	-80

For alloyed fluxes and/or wires, the best source of accurate information is the wire/flux supplier or manufacturer. Most commonly used wires are solid, but many new composite (tubular wires) are appearing on the scene. Alloying is easier to add through composite wires. Sometimes reduction of production costs can be realized by using these wires.

For more complete information on Submerged Arc wires and fluxes, it is best to contact the American Welding Society (AWS) or the manufacturers involved supplying your wire and flux. Many of the brochures are yours just for the asking.

## WIRES

Basically, in Submerged Arc Welding, a continuous consumable bare electrode is inserted into a mound of flux that covers the weld area. Upon arc initiation, the base metal, the electrode and the flux in the immediate vicinity of the arc, melt to form the molten pool. The wire is continually fed into the arc and flux is steadily added. The melted flux flows to the surface of the molten pool to form a protective layer while the metallic components flow together to create the weld.

Submerged Arc Welding can use high currents and develop extremely high temperatures. The current is applied to the electrode a short distance from the tip, therefore, high current can be used with small diameter electrodes. Submerged Arc Welding gives small electrodes 6 to 10 times the current density as compared to Shielded Metal Arc electrodes of the same diameter. High current density gives a very high burn off rate in comparison to Shielded Metal Arc Welding of equal diameter. This means a much higher deposition rate for SAW vs. SMAW.

Listed are some current and voltage ranges for commonly accepted wire diameters. These are *approximate values*—fluxes, wire types, AC vs. DC, polarity, electrode extension, type of power source, joint design and material thicknesses may cause these to vary quite extensively.

**DEPOSITION RATE FORMULA**  
(Pounds per hour, flux not included)

$$\frac{\text{Wire Speed (IPM)}}{12 \text{ inches}} \times 60 \text{ minutes} \times \frac{\text{Lbs. per foot}}{\text{(See Chart)}} = \text{Deposition Rate}$$

Example using 3/32" wire:

$$\frac{125 \text{ IPM}}{12"} = 10.4 \times 60 \text{ (min.)} = 625 \times .023 \text{ (Chart)} = 14.4 \text{ lbs. per hour}$$

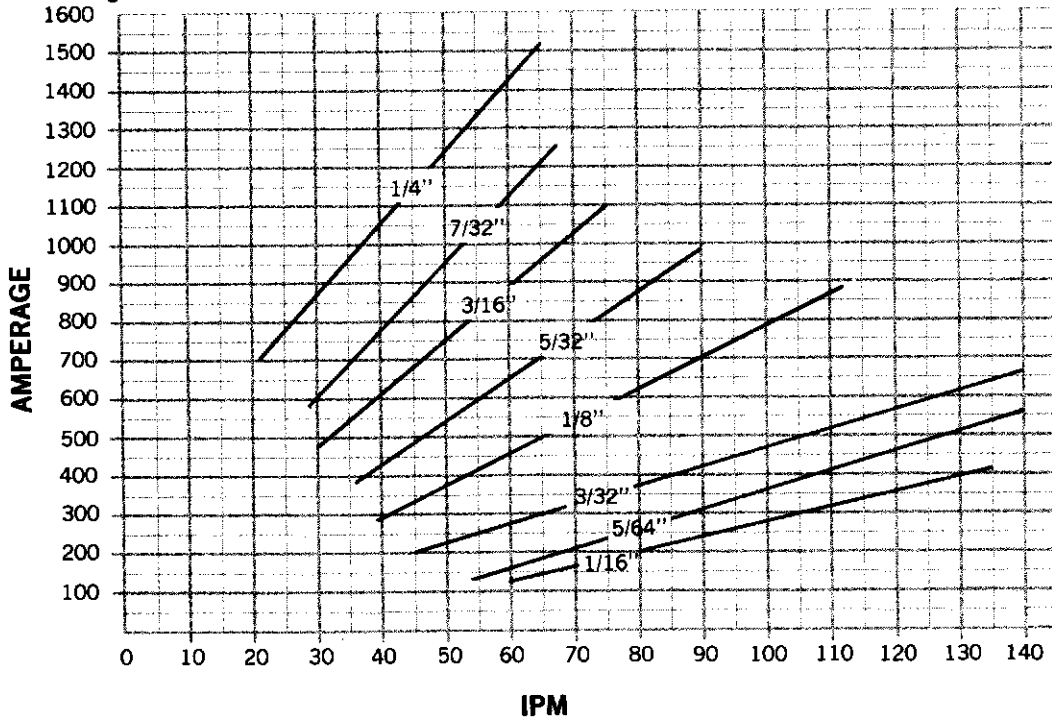
WIRE DIAMETER (INCHES)	CURRENT RANGE AMPERES DCRP	VOLTAGES DCRP	WIRE SIZE	MILD STEEL WEIGHT OF ELECTRODE PER FOOT (LBS.)
1/16	150-400	19-37	.035	.0033
5/64	200-600	20-37	.045	.0054
3/32	250-700	22-37	.052	.0072
1/8	300-900	23-37	1/16	.0100
5/32	400-1000	25-37	5/64	.0160
3/16	500-1100	27-37	3/32	.0230
7/32	600-1200	30-37	1/8	.0420
1/4	700-1600	30-38	5/32	.0650
			3/16	.0940
			7/32	.1280
			1/4	.1680

**SOLID WELDING WIRE—INCHES PER POUND**

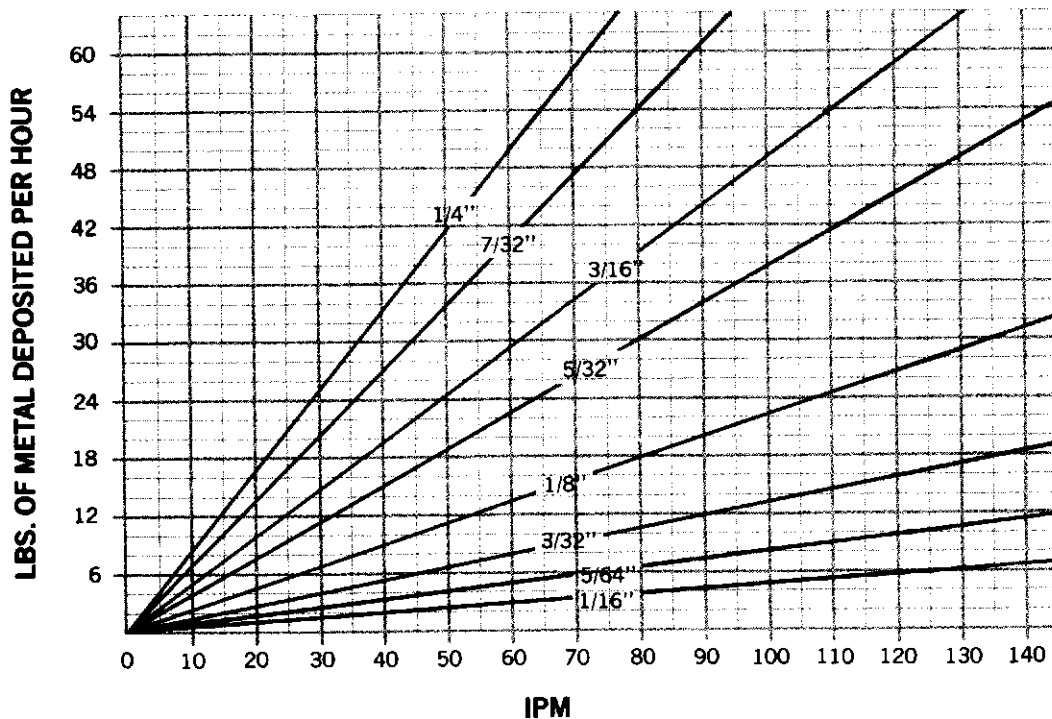
IN	DEC.	MM	ALUMINUM	ALUMINUM BRONZE	COPPER, DEOXIDIZED	COPPER-NICKEL	MAGNESIUM	NICKEL	SILICON BRONZE	STEEL, MILD	STEEL, STAINLESS 300	STEEL, STAINLESS 400	CROSS SECTIONAL AREA IN SQUARE INCHES	LINEAR INCHES PER CUBIC INCH
	.020	0.508	32400	11600	9800	9950	50500	9900	10300	11100	10950	11350	0.00031	3180
	.025	0.635	22300	7960	6750	6850	34700	6820	7100	7680	7750	7960	0.00051	2190
	.030	0.762	14420	5150	4360	4430	22400	4400	4600	4960	4880	5050	0.00071	1415
	.035	0.889	10600	3780	3200	3260	16500	3240	3380	3650	3590	3720	0.00096	1040
	.040	1.016	8120	2900	2450	2490	12600	2480	2580	2790	2750	2850	0.00100	796
	.045	1.143	6410	2290	1940	1970	9990	1960	2040	2210	2170	2240	0.00160	629
1/16	.062	1.587	3382	1120	1010	1040	5270	1030	1070	1160	1140	1180	0.00307	332
5/64	.078	1.984	2120	756	640	650	3300	647	675	730	718	742	0.00480	203
3/32	.093	2.381	1510	538	455	482	2350	460	480	519	510	528	0.00690	140
1/8	.125	3.175	825	295	249	253	1280	253	263	284	279	289	0.01227	81
5/32	.156	3.968	530	189	160	163	825	162	169	182	179	184	0.01911	52
3/16	.187	4.762	577	134	114	116	587	115	120	130	127	129	0.02746	36
1/4	.250	6.350	206	74	62	64	320	63	66	71	70	71	0.04908	20

# SUBMERGED ARC WELDING DCRP BUTT JOINT WIRE SPEED/AMPS AT NORMAL ARC VOLTAGE WITH 1" STICKOUT

The line length is the recommended approximate minimum and maximum settings for each wire.



## IPM/DEPOSITION DCRP BUTT JOINT (BASED ON 1" STICKOUT)



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# CALCULATED WELD METAL

## How to Estimate Filler Metal Consumption

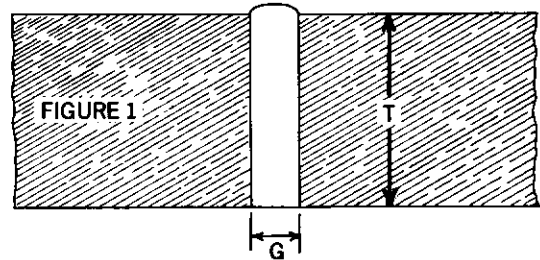
### Cubic Inches for Longitudinal Welds

CROSS SECTION OF WELD

#### Step 1

$$G \times T = AR$$

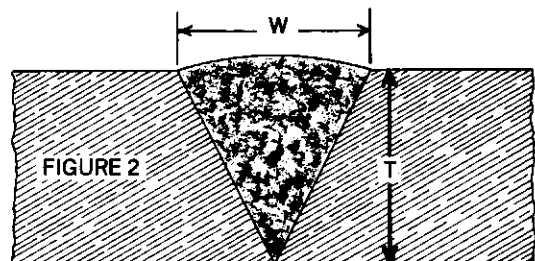
(Figure 1) Root opening (G) times Thickness (T) of plate equals the Area of the Rectangle (AR).



#### Step 2

$$W/2 \times T = AT$$

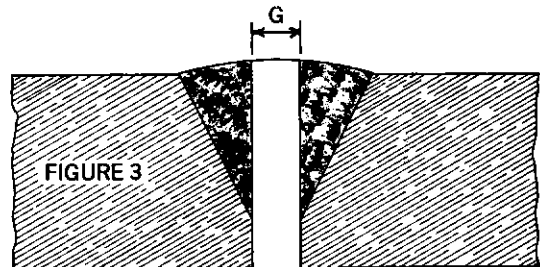
(Figure 2) Half the width (W/2) times the thickness of the Triangle (T) equals the Area of the Triangle (AT).



#### Step 3

$$AR + AT = TA$$

(Figure 3) The Area of the Rectangle (AR) – Step 1, plus the Area of the Triangle (AT) – Step 2, equals the Total Area (TA).



#### Step 4

To figure the VOLUME IN CUBIC INCHES of a longitudinal weld, take the area from either Step 1, 2, or 3 (depending on the type of joint) and multiply by the length of the weld.

## Volume of Circular Weld Beads (Pipe Welds)

### Step 5

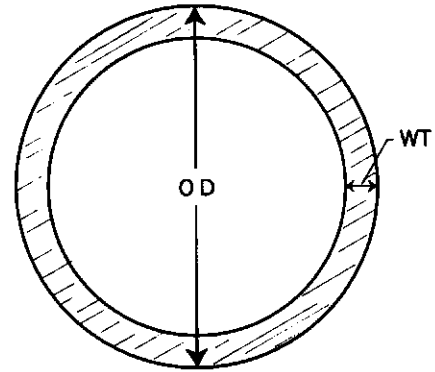
$$(OD - 1/2WT) \times \pi = \text{Longitudinal Weld}$$

(Figure 4) To figure the volume of a circular weld bead (pipe weld), take the Outside Diameter (OD) minus one-half the Wall Thickness (WT) and multiply by  $\pi$  ( $\pi = 3.14$ ). This will give you the length of the weld in a longitudinal form.

### Step 6

Visualize the weld cross section and apply Step #4 to obtain WELD VOLUME IN CUBIC INCHES.

FIGURE 4



### EXAMPLE

The mild steel pipe is  $6\frac{3}{4}$ " (6.75") OD, Wall Thickness is  $\frac{3}{8}$ " (.375") WT, Bead Width is  $\frac{3}{8}$ " (.375) W. For this example, we will use .035" wire.

### Step 5

$$(6.75 - .187) \times 3.14 = 20.607'' \text{ longitudinal weld length.}$$

### Step 6

Let's assume the weld cross section is similar to Figure 2, and referring to Step #4, we need to find VOLUME IN CUBIC INCHES.

$$.187 \times .375 = .07 \text{ (Step 2)}$$

$$.07 \times 20.6 = 1.442 \text{ (Step 4) VOLUME IN CUBIC INCHES}$$

By using the appropriate chart (Page 11), the weld Volume in Cubic Inches can be converted to linear inches, then to pounds.

Using .035" wire, locate the Linear Inches per Cubic Inch column, and note there are 1040 Linear Inches per Cubic Inch. Now, multiply 1040 times the Volume in Cubic Inches (the answer you got in Step 4).  $1.442 \times 1040 = 1499.68$  Linear Inches of .035" wire.

By consulting the same chart, we note that for .035" wire, it takes 3650 inches to make one pound of mild steel wire. Therefore, by dividing the Linear Inches of wire used by the 3650 inches in a pound, the weld required .41 pounds.  $1499.68 \div 3650 = .41$  pounds.

This, of course, does not include any losses due to spatter, excessive weld crowning or wire pieces the operator may have clipped off.

### KEY

G = Gap or Root Opening

W = Width of Prepared Joint

T = Thickness of Plate

AR = Area of Rectangle

AT = Area of Triangle

TA = Total Area

OD = Outside Diameter

WT = Wall Thickness



Properly done, Submerged Arc Welding results in good ductility, impact resistance and uniform bead appearance. Mechanical properties are at least equal to that of the base metal on a consistent basis. The base metal/filler metal dilution for single pass welds is greater than multi-pass welds. Thus the filler metal will have a greater influence on the chemical and mechanical properties of the weld when using only a single pass. Because of this, electrodes of the same chemical composition as the base metal are not always used. Multi-pass welds, however, are less affected by the base metal/filler metal dilution and rely more on the combination of the electrode, flux and welding conditions to achieve acceptable results.

Commonly associated only with low carbon steel, submerged arc welding has gradually expanded to many other metals such as: low alloy steel, high carbon steel, stainless steel, non-ferrous alloys and many special alloys for surfacing applications.

## PREPARING TO WELD

### Joint Cleaning

Oil, grease, water, paint, rust, mill scale, etc. will all emit gases when heat is applied. These gases can affect the weld. Thus, cleanliness should be a part of joint preparation as in any welding procedure. Cleanliness is especially important on thin gauge high travel speed welds. Slowing weld travel speed will sometimes allow gases to escape from the weld before weld metal solidification. Cleaning can be done by several methods.

Flame cleaning requires a heating torch to remove mill scale, rust or moisture.

Grinding or wire brushing will remove light rust and dirt. Either power brushed or hand held steel brushes can be used.

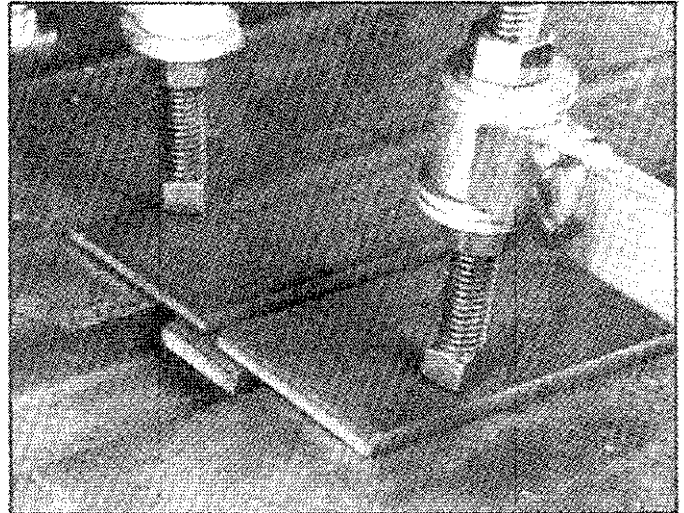
Sandblasting removes heavy scale and rust.

Chemicals such as degreasers or pickling baths can also be used.

### Joint Fit-Up

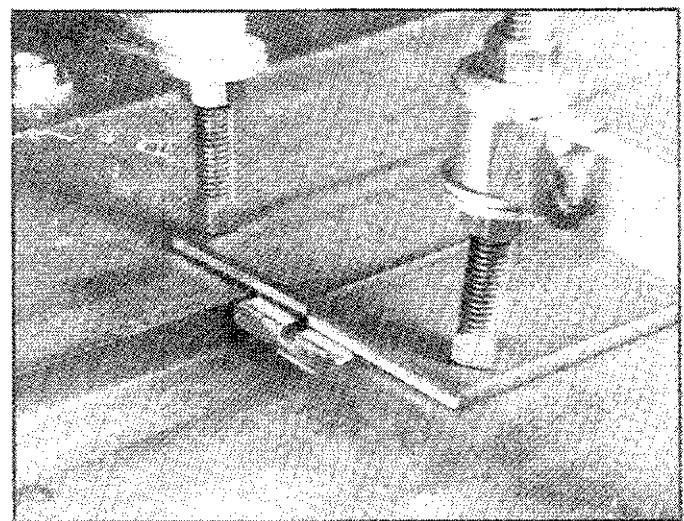
Submerged arc (DCRP) is typically a deep penetrating process. Plates being welded should either be butted tightly together or separated for use with a backing material. Gaps of any type increase penetration and can result in burn-thru or flux drop through. Several backing methods can be used.

Permanent backing is a steel strip of the same basic composition as the base metal. The backing becomes part of the structure and weld joint.



*Permanent backing strip*

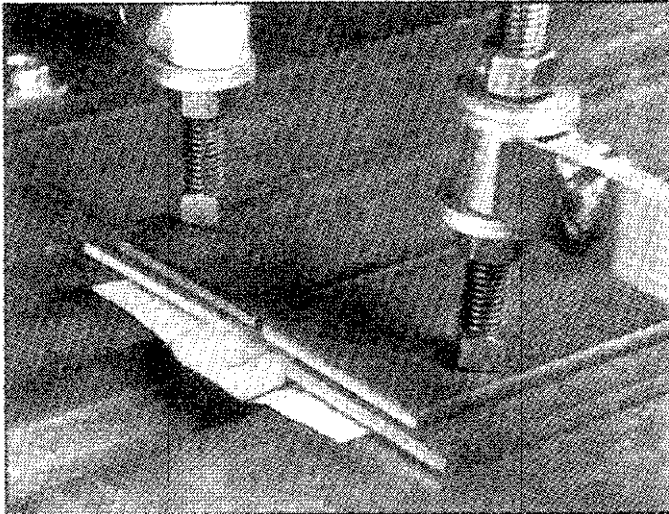
A large copper block for backing with a groove for proper bead conditions or a water cooled copper chill block to reduce distortion especially on thin gauge material is commonly utilized.



*Copper backing*

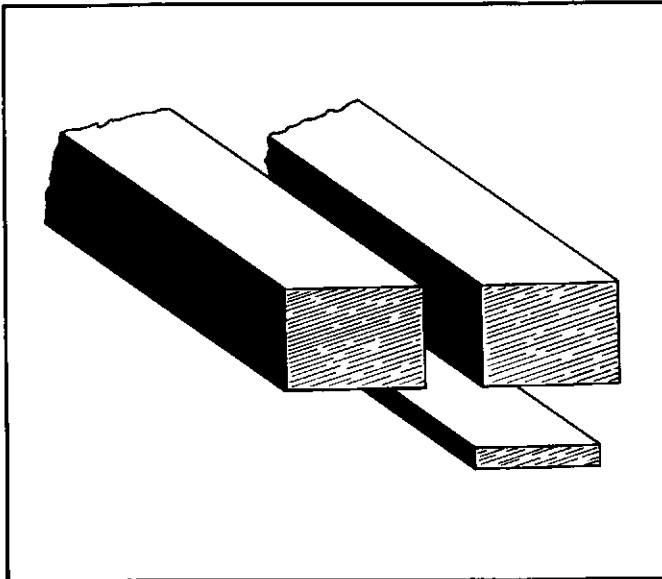
Flux backing can be held in place by a pressurized fire hose which presses the flux against the plate.

Commercial tape backings have either a binder which contains flux or a ceramic material that conforms with various joint designs and materials. These are held in place with a sticky pressure adhesive tape, usually a part of the backup strip.



**Ceramic/Tape Backing**

Run-on and run-off tabs are used extensively in submerged arc welding. The arc is then established and gains stability on the tab, allowing the bead to achieve uniformity before reaching the main weldment.



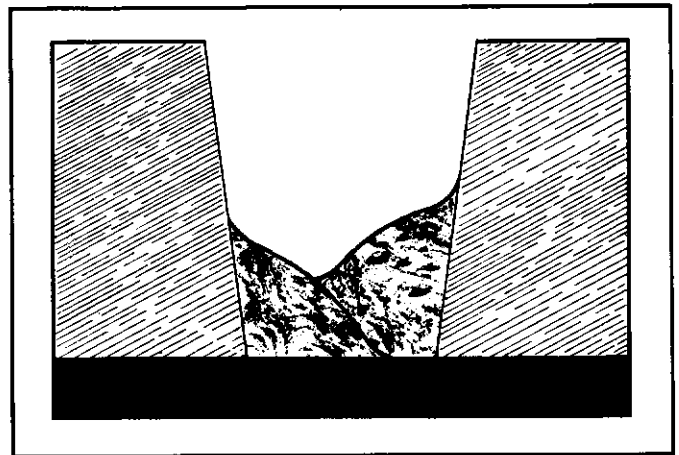
**Run on/off Tab**

Crater fill is not required when a run-off tab is used. These tabs should be of similar base metal composition as the main weldment. Tabs prevent molten metal run-off at the ends and give good start and finish ends to the weldment when they are removed.

Tack welds are required when a part requires support during welding. These tacks should be as small as practical and of a comparable composition to that of the submerged arc filler wire. Shielded Metal Arc Welding is used mostly for Submerged Arc tack weld preparation. Other processes may be used, but more consideration must be given to wire composition.

## Bead Placement

Narrow gap deep groove welds should be made with beads that do not completely bridge the groove. This allows easier slag removal. This applies to both AC and DC weldments. Narrow grooves which are completely bridged with one pass not only make slag removal difficult, but increase possibilities of centerline cracking, lack of side wall fusion or side wall undercut. Special attention should be paid to assure the workpiece is level. Molten metal is subject to gravity's pull which affects bead appearance and bead "tie-in" capabilities.



**Deep Groove Beads**

## Flux Depth

Never apply more flux to a weld than is required to make a proper weld. Flux depths vary with the current level. Excessive flux burden will produce narrow humped beads with unappealing bead appearance. The proper depth for the application prevents flash thru and still allows escape of the gases generated in the arc.

## Preheat and Interpass Temperature

Preheat is essential for heavy mild steel weldments and alloyed metals. Initial passes on mild steel need preheat to achieve proper tie-in with the base metal and good slag removal. Preheat is needed in alloyed materials and to assure good mechanical properties. The amount of preheat needed increases with the plate thickness, joint rigidity, higher carbon and alloy content. Multiple pass welds require an interpass temperature equal to the preheat temperature until the weld joint is completed.

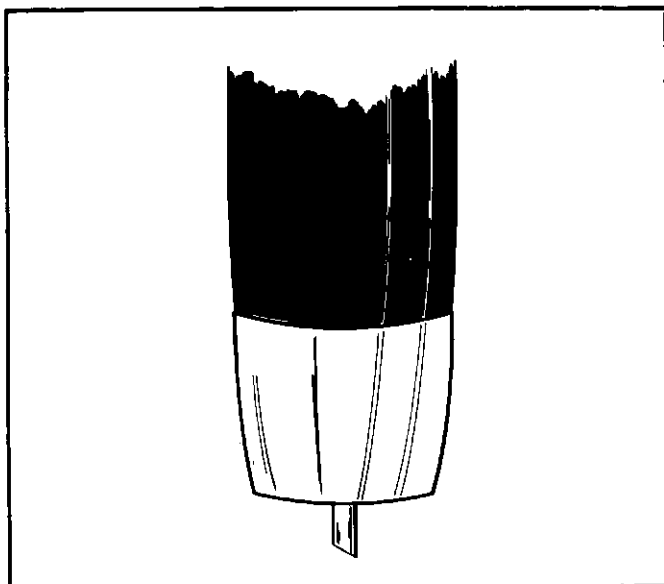
## MAKING THE WELD

### Starting

Most modern automatic equipment has a run-in feature that greatly enhances arc starting. On successive starts, however, some characteristics of the process can cause trouble, that is the formation of a small slag ball on the end of the wire. This virtually insulates the wire and unless other measures are taken, will prevent good starting.

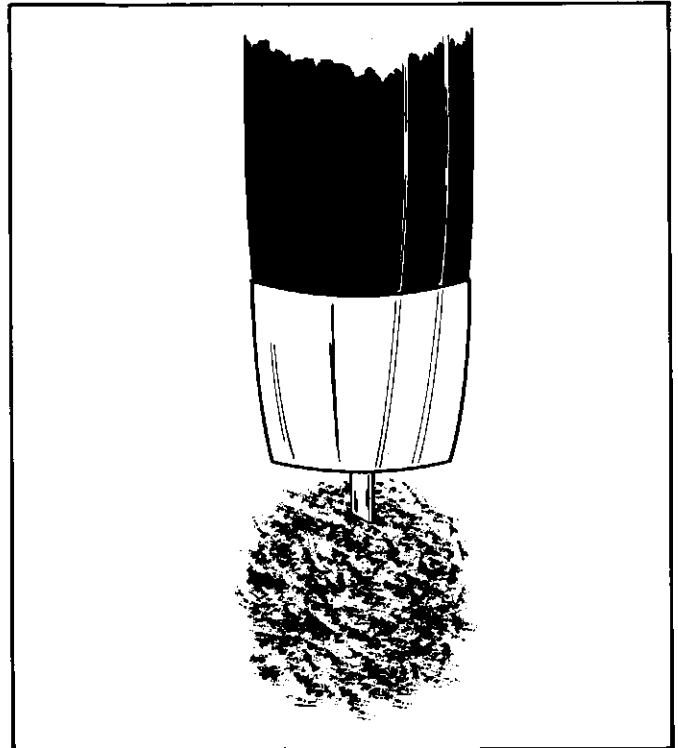
Several methods are in common use today to enhance the arc starting in Submerged Arc Welding:

1. The most common is to cut the wire (diagonally) to a sharp, pointed configuration. This removes the ball and increases the chances for sure arc starts. The wire point contacts the work while current is applied and the sharp, pointed end melts away giving a positive arc start.



*Diagonally Cut Wire*

2. A small rolled ball of steel wool (1/2") can be placed under the wire in the weld joint. The wire is lowered to compress the steel wool ball to about half its normal height. When the arc is initiated, the ball creates a current path to the work. The ball melts quickly while creating the arc and becomes part of the weld.



*Steel Wool*

3. To use a scratch start, lower the wire to the work and start the carriage. The current is applied immediately after the carriage starts. The carriage motion causes the wire to scratch the work, transferring the current to the work for sure arc starts. The carriage motion prevents the chance of wire fusion to the work.
4. A wire inserted into a molten weld pool with current applied will give good arc starts. This method is used when two or more wires are used in multiple-wire Sub Arc. When using multiple wires, only the first wire needs an arc start, the remaining wires only need to be inserted into the molten pool and current applied.
5. The equipment must be specially designed to accomplish retract wire starting. As the wire contacts the work and current is applied to it, the feeding system senses the low voltage (short circuit) and retracts the wire away from the work surface. When this takes place, an arc is struck. As the arc voltage increases, the wire feed motor changes direction to feed the wire toward the work. The wire speed is increased until the melting rate and voltage stabilize at the desired values.

6. High Frequency starts require no extra work by the welding operator. The circuitry allows one button to be pushed and high frequency creates a path for the welding current to follow. The arc is begun easily and smoothly. This is probably the most common method used if starting is a problem. This is the method used when it is not possible to angle-clip the wire after each weld.
7. The trend today is toward using constant potential power sources for Sub Arc. There are two reasons for this: 1) reliable starts because of high short circuiting current available and 2) the ease of adjustment of the weld parameters. Constant current power sources provide critical starts. The CC machine's slower rise time (response time) to weld output can give unreliable arc initiation. Added to this, if feeding equipment is not designed to regulate wire run-in speed, too much wire will be available at the arc start and cause stumbling.

## Voltage

The primary function of voltage is to control the shape of the bead cross section and its outward appearance. Any variation in arc voltage creates a change in arc length. An arc voltage increase brings an arc length increase, an arc voltage decrease brings an arc length decrease.

Increasing the arc voltage with amperage and travel speed held constant will:

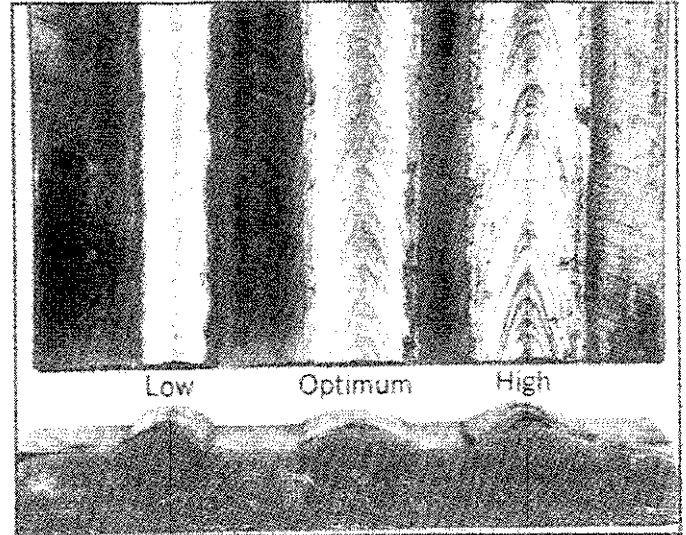
- Produce flatter and wider beads.
- Increase flux consumption.
- Improve slag removal on straight butt and fillet welds.
- Reduce porosity caused by rust and mill scale.
- Bridge gaps when poor fitup occurs.
- Increase pickup of alloying elements from alloy fluxes into the weld deposit. This can be used to an advantage when trying to raise the alloy content of the weld.

Excessively high arc voltage will:

- Produce a hat shaped wide bead subject to cracking (single pass welding).
- Hinder slag removal.
- Produce a concave shaped weld bead which will be subject to cracking (multiple pass in a groove).
- Provide increased alloy pickup in multiple pass welds, thereby increasing chances of cracking.
- Increase edge undercutting on fillet welds.

Lowering the arc voltage increases penetration in groove welds, improves slag removal and lessens arc blow when using high travel speeds.

Excessively low arc voltage will produce a high, narrow bead that makes slag removal difficult.



*Voltage Varied Welds*

## Amperage / Wire Feed Speed (WFS)

Amperage and WFS are directly related to each other in that as wire feed speed is increased, amperage will also increase. If wire feed speed is reduced, amperage will also be reduced. This assumes all other variables have remained constant, and that a CP power source and constant speed feeder are being used.

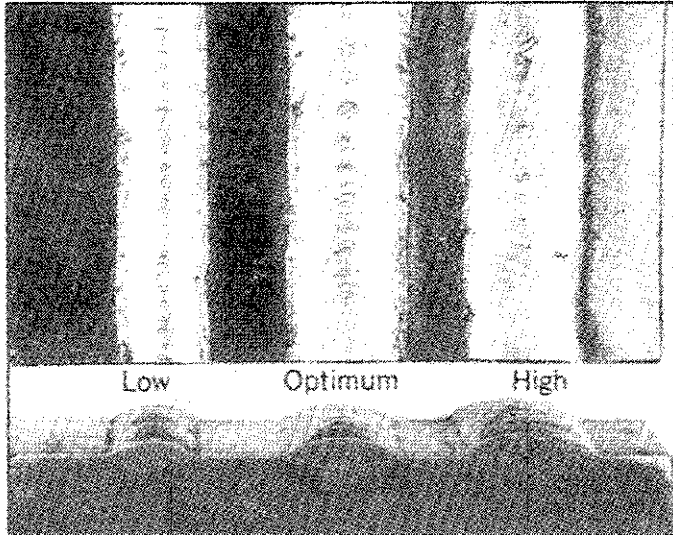
Amperage/WFS controls wire melt off rate, depth of penetration and the amount of base metal dilution. Too high an amperage/wire feed speed at a given travel speed will result in too great a depth of fusion or penetration. The weld may penetrate so far that melt-thru of the backing may occur. Too high an amperage/wire feed speed for a given condition can cause excessive weld reinforcement, increased weld shrinkage, added stress and a greater chance of distortion. Too low an amperage/WFS results in inadequate penetration, lack of proper fusion, and insufficient joint fill (low deposition).

Some specific things to remember about amperage are:

Increased amperage/WFS increases penetration and wire melt off rate—deposition.

Excessively high amperage/WFS produces an unstable arc, undercut or a high narrow bead.

Excessively low amperage/WFS produces an unstable arc.

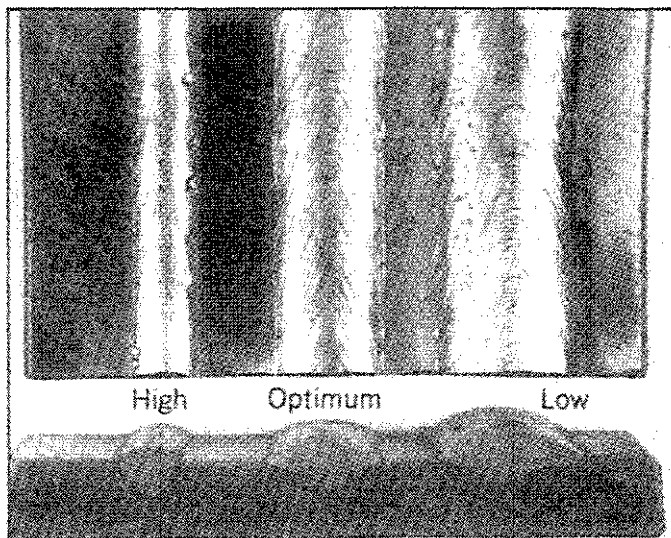


**Amperage Varied Welds**

## Travel Speed

Travel speed is one of the most important variables affecting penetration and bead size. High speeds decrease penetration and increase tendencies for undercut, arc blow, porosity and non-uniform bead shape. Proper speeds give gases time to escape from the molten metal before it solidifies, which reduces porosity. Very slow speeds will produce bead shapes that are subject to cracking, excessive open arc exposure for the welding operator and a large, uncontrollable molten pool that results in a rough bead and possible slag inclusions.

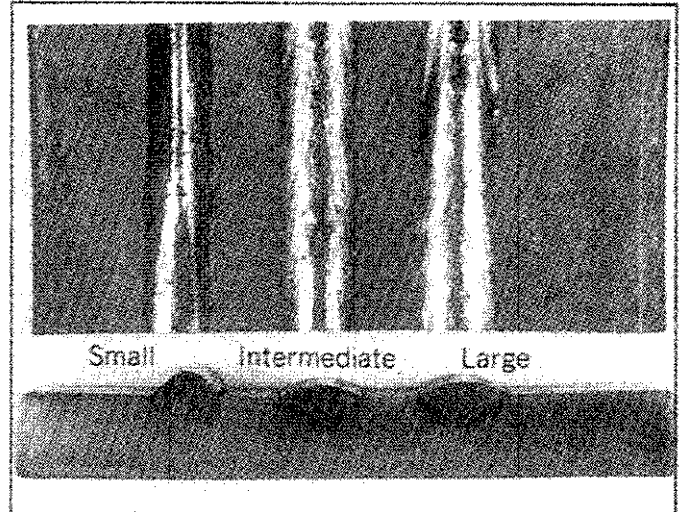
For single pass welds, the current and travel speed should be as high as possible and still obtain proper weld bead size and proper penetration without burning through. In multiple pass welding, the travel speed can be varied to obtain the desired fill for the joint.



**Travel Speed Varied Weld**

## Electrode Size

The electrode diameter choice can affect weld bead shape and penetration depth for a fixed current setting. See picture.



**Wire Sizes**

Small electrodes are used in semi-automatic applications because of the flexibility and ease of handling. They are also used with dual wire and tandem wire systems.

Large wire diameters are generally used for poor fitup because of their ability to bridge large root openings.

The electrode diameter will affect deposition rates. At a given current setting, a small wire will give a higher current density and thus a higher deposition rate than a larger diameter wire. However, a larger wire can carry more current so larger wires give a higher deposition rate at higher currents.

For a given diameter size, a high current gives a high current density with deep penetration of the base plate. Low current on the same size wire gives a less penetrating arc. Wire size also affects arc starting. Small diameter wire arc starts are more consistent.

Automatic submerged arc will begin most often with 1/16" diameter wire with a common maximum of 3/16" or 1/4" diameter wire. Occasional situations will show a need for 5/16", 1/4" or 3/8" diameter wires. However, multiple head and narrow groove applications seem to have decreased the need for the excessively large single wires.

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## Electrode Extension

Electrode extension is the distance from the contact tip to the base metal. As this distance increases, amperage will drop off which results in less penetration, narrower bead and more build up. If wire feed speed is increased to return amperage to its previous level, this will increase deposition rate. The increased wire feed speed and amperage still will not achieve as much penetration as when the short electrode extension is used. However, this can be used to an advantage when deep penetration is not required.

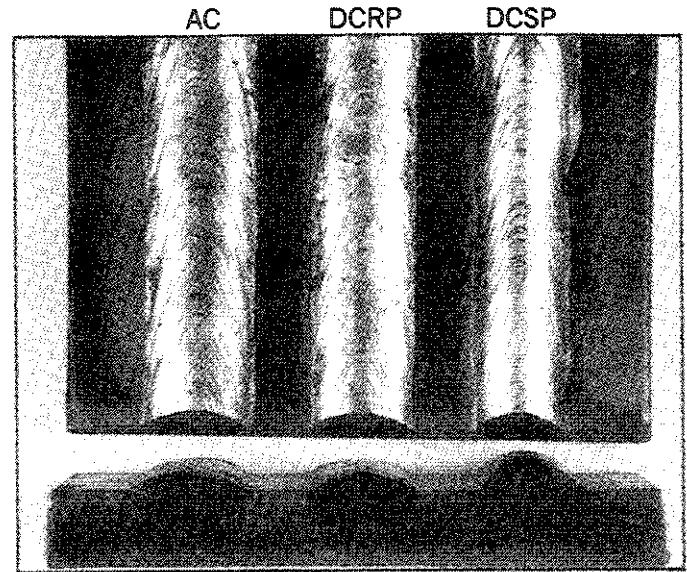
If electrode extension is reduced, amperage will increase. The penetration and bead width increases also. As experience is gained, the ability to optimize the wire electrode extension to achieve the best deposition rate and penetration characteristics for each particular weldment is realized.

A rule of thumb for setting wire extension is to go eight times the wire diameter. (Example: If 1/8" wire is used, the extension would be eight times 1/8" or approximately 1.")

## Polarity

Direct current is most commonly used but base metal type, joint design, and thickness are factors when choosing polarity. DC usually provides more control over the bead shape, penetration, deposition, and welding speed. DC makes arc starting easier than conventional AC power supplies, although Square Wave AC Sub Arc does provide most of the same features with very reliable arc starts. Both conventional AC and Square Wave AC output power sources greatly reduce the possibility of arc blow problems.

Direct Current Reverse Polarity (DCRP—electrode positive) provides the best control of bead shape and maximum penetration. The deep penetration allows the use of small welding grooves, or no groove at all in thin material, minimizing the amount of filler metal per foot of joint and permitting fast welding speeds. These high speeds lessen the total heat input and tend to reduce the problem of heat distortion. Reverse polarity also has a tendency to produce less weld porosity as opposed to straight polarity.



*Polarity Varied Weld*

Straight Polarity (electrode negative—DCSP) is used to reduce penetration. The deposition rate is improved because faster wire feed speeds are required to achieve the same current as DCRP. DC Straight Polarity is often used:

On clean plate, free from rust and mill scale for fillet welds.

On occasions where deep penetration is not required.

On hard surfacing applications where higher melt-off rates are desired and less base metal dilution.

Where reduced admixture (dilution) of filler metal with base metal is required. This is true for hard-to-weld steels. Straight polarity's shallow penetration is needed to lessen cracking or porosity.

Where greater build up is needed, but less penetration, to stop cracking in primary passes of deep groove weldments.

A switch from reverse to straight polarity should be accompanied by an approximate 3-4 volt increase. Holding the current at the same level as the reverse polarity setting is recommended to maintain the same bead shape.

The Sub Arc process operates with a very stable arc. This maintains good weld quality and keeps possible weld repairs to a minimum. This reliability can substantially boost weld productivity.

# WELDING HINTS

## Circumferential Welds

Making submerged arc welds on round workpieces, especially small diameters (less than 8") differ from flat and horizontal welds for the following reasons: Molten flux and weld metal tend to spill off the circular workpieces, and slag must be removed ahead of the arc if a continuous multiple pass weldment is being made. Remedies for these problems are as follows:

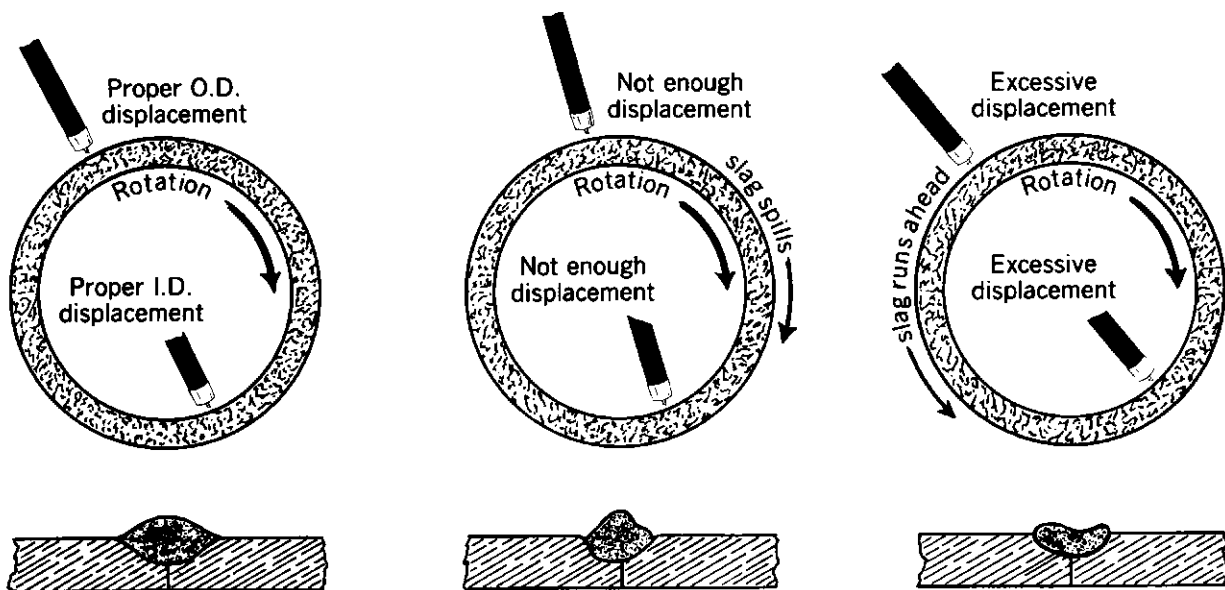
1. Wire positioning — position the wire before the outside diameter vertical centerline (11 o'clock for clockwise rotation, 1 o'clock for counterclockwise rotation). Angle the tip toward the direction of travel. (Note: Position wire at 5 o'clock for clockwise rotation and 7 o'clock for counter clockwise rotation on inside diameter welds.) The amount of displacement before the center line varies with each cylinder's diameter. Suggested settings follow:

CYLINDER DIAMETER	WIRE DISPLACEMENT
1" – 3"	3/8" – 3/4"
3" – 18"	3/4" – 1"
18" – 36"	1 1/4" – 1 1/2"
36" – 42"	1 1/2" – 1 3/4"
42" – 48"	1 3/4" – 2"
48" – 72"	2" – 2 1/2"
72" – over	3"

2. Limit bead sizes by lowering the current (wire feed speed), lowering the voltage, using smaller diameter wire or use faster travel speeds. Small beads solidify faster and the fused flux cools quicker for easier slag removal.
3. Support the flux with flux dams or shields to maintain proper flux depth at the arc.
4. Consult the wire and flux manufacturers for information on fast freeze wire and flux combinations.
5. Add air cooling to the work and slag to aid in slag removal. Air can be added at some point past the arc after the weld metal and flux have solidified.
6. Small multiple passes in heavy metals reduce the possibility of undercutting and give better contour for easier slag removal.

Cylindrical submerged arc welds can be as easy as flat welds if the following items are given adequate attention:

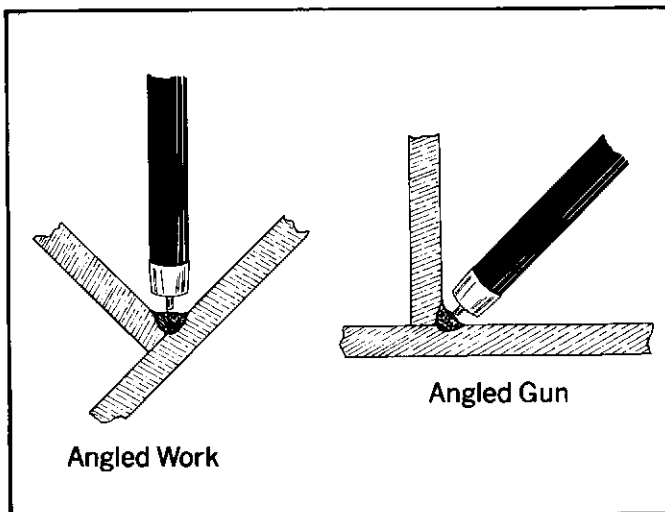
- Set bead size with current (wire feed speed) and travel speed.
- Position and angle the wire properly.
- Support flux for proper flux level on small diameter cylinders or bars.
- Support the flux when welding near an edge.
- Adequately provide for slag removal.
- When recovering flux, make sure all debris is screened from the reused flux. Dirty flux not only contaminates the weld, but clogs the flux feeding system thereby hindering proper flux coverage.



## Fillet Welds

Generally fillet welds require slower travel speeds and lower voltages than butt welding with the same amperages (wire feed speed). Using a single wire, a 3/8" throat size fillet can be made in one pass. Larger single pass, horizontal fillet beads can be made with multiple wires. Fillet welds 5/16" and larger are made in the flat position by positioning the work. Submerged arc fillet welds of a specific size have deeper penetration than Shielded Metal Arc fillet welds of the same size.

The bead width to depth ratio should be carefully regulated. The bead width should be 20-25 percent greater than the depth to prevent cracking. Even when welding procedures are rigidly followed, fillet welds may crack due to the highly restrained character of fillet welds. Maximum fillet weld penetration always comes at the point aligned with the wire's axis. This can be accomplished by two methods: Angling of the torch or tilting of the workpiece to obtain the right joint angle.

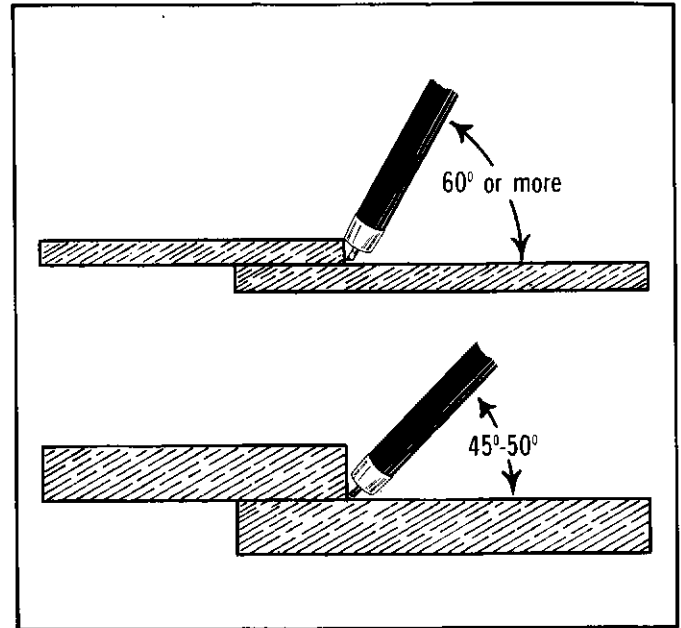


**Fillets**

Special precautions should be taken to prevent arc blow problems in fillet welds. Intersecting workpieces can intensify arc blow problems which may produce porosity and an uncontrollable weld bead.

## Lap Welds

Good fit-up and proper electrode alignment are prime considerations for good lap welds. If plates aren't tightly held together, the gaps will produce poor bead shape and defective welds. A clean plate, free from all contaminants is particularly important to good lap weld quality. If the wire is positioned too high on top plate, proper fusion to the bottom plate will not occur. If positioned too far away from the top plate, fusion to the top plate will be inadequate and may result in burn-thru of the bottom plate.



**Lap Joints**



## Weld Defects and Troubleshooting Full Automatic, Semiautomatic, Single Wire and Twin Wire

Joint	Problem	Possible Solutions	
All	Low Penetration	Increase welding amperage/WFS Use electrode positive Lower voltage on fillets or V-joints	Shorten wire extension Decrease travel speed Increase included angle on V-joints
Fillet	Cracking	Use EM12K electrode Use electrode negative Lower voltage	Decrease travel speed Preheat joint Increase electrode diameter and lower voltage
Root Pass in Groove	Cracking	Lower amperage/WFS and voltage Use electrode negative Increase root opening or included angle	Preheat joint Make sure back gouging is not narrow and deep
Multiple Pass Weld	Transverse Cracking	Increase interpass temperature Decrease travel speed	Decrease voltage Decrease amperage and voltage
Square Butt Weld	Cracking	Check fixture for plate movement Decrease travel speed	Check for copper pick-up from back up
Fillet Lap or Square Butt	Pock Marking or Slag Sticking	Use EM12K electrode Increase voltage Decrease amperage/WFS Decrease travel speed	Position fillet, if possible Heavier plate than normal will cause pocking Clean all mill scale, rust and oil off plate
Spud or Deep Groove	Slag Sticking	Decrease voltage	Decrease amperage/WFS and voltage
Spud	Not overlapping	Decrease voltage	Decrease amperage/WFS and voltage
All	Undercutting	Use electrode negative Decrease voltage Decrease amperage/WFS	Increase electrode diameter and lower voltage Decrease travel speed
All	Rust Porosity	Use EM12K or EM13K electrode Increase voltage Lower amperage/WFS Use electrode positive	Use torches in front of arc Clean joint completely (butt edges also) Decrease travel speed
All	Organic Porosity	Use EL12 electrode Use electrode positive	Decrease travel speed Degrease joint and dry completely
All	Arc Blow Porosity	Usually caused by improper tie-in Decrease welding amperage/WFS to tie-in	Decrease travel speed to tie-in If 100% fusion is not required, then decrease penetration
All	Metal Spots	Lower voltage Use electrode negative	Decrease amperage/WFS and voltage Increase travel speed
Out of Position	Metal Spillage	On roundabouts, move farther off center opposite to direction of travel Lower voltage Lower amperage/WFS and voltage	Increase travel speed on horizontal fillets On roundabouts, increase travel speed, lower amperage/WFS and voltage
All	Bead Shape	Increase voltage to get wider, flatter bead Decrease amperage/WFS to get flatter bead Decrease travel speed to get flatter bead on fillets	Use electrode diameter that is proper for welding amperage Use electrode positive on square butt welds and fillets smaller than 1/4"

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## SPECIAL APPLICATIONS

### Cladding

Strip cladding is a Submerged Arc process which uses a wide "strip" electrode and flux to make an overlay bead of various widths. Less cost is the reason a corrosion resistant overlay is made on a less expensive base material rather than making the entire structure of corrosion resistant material. "Strip" heads are available that can be fitted to a standard automatic wire feeder to allow feeding of various widths (1" through 9") and thicknesses (.010" through .050") of overlay material. Strip overlay gives a wider coverage bead with less dilution of the base metal compared to standard Submerged Arc methods because of the wider fusion area. Uniform surfaces of overlay beads are a must to give a smooth overall surface. Tie-ins between adjacent overlay beads must be uniform to maintain a smooth overlay surface devoid of highs and lows. The amperage demand is high for "strip" overlay work. Either constant current, constant potential or combination power sources can be used.

The flux used in "strip" overlay is specifically designed for that purpose. Information about this process is available from manufacturers of strip electrodes, flux and overlay weld heads.

Submerged Arc Welding of stainless seems to have found more acceptance in stainless cladding or overlay operations where, because of its wide and unique fusion pattern, the deep penetration is not obtained.

Fluxes used for stainless steel may be alloyed, of a "neutral" type or of a proprietary type made just for stainless steels. Flux manufacturers should be consulted for the proper choice of flux and wire. When using alloyed flux, voltage becomes a critical factor.

### Stainless Steel

Nearly all variables considered for mild steel Submerged Arc Welding must be considered for stainless steel Submerged Arc Welding. However, some distinct differences must be considered when welding stainless.

Currents used on stainless steel applications are about 80 percent of those for carbon steel. Submerged arc is not widely used on stainless steel because of the high heat input from the Submerged Arc process.

Where high heat input and slow solidification can be allowed, it can be used. Austenitic stainless has a higher thermal coefficient of expansion, and a lower thermal conductivity than mild steel. A high input will enhance chances of carbide precipitation and distortion.

Ferritic and martensitic stainless can be welded with the Submerged Arc process, but has not gained the acceptance that Gas Tungsten Arc, Gas Metal Arc and Shielded Metal Arc has found.

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## GLOSSARY

**Agglomerated.** A type of flux that is produced with a ceramic binder. Deoxidizers and alloying elements are limited.

**Alternating pass.** In a grooved joint, the practice of laying one pass next to the previous pass (instead of one wide pass in narrow groove joints).

**Arc Voltage.** The voltage across the welding arc.

**Arc Wander.** The tendency of the arc to be drawn toward the side of the joint. (See magnetic arc blow).

**Automatic Welding.** Welding with equipment which performs the welding operation without adjustment of controls by a welding operator. The equipment may or may not perform the unloading and loading of the work.

**Back Gouging.** Weld metal and base metal is removed from the other side of a partially or completely welded joint. It assures complete penetration of succeeding passes from the side the metal was removed (gouged).

**Backing.** A material (base metal, weld metal, carbon or granular material) placed at the root of a weld joint for the purpose of supporting flux and molten weld metal.

**Backing Pass.** A weld made to provide a back up for the Sub Arc weld.

**Backing Strip.** Backing in the form of a strip (see Backing).

**Backing Weld.** Backing in the form of a weld (See Backing Pass).

**Burn-Thru.** A weld defect occurring in a weld joint when the weld metal no longer fuses the base metals being joined. Also referred to as excessive melt-thru or excess penetration.

**Butt Weld.** The weld that is made in a joint whose edges meet in the same plane.

**Centerline Cracking.** After a weld bead is complete or partially completed, stress may cause a crack down the center of the weld bead. In most cases, this can be eliminated by using alternating passes.

**Cladding.** A relatively wide layer of material applied by surfacing (lining) for the purpose of improved corrosion resistance.

**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.

**Constant Potential (CP) Welding Machine.** Also referred to as Constant Voltage (CV). "Potential" and "voltage" are basically the same in meaning. This type of welding machine output maintains a relatively stable, constant 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 SMAW (stick) welding machine.

**Contact Tube.** A device which transfers current to a continuous strip or wire.

**Crater.** In arc welding, a depression in the weld metal at the termination of a weld bead.

**Crater Fill Current.** The current (wire feed speed) value during crater fill time.

**Crater Fill Time.** The time interval following the weld time but prior to burn back time during which arc voltage or current reach a preset value greater or less than welding values. Weld travel may stop during this period.

**Crater Fill Voltage.** The arc voltage value during crater fill time.

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**Deposition Rate.** The weight of material (weld metal) deposited in a unit of time. It is usually expressed in kilograms per hour (Kg/h) or pounds per hour (lb/h).

**Dilution.** A chemical composition change within the deposited weld metal. The change is due to different alloys coming in contact in the weld puddle. The alloys are from the electrode wire and the base metal. Dilution can be measured by the base metal percentage or previous pass of weld metal percentage found in the weld bead. Dilution can cause changes in weld bead strength.

**Direct Current Electrode Negative.** The arrangement of direct current arc welding leads in which the work is the positive pole and the electrode is the negative pole of the welding arc (straight polarity).

**Direct Current Electrode Positive.** The arrangement of direct current arc welding leads in which the work is the negative pole and the electrode is the positive pole of the welding arc (reverse polarity).

**Electrode Extension.** The length of unmelted electrode extending beyond the end of the contact tube during welding.

**Extension Guide.** A guide that fits between the gun and nozzle over the contact tip to help preheat the wire.

**Ferritic Stainless.** Contains 16-30 percent chromium as an alloying agent. It is corrosion and oxidation resistant. It is magnetic and less weldable than austenitic stainless. Ferritic types usually are the 405, 430, 442 and 446 Series and require preheat.

**Filter Plate (eye protection).** An optical material which protects the eyes against excessive ultraviolet, infrared and visible radiation.

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

**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. An example of poor fit-up can be too large of a root space in a V-groove butt weld.

**Fixture.** A device designed to hold parts to be joined in a proper relation to each other.

**Flash Thru.** In submerged arc, when the flux coverage is not adequate, open arcing will occur.

**Flux Depth.** Optimum amount of flux necessary to cover the arc without flash thru.

**Head and Tail Stock** is a positioner that supports long weldments (usually cylinders) so that they can be rotated 360 degrees and welded in the horizontal position. The weldments are held in place by chucks or bolts. The head stock is powered.

**Helmet (eye protection).** A protection device used in arc welding for shielding the eyes, face and neck. A helmet is equipped with a suitable filter plate and is designed to be held in the hand or worn on the head.

**Included Angle.** When a groove is made between two materials to be joined together, the included angle represents the totals of the angles between the two bevelled edges. Also known as groove angle.

**Interpass Temperature.** In a multiple pass weld, the temperature (minimum or maximum as specified) of the base metal and deposited weld metal before the next pass is started.

**Land.** The edges of the groove opening that run parallel to each other at the root. It is also known as root face.

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

**Machine Welding.** Same as automatic welding, however, the operator must maintain proper gas/joint alignment.

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**Magnetic Arc Blow.** When welding with Direct Current (DC), magnetic forces may cause the arc to be deflected from its normal path.

**Manipulator** consists of a swivel or track mounted base, vertical support beam and a horizontal boom, all of which are movable, to which welding equipment or a gun is mounted. It can raise and lower the equipment (arc) into position and move the arc in and out or in a straight line at a preset speed.

**Martensitic Stainless** contains 11-18 percent chromium as an alloying element. It is magnetic and has a low nickel content, sometimes referred to as "straight chrome." Like ferritic, it is hard to weld, pre- and post-heat are used to control brittleness and cracking. Martensitic stainlesses are 403, 410, 420, 431, 502 and 505.

**Organic Porosity.** A weld defect caused by oil, grease, paint, etc. as opposed to porosity caused by gas entrapment.

**Pock Mark.** A defect on the face of the weld, a surface indentation.

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

**Root Opening.** The separation of the members to be welded together at the root of the joint. Its purpose is to allow better fusion and penetration to take place. Sometimes referred to as root gap.

**Root Penetration.** The depth that a weld extends into the root of a joint measured on the center line of the root cross section.

**Run-In Speed.** Speed of the wire prior to arc start. Assists arc starts.

**Segregation.** The separation of types of flux in a mechanically mixed flux.

**Semiautomatic Arc Welding.** Arc welding with equipment which controls only the filler metal feed rate and voltage. The advance of the welding gun angle and wire extension is manually controlled.

**Shielded Metal Arc Welding (SMAW).** An arc welding process which melts and joins metals by heating them with an arc, 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 wire. Also called Stick Welding.

**Side Beam Carriage** is a fixture that holds the part stationary and the gun and drive mechanism travels in a straight line over the weldment.

**Slag Entrapment** is a weld defect that can occur because of poor welding conditions or poor cleaning between passes. The slag (melted and solidified flux) is trapped in the weld bead or between the weld bead and base material. Can also be called slag inclusion.

**Spatter.** The metal particles expelled during welding and which do not form a part of the weld.

**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.

**Tie-In** refers to the fusion of the base metal to the filler metal or the previous weld pass to each succeeding weld pass.

**Turning Rolls** are support and drive wheels for cylindrical weldments. They will turn at various speeds so the welds (usually vertical) can be accomplished.

**Turntable** is a fixture that rotates the weldment so that the operator or automatic system can weld from one position.

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*Undercut.* A groove melted into the base metal usually along the toes (edges) of a weld. Undercut can also occur on either side of the first pass of a full penetration weld, such as an open groove butt weld. Undercutting produces a weak spot in the weld, and since it is considered a defect, it must be corrected in many cases.

*Unfused.* After a weld is made, the flux that remains in its original granular form is unfused.

*Wire Preheating.* The application of heat to the wire by an extension on the gun, usually to obtain higher deposition.





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