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An Approach to Best Welding Practice. Part – XXI. Section – III- B - IVb

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"AN APPROACH TO BEST WELDING PRACTICE. Part – XXI." is the Twenty First Detail Part of **"AN APPROACH TO BEST WELDING PRACTICE"** which was written as a General and Overall approach to the subject matter.

AN APPROACH TO BEST WELDING PRACTICE. Part – XXI., Section III –B IVb is particularly focused on the Generation and Computer based Storage of Welding Data on SAW Process for Fabrication. It is required as a Working Guideline for Planning Engineers, Welding Coordinators and Quality Managers working in an Engineering Fabrication Plant using welding as the main manufacturing process.

In fact, this is a lengthy process to develop and as each and every step is connected with each other for cross references, none can be eliminated.

In every Fabrication concern where Welding is the major manufacturing process preparation, recording and data storage of welding processes must be done.

The Importance of Record Keeping

Record keeping critical in case of Fabrication and Manufacturing concerns employing welding as the main manufacturing process, as because welding is a "Special Process" and the Product acceptance is dependent upon follow up of a number of Procedures, Codes and Standards. Documentation of all these proceedings are to be meticulously prepared and maintained – normally by the "Welding Engineer" or "Welding Coordinator." Again, apart from documentation so many data related to the Power Source, Electrodes, Gases used, Maintenance schedules etc are to be coordinated with variety of data converging for a product to be manufactured and to be accepted by the customer. Normally, most of these are paperwork and the tendency is either to destroy the past records of papers or to dump them somewhere beyond restoration. Even the large volume of information kept in mind of the Welding Engineer or the Welding Coordinator in course of work are irretrievable to any new incumbent or others.

It is an accepted fact now that data collection, storage and retrieval can not be done effectively with human individuals or even by groups and possibilities of distortion of retrievable data cannot be ruled out.

I. What data are needed ?

It is understood and accepted that in Fabrication and manufacturing Industries where Welding is the main process, classification of Data used and needed is very difficult. We can at best identify the following needs

1. Welding processes
2. Welding Power Sources with Ancillary Equipment
3. Consumables – Electrodes, Wires, Flux Cored Wires
4. Shielding Gases
5. Joint design weldment design and surface preparation
6. Weld location Welding position

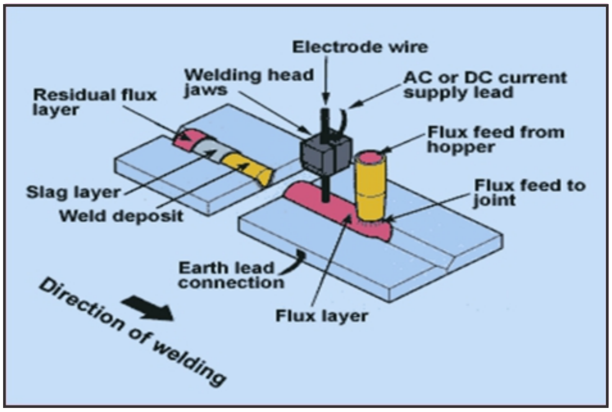
II. How to store and retrieve data ?

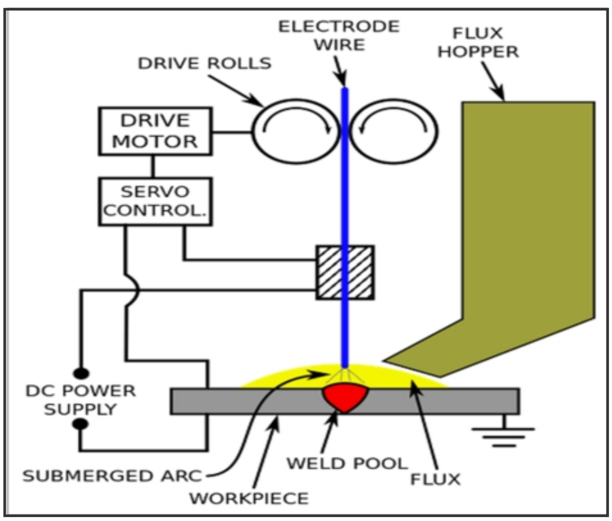
A large number of computer softwares have been developed to store data, modify and to retrieve as and when required. This system will eliminate human error, can link and compare past performances with the present one instantly, may even point out optimum use of resources for increased efficiency, effectiveness of resources for ultimate gain of productivity and quality improvement.

An integrated system will include:

- Filler and base metals and their chemical and mechanical properties;
- Histories of welder qualification and the quality of welds by each welder;
- Welding-procedure information, including WPSs, PQRs, and pre- and post weld heat-treatment information;

SUBMERGED ARC WELDING (SAW)



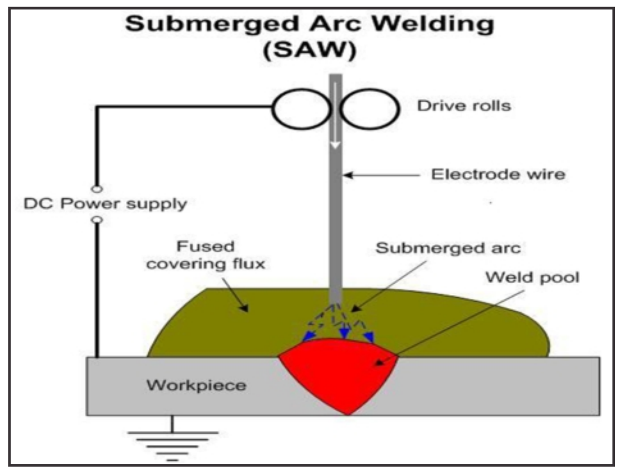


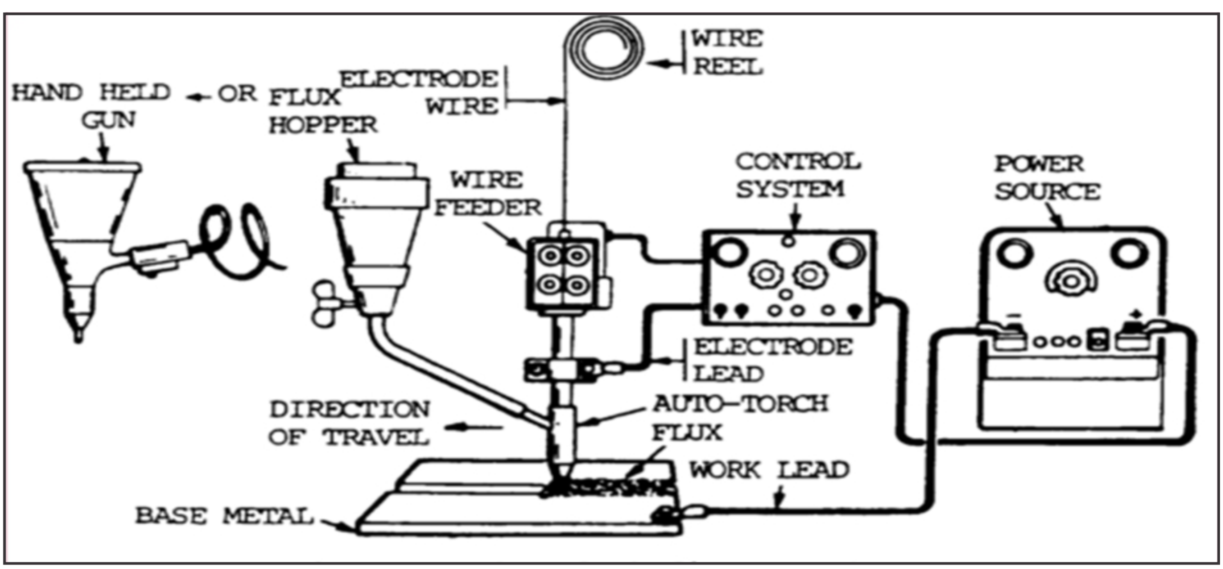
- Design information, including joint design graphics and welding symbol information; Corrosion-resistant and wear-resistant material information, such as ferrite content and prediction for stainless steel welds.

The softwares art all designed to operate in the computing environment of the desktop computer, turning the computer into a welding engineering work station.

Submerged Arc Welding

Submerged Arc Welding process uses a continuously-fed tubular or consumable solid electrode and may be fully automatic or semi-automatic. The arc is flat and is maintained between the end of a bare wire electrode and the weld. The electrode is constantly fed into the arc and as it is melted, a layer of granular flux fed provides a protective cover beneath





which the welding occurs. The cover is created as some of the flux becomes molten. This fusible flux may consist of lime, silica, manganese oxide, calcium fluoride, and other compounds. In a molten or melted state, the flux becomes conductive. This allows it to supply a constant current between the electrode and the welding work. The remainder of the flux is recovered and reused.

In the automatic version of SAW, the process is operated with a set of rollers driven by a controlled motor to ensure that the wire is fed into the arc at a speed rate that is equivalent to the rate at which the electrode is melted. The arc length remains constant as a result. The SAW process is usually automated, however, semi-automated systems are also available. Properly performed Submerged Arc Welding should consistently result in mechanical properties that are at least equal to that of the base metal. Ductility and impact resistance should be good, and bead appearance should be uniform.

PROCESS CHARACTERISTICS

- High deposition rates – compared to other welding processes
- Faster travel speeds – compared to other welding processes
- Economical - High deposition rates and high travel speeds reduce overall costs
- Simple - mechanized process, easy to train machine operators
- Clean environment - minimal smoke or fumes
- Operator friendly - no visible arc, no spatter.

WELDING VARIABLES

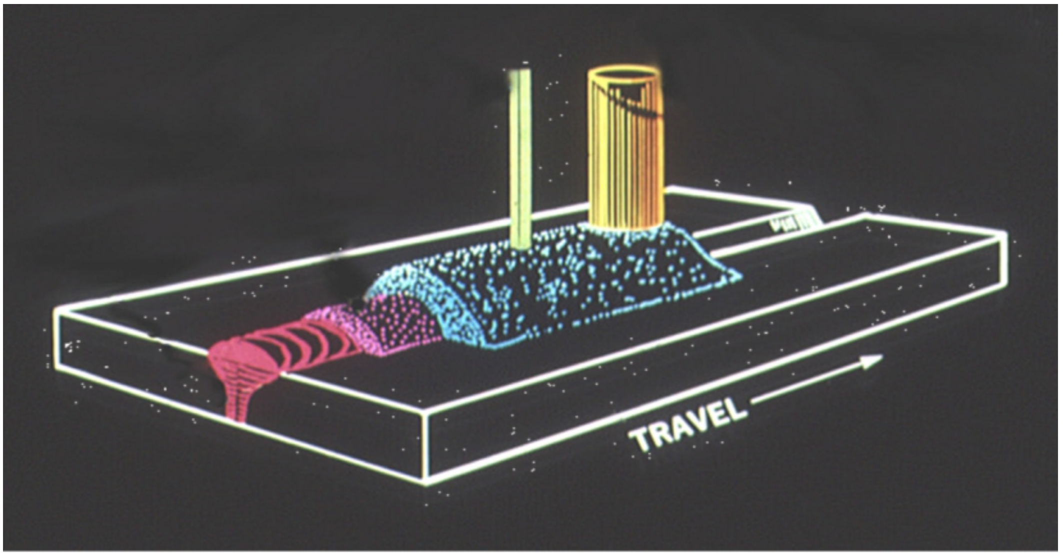
- Welding current
- Arc voltage
- Travel speed
- Wire size
- Wire extension o

EQUIPMENT USED

- Power supply Source
- Start plate
- Copper mold
- Electrode
- Guide tube
- Wire feeder
- Power source
- SAW head
- Flux handling
- Protective equipment

ADVANTAGES

- High deposition rates (over 100 lb/h (45 kg/h) have been reported).
- High operating factors in mechanized applications.
- Deep weld penetration.
- Sound welds are readily made (with good process design and control).
- High speed welding of thin sheet steels up to 5 m/min (16 ft/min) is possible.
- Minimal welding fume or arc light is emitted.
- Practically no edge preparation is necessary.
- The process is suitable for both indoor and outdoor works.
- Distortion is much less.
- Welds produced are sound, uniform, ductile, corrosion resistant and have good impact value.



- Single pass welds can be made in thick plates with normal equipment.
- The arc is always covered under a blanket of flux, thus there is no chance of spatter of weld.
- 50% to 90% of the flux is recoverable

LIMITATIONS

- Limited to ferrous (steel or stainless steels) and some nickel based alloys.
- Normally limited to the 1F, 1G, and 2F positions.
- Normally limited to long straight seams or rotated pipes or vessels.
- Requires relatively troublesome flux handling systems.
- Flux and slag residue can present a health & safety issue.
- Requires inter-pass and post weld slag removal

CURRENT IN SUBMERGED ARC WELDING

From 300A to 3000A are commonly used in SAW. Currents up to 5000A can also be used in multiple arc welding system. DC or AC powers as well as a combination of both are common sources of power on multiple electrode systems. Constant voltage power supply is a most commonly used source. However, constant current system in combination with a voltage sensing wire-feeder is also utilized in semiautomatic systems.

WELDING CURRENT

- Controls = Penetration and deposition rate
- current = penetration
- current = burn-off rate
- current = deposition rate
- Polarity and current type (may be either AC or DC), as well as variable balance AC current

INFLUENCE OF POLARITY

- DCEP - Deep penetration
- DCEN - Shallow penetration
- AC - Penetration is in between DCEP and DCEN

ELECTRODES / WIRES USED IN SAW

In AWS system a dual flux type/wire composition designation to identify the flux/wire combination are used that will provide the required properties. The AWS system is somewhat simpler than the BS EN method, particularly if the full flux descriptor is used. There are, however, only two specifications that deal with both wire composition and the flux but an additional two specifications that cover bare wires for stainless steels and the nickel based alloys. These are

- A5.17 Carbon Steel Electrodes and Fluxes for Submerged Arc Welding and
- A5.23 Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding.

The bare wire specifications are

- A5.9 Wire Electrodes, Strip Electrodes, Wires, and Rods for Arc Welding of Stainless and Heat Resisting Steels-Classification and
- A5.11/A5.11M Nickel and Nickel-Alloy Bare Welding Electrodes and Rods for Shielded Metal Arc Welding.

In AWS A.5.17 and AWS A5.23 the first part of the designation describes the flux type and may comprise up to six digits depending upon whether the flux is supplied with the tensile strength expressed in increments of 10 megapascals (two numbers where 43 represents 430MPa) or in pounds per square inch (1 digit i.e. 6 represents 60,000psi or two digits ie 12 represents 120,000psi).

- The first digit, the letter 'F', identifies the consumable as a submerged arc welding flux,
- Next letter 'S' is only included if the flux is made from or includes crushed slag. Omission of this letter 'S' indicates that the flux is unused and contains no crushed used flux introduced either by the flux manufacturer or the welding fabricator.
- The next one or two digits specify the minimum tensile strength as explained above and this is followed by 'A' or 'P' for whether the test results were obtained in the as-welded, (A condition) or post-weld heat treated, (P condition). The last digit identifies the minimum temperature at which a Charpy-V impact value of 27J can be achieved as in the Table below.

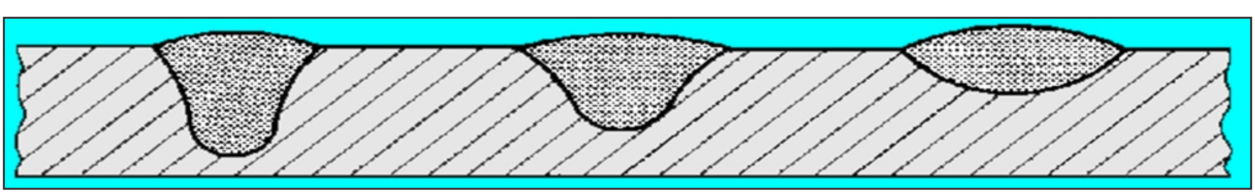


Table Impact Test Requirements

Digit	Test Temperature		Impact Value	Impact Value
	°C	°F	(Joule)	(ft.lbf)
Z	no impact requirements		27	20
0	-18	0	27	20
2	-29	-20	27	20
4	-40	-40	27	20
5	-46	-50	27	20
6	-51	-60	27	20
7	-70	-	27	-
8	-	-80	-	20
10	-100	-100	27	20
15	-	-150	-	20

In AWS A5.17 wires are split into three groups of low, medium and high manganese.

- The first digit, 'E', identifies the consumable as a bare wire electrode. If supplemented by 'C' the wire is a composite (cored) electrode. The composition of the solid wire is obtained from an analysis of the wire. However, since the composition of a cored wire may be different from that of its weld deposit the composition must be determined from low dilution weld deposit made using a specific, named flux.
- The next letter, 'L', 'M' or 'H' indicates a low (0.6% max), medium (1.4% max) or high (2.2% max) manganese content.
- This is followed by one or two digits that give the specific composition.
- An optional letter 'K' indicates a silicon killed steel.
- There are a final two or three optional digits identifying the diffusible hydrogen in ml/100g weld metal, H16, H8, H4 or H2.

A full designation for a carbon steel flux/wire combination could therefore be

F6P5-EM12K-H8.

This identifies this as being a solid wire with a nominal 0.12% carbon, 1% manganese and 0.1 to 0.35% silicon capable of achieving an ultimate tensile strength of 60 k.p.i. (415MPa), a Charpy-V impact strength of 27J at -50°F (-46°C) in the post weld heat treated condition.

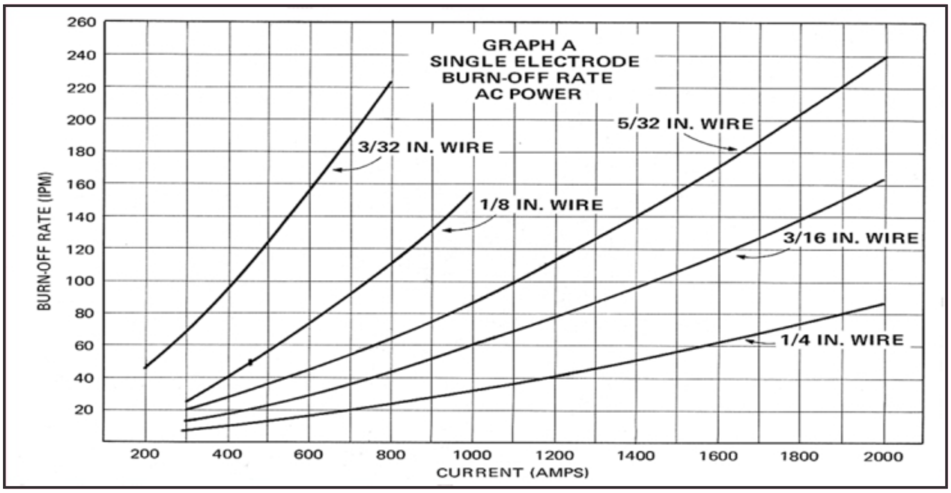
The classification in AWS A5.23 is, of necessity, rather more complicated as this specification covers a wide range of low alloy steels, a total of forty six solid wires and thirty two composite wire weld metal compositions. Within the confines of this brief article it will not be possible to cover in full the entire classification of the wires.

The flux designation is almost identical to that of AWS A5.17, except that a four, five or six digit identifier may be used. The additional sixth digit indicates that some of the electrodes in the specification are capable of providing tensile strengths above 100,000 psi - in these cases the designation may be, for example, F11, identifying the flux as providing 110 ksi (760MPa) minimum tensile strength.

The classification of the wire comprises two parts – the first that of the wire, solid wires being prefixed 'E' and composite wires 'EC', the second part specifies the composition of the weld deposit.

The wire classification commences with

- 'E' to identify a bare wire,
- the next letter places the wire in a 'family' of wires. 'L' or 'M' identifies the wires as being alloyed with
- copper, 0.35% max; '
- A'as containing molybdenum, 0.65% max;
- 'B' as the creep resisting steels containing chromium and molybdenum; 'Ni' for those wires containing nickel.
- 'F comprises the Ni-Mo or Cr-Ni-Mo wires;
- 'M' triple de-oxidised Ni-Mo wires;
- 'W' aNi-Cu wire and 'G' not specified.



Thus a full designation for a flux/wire combination for an as welded 1% Ni/0.25% Mo weld deposit with an ultimate tensile strength of 80ksi and an impact strength of 27J at -60°F (-51°C) may therefore be

F8A6-ENi1-Ni1

and for a similar deposit using a cored wire in the PWHT'd condition

F8P6-ECNi1-Ni1.

FUNCTION OF THE FLUX

- Molten flux shields the weld pool
- Affects weld metal chemistry
- Affects weld metal mechanical properties
- Affects weld performance/characteristics
- Fluxes have variable burn-off rates

The granular flux used in SAW serves several functions. In addition to providing a protective cover over the weld, the flux shields and cleans the molten puddle. The flux also affects the chemical composition of the weld metal, the weld bead shape, and the mechanical properties of the weld.

Another function of granular flux is to act as a barrier that holds the heat in and concentrates the heat into the weld area to promote deep penetration.

Types of Granular Fluxes

The methods used to manufacture fluxes determine the flux types. There are :

- fused fluxes,
- bonded fluxes,
- agglomerated fluxes, and
- mechanically mixed fluxes.

When manufacturing fused fluxes, raw materials are melted into a liquid state with a high temperature electric furnace. The material is then cooled and crushed or ground into the desired particle size.

When making bonded fluxes, the ingredients are dry mixed, then glued together with a liquid binder. This binder may be a liquid such as sodium silicate. After the particles are bonded, they are baked and then sifted through a sieve to attain flux particles of the desired size.

Agglomerated fluxes are manufactured much the same way that bonded fluxes are made. However, instead of a liquid binder, a ceramic binder is used. A higher drying temperature is used, too. (The higher drying temperature limits the use of deoxidizers and alloy elements.) Fluxes that are mechanically mixed are combinations of two or more bonded or agglomerated fluxes. Although mechanically mixed fluxes make it possible to create special mixtures for more sensitive welds, these fluxes may separate during storage, use, and recovery of flux.

Fused Fluxes versus Bonded Fluxes

Among the various types of fluxes use in Submerged Arc Welding are the fused flux and the bonded flux. Each of these fluxes offers some advantages and some disadvantages.

Fused Fluxes

When making fused fluxes, the raw materials are dry mixed together, and then they are fused or melted into a liquid state by using a high temperature furnace. After fusion is complete, the fluxes are cooled. This may be accomplished by using a stream of water or with big chill blocks.

Once the fluxes are cooled, they are crushed or ground into particles. A variety of particle sizes are made to ensure optimal performance for different applications.

Advantages of fused fluxes include:

- The non-hygroscopic flux particles do not absorb moisture and, therefore, any surface moisture can be eliminated merely by drying the particles at a low temperature oven setting of 300 degrees F.

- Low temperature drying of condensation on the fused flux particles provides better protection against hydrogen cracking.
- Flux particles create welds that are chemically consistent.
- Recycling of fused flux particles through the flux recovery systems can be achieved without losing sizing or composition.

A disadvantage of fused fluxes is that the high temperature used during the manufacture process makes it difficult to add alloys and deoxidizers.

Bonded Fluxes

The manufacture of bonded fluxes involves combining the dry ingredients, then using a liquid binder such as sodium silicate or potassium silicate to glue the ingredients together. After the bonded mix is made into pellets, the pellets are baked at a low oven temperature. Once the drying of the pellets is complete, the pellets are broken up by using a sieve to attain the desired particle size. The particles are then packaged for shipping.

Advantages of bonded fluxes include:

◈ Deoxidizers are present in bonded fluxes, protecting against rust and mill scale. These deoxidizers also help to prevent welds from becoming porous.

◈ Alloys can be added to bonded fluxes. Alloy elements may improve chemical and mechanical properties of the flux.

◈ Bonded fluxes allow for a thicker flux layer when welding.

◈ Bonded fluxes can be identified by color.

◈ Bonded fluxes typically provide better peeling properties than fused fluxes.

◈ There are at least two disadvantages of using bonded fluxes. These are:

◈ They absorb moisture.

◈ They can change in composition due to segregation or loss of fine particle size.

A further classification may be made as :

- Neutral – Multi-pass, unlimited thickness, high toughness
- Active – High in deoxidizers, high speed, weld over rust, limited thickness
- Alloyed – Addition of Cr, Ni ..., enhanced mechanical properties.

Fluxes termed "neutral" or "active" according to their potency in modifying weld composition. They are also categorized as "basic" or "acid" based on their chemical reaction. "Acid" silicate fluxes are active types. Active fluxes and/or electrodes deoxidized with silicon and manganese are useful when making single pass welds on scaled or rusty steel plate. However, Si and Mn build up may give poor toughness and soundness in multi-pass welds Basic fluxes give optimum strength and toughness in steel welds

Flux Basicity

The flux basicity index (BI) is calculated using various formulas that quantify the ratio between basic and acidic components of the flux.

Lincoln Electric uses the Boniszewski basicity index formula:

$BI = 0.5(FeO + MnO) + CaO + MgO + Na_2O + K_2O + CaF_2 / SiO_2 + 0.5(TiO_2 + ZrO_2 + Al_2O_3)$

Granular flux used in welding is a type of granular insulative materiall that is made up of numerous small particles. In Submerged Arc Welding (SAW), the granular flux provides a blanket over the weld, which protects against sparks and spatter. In SAW, the granular flux is frequently the means for achieving high deposition rates. The flux is also instrumental in producing the type of quality weld that is common in this particular welding process.

Various formulations that are used as flux are,

- Calcium silicate
- Manganese silicate
- Aluminate rutile or basic
- Basic fluorides

Variations of the Submerged Arc Welding Process

The submerged arc welding process may be varied in a number of ways to give it more capabilities. These include, but are not limited to, varying the number of wires and power sources, adding iron powder to the flux, and using a strip electrode for surfacing.

Multi-wire systems offer advantages, because the use of more electrodes can improve deposition rates and travel speeds. The utilization of more than one electrode in submerged arc welding may be accomplished with either a single power source or separate power sources for each wire.

The use of multiple power sources with two or more electrodes allows for the utilization of different polarities on the electrodes. Also, with separate power sources for two electrodes, alternating current may be used on one, while direct current is used on the other electrode. Typically, when three wires are used in the tandem position (one electrode is placed in front of the other), alternating current is used. The electrodes are connected to three-phase power systems, which are used for making high-speed longitudinal seams on large pipes and fabricated beams.

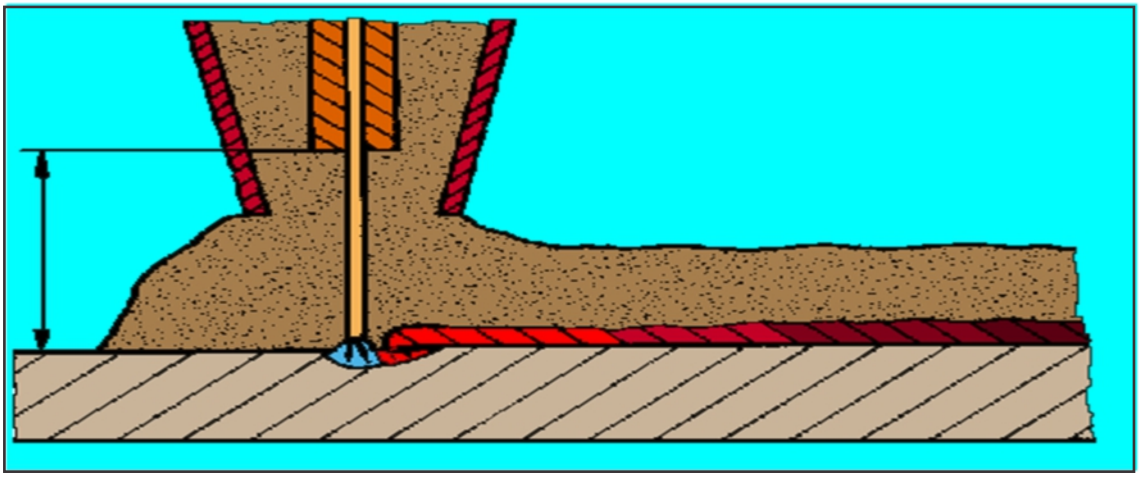
Adding iron powder to the flux increases deposition rates of submerged arc welding, but it does not decrease the properties of the weld metal.

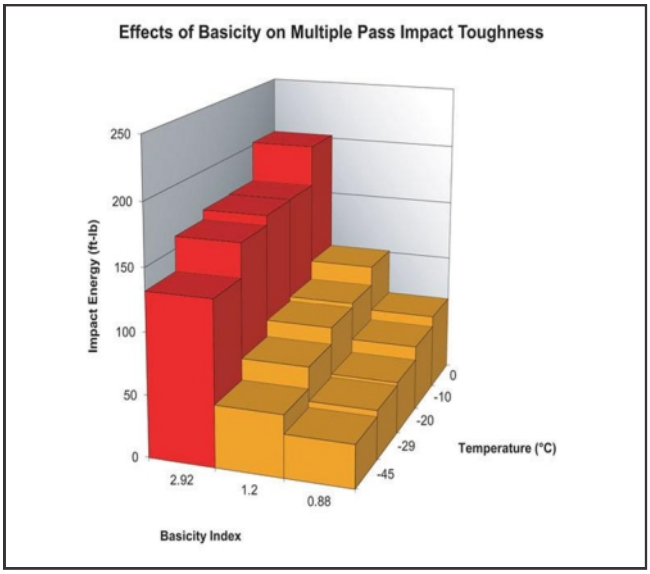
The utilization of a strip electrode for surfacing may be done to save money. This particular welding system uses the strip electrode and flux to make a corrosion-resistant overlay on a less expensive base material such as stainless steel. During this procedure, a wide, uniform bead is produced that has minimum penetration. The uniform bead is necessary to provide a smooth overall surface. The strip welding system is often used for overlaying the inside of vessels. The flux that is used in strip surfacing is made specifically for that purpose.

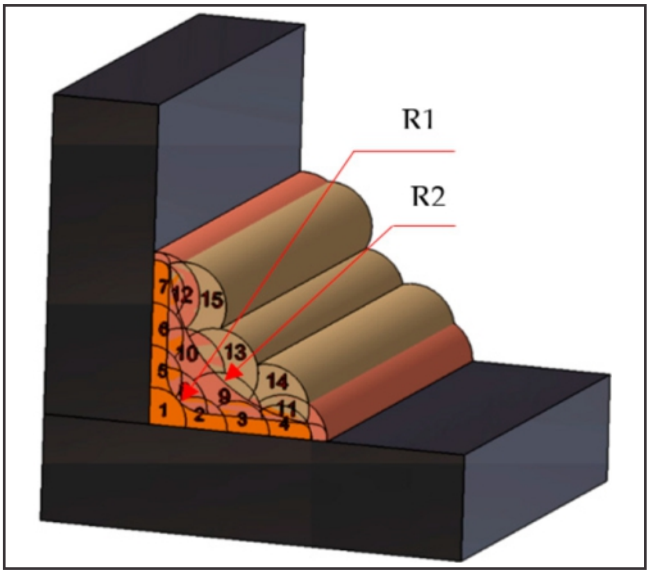
Advantages of Submerged Arc Welding

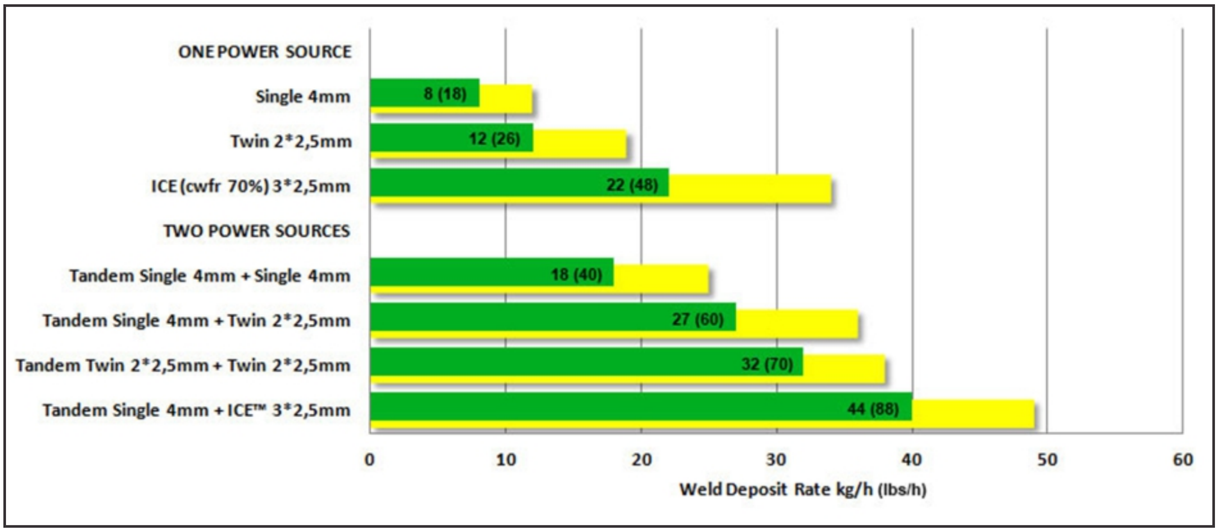
- Wire stick-out should be about 8 times the wire diameter - (1/8" wire = 1")
- Electrical Stick-Out (ESO) - Tip-to-work distance
- Longer stick-out – At the same wire feed speed decreases welding current and penetration
- Longer stick-out – At the same current increases deposition due to the higher burn-off rate
  – As stick-out increases, the wire feed speed must be increased to maintain the same welding current

ELECTRODE STICK-OUT = 8X WIRE DIAMETER









	POWER WAVE AC/DC 1000 SD	FLEXTEC 650X
Power Supply (3x50-60Hz)	380-400-460-500-575 V	380-460-575 V
Effective Power at 100%	55 kVA	46 kVA
Current Range	100 - 1000 A	40 - 650 A
Duty Cycle at 100%	1000 A / 44 V	650 A / 44 V
Weight	363 Kg	75 Kg
Dimensions L x I x H	1248 x 501 x1184 mm	745 x 410 x 554 mm
Protection Index	IP 235	IP 23

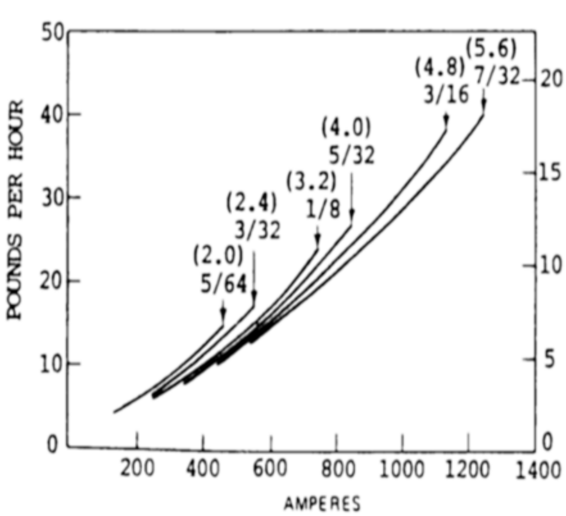


Fig. : Deposition rates for single electrodes

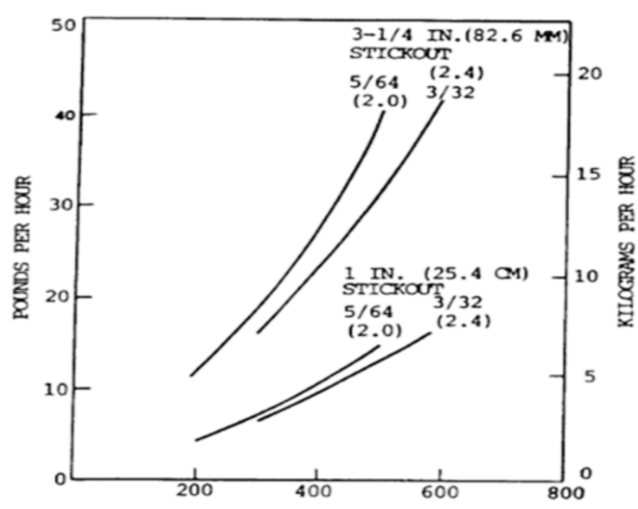


Fig. : Stickout vs. deposition rate

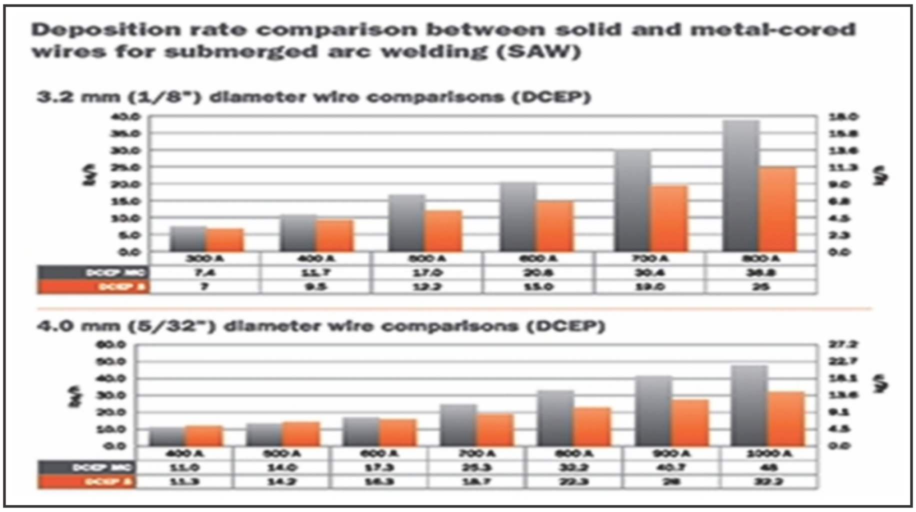
ORTHOGONAL ARRAY DESIGN AND OUTPUT RESPONSES

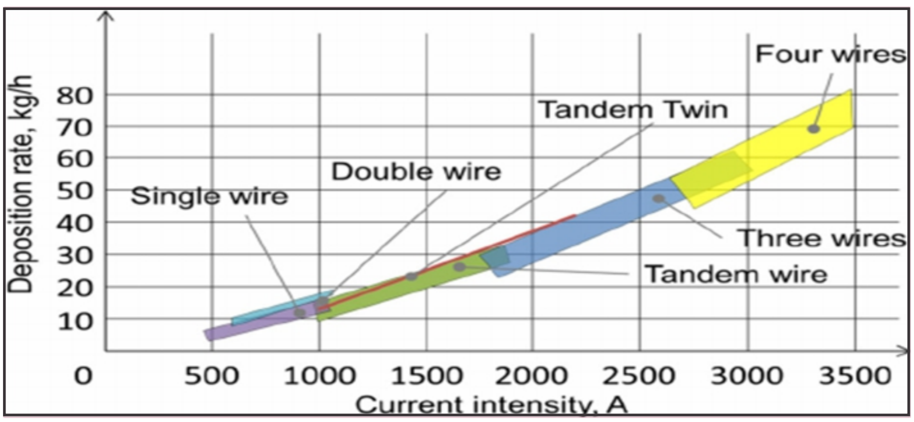
RUN	VOLTAGE (V)	CURRENT (A)	SPEED (m/h)	WIDTH (mm)	HARDNESS (HRC)
1	25	420	25	10.5	40.5
2	25	420	30	10	39.5
3	25	450	25	11	46.5
4	25	450	30	12	45
5	30	420	25	12	44.5
6	30	420	30	9.5	47.5
7	30	450	25	13.5	48.5
8	30	450	30	11.5	47.5

OPTIMIZATION OF SAW PARAMETERS FOR JOINING DISSIMILAR METAL

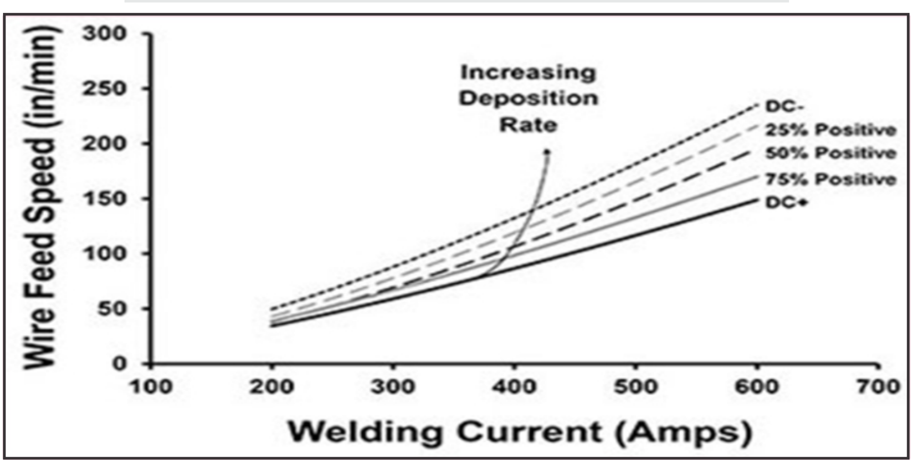
Table : Deposition Rate Comparision

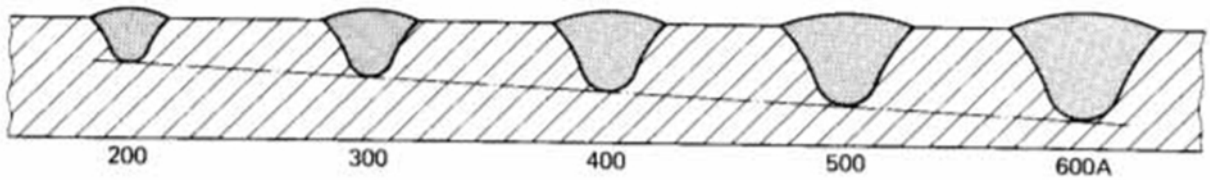
Wire Size		Current	SAW DC+ve			Generation I			AC Ctr. Wave from 50/50*		Generation II		
mm	inch	A	EE"	lb/hr	kg/hr	EE"	lb/hr	kg/hr	lb/hr	kg/hr	EE"	lbs/hr	kg/hr
4.0	5/32	500	1¼	11.1	5.0	2¾	13.1	6.0	14.7	6.7	3¾	18.0	8.2
4.0	5/32	600	1¼	14.7	6.7	2¾	18.3	8.3	18.8	8.5	3¾	23.5	10.7
4.0	5/32	700	1¼	18.2	8.3	2¾	26.8	12.2	23.7	10.8	3¾	27.5	12.5
4.0	5/32	800	1¼	22.1	10.0				28.6	13.0	3¾	33.7	15.3
3.2	1/8	450	1	10.1	4.6	2½	15.1	6.9	14.2	6.5	3	16.0	7.3
3.2	1/8	500	1	11.5	5.2	2½	16.3	7.4	16.3	7.4	3	17.5	8.0
3.2	1/8	600	1	14.8	6.7	2½	22.5	10.2	21.3	9.7	3	24.0	11.0
3.2	1/8	700	1	18.8	8.5	2½	26.8	12.2	26.1	11.9			
2.4	3/32	450	1	11.8	5.4	2¼	17.6	8.0	15.2	6.9			
2.4	3/32	500	1	13.1	6.00	2¼	20.6	9.4	17.6	8.0			



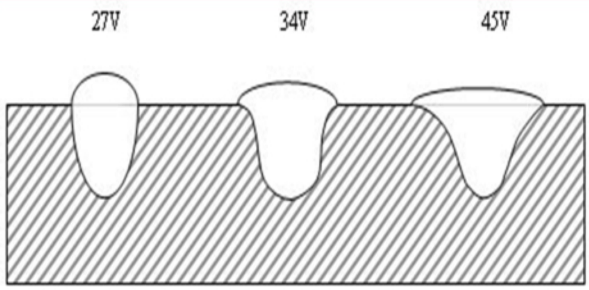


DEPOSITION RATES OF DIFFERENT SAW PROCESSES

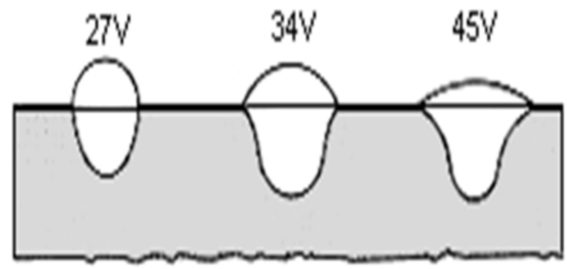




Increasing welding current results in deeper penetration.



Effect of arc voltage on bead shape.



Submerged Arc Wires –
Diameters vs Current Range

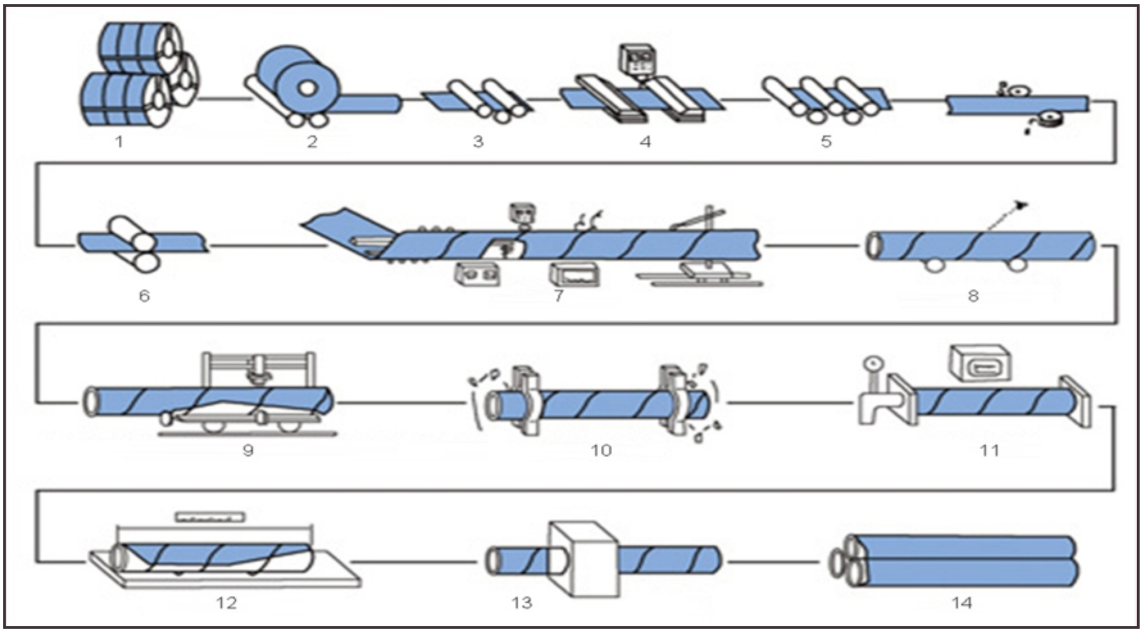
Wire Diameter		Current Range
mm	inch	A
2.3	5/64	200-500
2.4	3/32	300-600
3.2	1/8	300-800
4.0	5/32	400-900
4.8	3/16	500-1200
5.6	7/32	600-1300
6.4	1/4	600-1600

Table : Process parameters with their values at five levels

Parameter	Level 1	Level 2	Level 3	Level 4	Level 5
Arc Voltage (volts)	24	26	28	30	32
Welding current (Amp)	375	425	475	525	575
Trolley Speed (m/min.)	0.25	0.30	0.35	0.40	0.45
Nozzle to plate distance (mm)	15	16	17	18	19

Welding Parameters	Data
Polarity	+ at the strip electrode
Voltage (V)	27
Intensity (A)	750 ± 20
Travel speed (cm.min-1)	13.5 - 14.5
Stickout (mm)	28
Strip angle (°)	90
Pre-heating temperature (°C)	130

SPIRAL SAW OF STEEL PIPES



OPTIMIZATION PROCESS PARAMETERS OF SAW

Table : Process Parameter Levels

Level	Voltage (V)	Current (A)	Speed (m/h)
1	25	420	25
2	30	450	30

Table : Response table for S/N ratio (SB)

Level	Voltage	Current	Speed
1	-20.71	-20.39	-21.36
2	-21.24	-21.56	-20.59
Delta	0.53	1.17	0.77
Rank	3	1	2

Table : L8 Orthogonal Array design and output responses

Run	Voltage (V)	Current (A)	Speed (m/h)	Width (mm)	Hardness (HRC)
1	25	420	25	10.5	40.5
2	25	420	30	10.0	39.5
3	25	450	25	11.0	46.5
4	25	450	30	12.0	45.0
5	30	420	25	12.0	44.5
6	30	420	30	9.5	47.5
7	30	450	25	13.5	48.5
8	30	450	30	11.5	47.5

Bead Hardness