An Approach to Best Welding Practice. Part – XXI : Section III(A)

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DOI : 10.22486/iwj.v54i1.205486

"AN APPROACH TO BEST WELDING PRACTICE. Part–XXI: Section III(A)" 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. This write up is particularly focused on the Generation and Computer based Storage of Welding Data on Shielded Metal Arc Welding 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.

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

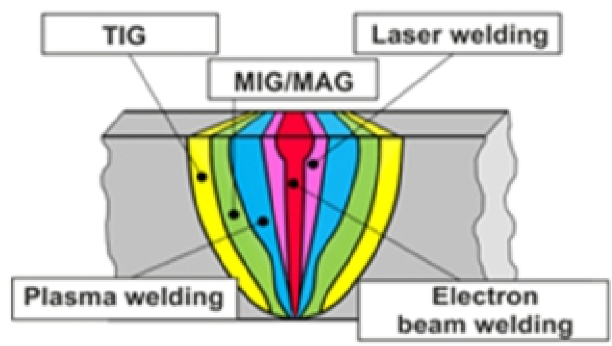
1. Welding Power Sources with Ancillary Equipment
2. Consumables – Electrodes, Wires, Flux Cored Wires
3. Shielding Gases
4. Joint design weldment design and surface preparation
5. Weld location Welding position –

MAJOR WELDING PROCESSES

Discussing all the processes in details and listing the data will be an enormous task. We will therefore confine our discussion for data collection and storage only for the most common Welding Processes used in Fabrication and Manufacturing industries where welding is the main manufacturing and a special process as under :

1. Shielded Metal Arc Welding (SMAW) / Manual Metal Arc Welding (MMAW).
2. Gas Metal Arc Welding (GMAW)
3. Gas Tungsten Arc Welding.(GTAW)
4. Submerged Arc Welding (SAW)
5. Friction Stir Welding.(FSW)
6. Laser Beam Welding (LBW)
7. Electron Beam Welding (EBW)
8. Resistance Spot Welding
9. Resistance Seam Welding
10. Resistance Butt Welding
11. Resistance Projection Welding

In the discussion to follow we will confine to the data required and collected characteristics of each Process. Equipment used, Consumables Electrodes and Gases used, Process Variation and Change of Parameters and their effects on the weldment.



Geometry of a butt joint made using various welding technologies

SHIELDED MERAL ARC WELDING (SMAW / MMAW) PROCESS

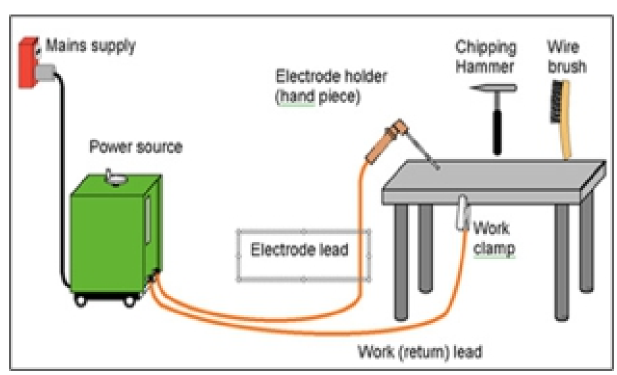


Fig. 1 : Shielded Metal Arc Welding/ Manual Metal Arc Welding

Shielded Metal Arc Welding/ Manual Metal Arc Welding is a manual welding process in which a Welding Transformer is used as a power supply unit. The Electrode conducting the current is coated. When the arc is struck between the electrode and the Work piece, current passes through the arc melting the electrode tip and the workpiece at the welding joint. Droplets of molten electrode tip mixes with the molten workpiece and forms the welded joint.

Data required are for:

I. POWER SUPPLY

II. SMAW / MMAW ELECTRODEs & ELECTRODE IDENTIFICATION SYSTEM

SMAW Advantages	SMAW Disadvantages
Simple equipment; simple to set up	High Skill required
Easy to move / portable	Long training cycle
Versatile	Higher cost per pound of deposited weld metal
Excellent outdoor usability	Slow travel speed
Highly tolerant of contaminants such as rust, dirt, and oil	Low deposition rate
Excellent mechanical properties	
Excellent puddle control in all positions	
Wide range of materials	

POWER SUPPLY

The power supply used in SMAW has constant current output (Drooping Characteristics), ensuring that the current (and thus the heat) remains relatively constant, even if the arc distance and minor voltage change. This is important because in most applications, welder hold the electrode holder to weld. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult. However, because the current is not maintained absolutely constant, skilled welders performing complicated welds can vary the arc length to cause minor fluctuations in the current.

Power Source Principles

- Input power from the mains is usually high voltage and has low current availability
- Welding demands high amperage at a relatively low voltage
- Usually this characteristic is achieved by employing a step-down transformer.
- Constant current power source, or power source with drooping characteristics is usually selected for MMA where consistent arc-voltage may be difficult to achieve.

AC sources are almost without exceptions of the constant current or drooping type. In the Drooping Arc Voltage characteristics the highest potential voltage is present when the welding current circuit is open and there is no flow of current. As the arc is struck, the voltage varies with the arc length, increasing with the length with decreased current and decreasing with the arc length with increased current. But the variations of current according to the Drooping nature of curve is small thereby restricting the energy variation to a minimum. Hence, during manual welding any variation in the Arc length will not cause too much current flow variation to cause uneven weld pool and therefore the welded joint will be more or less uniform in shape and size.

Fig. 2 : SMAW Power Source.

TABLE – SMAW – I & II
CODES FOR WELDING PROCESSES

Code	Welding process	Code Welding	Process
AAW	Air acetylene	AHW	Atomic hydrogen
BMAW	Bare metal arc	CAW	Carbon arc
EBW	Electron beam	EGW	Electro gas
ESW	Electro slag	FCAW	Flux cored arc
FW	Flash	FLOW	Flow
GCAW	Gas carbon arc	GMAW	Gas metal arc
GTAW	Gas tungsten arc	IW	Induction
LBW	Laser beam	OAW	Oxy-acetylene
OHW	Oxy-hydrogen	PAW	Plasma arc
PGW	Pressure gas	RPW	Resistance projection
RSEW	Resistance seam	RSW	Resistance spot
SAW	Submerged arc	SMAW	Shielded metal arc
SCAW	Shielded carbon arc	SW	Stud arc
TW	Thermit	UW	Ultrasonic

AWS Specifications

AWS specification number	General content of booklet
A5.7	Copper Alloys
A5.9	Stainless Steel
A5.10	Aluminium Alloys
A5.12	Tungsten Electrodes
A5.14	Nickel Alloys
A5.15	Cast Iron (FCAW)
A5.16	Titanium Alloys
A5.18	Carbon Steel
A5.19	Magnesium Alloys
A5.21	Surfacing Alloys
A5.24	Zirconium Alloys
A5.28	Zirconium Alloys
A5.30	Consumable Inserts
A5.32	Shielding Gases

Standard Coating Factor

The ratio of electrode dia to the core wire dia is called coating factor.

Coating factor = Total dia of an electrode / Core dia of an electrode

a) Light coated electrode coating factor = 1.24 approx.
b) Medium coated electrode coating factor = 1.44 approx.
c) Heavy coated electrode coating factor = 1.6 to 2.2

DUTY CYCLE AND THE PERMISSIBLE CURRENTS

Duty cycle can be defined as a ratio, as a percentage, of the load-on (generating an arc) time to a specified time of cycle in welding operation.

Duty cycle (%) = (Arc time) / (Time of one cycle) x 100

Duty cycle is a major factor in determining the type of service for which a power source is designed. The rated duty cycle of SMAW power sources of constant current output is specified as 20%, 40%, 50%, 60%.

The use of a power source in the conditions that exceed the rated duty cycle can cause burning of the power source because of overheating the power source components. Power sources are designed, in an economical point of view, to use under the conditions of intermittent loads where the arc is often turned on and off as seen in usual welding operations. In other words, power sources including their accessories are designed thermally safe, provided they are used within specified rated duty cycles.

Power source manufacturers perform duty-cycle tests under what the pertinent standard defines as usual service conditions.

Factors that cause lower than the tested or calculated performance include

- high ambient temperatures,
- insufficient cooling-air quantity, and
- low line voltage.

Rated duty cycle (Tr), rated current (Ir), permissible duty cycle (T), and permissible current (I) have the following relationship:

$$Tr \times Ir2 = T \times I2.$$

Based on this relationship, the following formulas are given for estimating the duty cycle at other than rated output (3-1), and for estimating other than rated output current at a specified duty cycle (3-2).

$$T = (Ir / I) x (Ir / I) x Tr$$

Example 1: What duty cycle does the use of 300A output make in use of a power source rated at 60% duty cycle at rated current of 350A?

Using equation (3-1): $T = (350/300)2 \times 60\%$ = approx. 82%.

Therefore, this unit (a non-constant duty cycle type) can be loaded approximately 8 minutes out of each 10-minute period at 300A.

$$I = Ir \ x \ \sqrt{}(Tr / T)$$

TABLE - SMAW - III.

CLASSIFICATION OF ELECTRODES AS PER THEIR APPLICATION ALONG WITH IS/ AWS SPECIFICATION AND CODING THEREOF

SL. NO.	USE	IS / AWS SPEC.	IS / AWS CODE
1	Fabrication of component meant for static application made of steels to IS : 2062-11, Gr. E250 Quality A, IS : 1875-04 Class 1 & 1A or equivalent. Suitable for joining steel sheets to IS:513-98, IS : 1079-94 & Gr. Fe 330 to IS : 5986-02 or equivalent and for repair welding of cast steels to IS : 1030-98 Gr. 200-400W. This electrode can also be used for welding where strength requirement is not specified.	IS: 814-04	ER 4112 (medium coated)
2	Fabrication of component meant for semidynamic application such as bridges etc., made of steel to IS : 2062-11 Gr. E250 Quality BR & B0, IS : 1875-04 Class I & IA or similar. The weld deposit shall be of radiographic quality.	IS: 814-04	ER 4211X (medium coated)
3	Fabrication of component meant for highly dynamic application made of steels to IS : 2062-11 Gr. E 250 quality C or for other applications where low temperature impact property is required. The weld deposit shall be of adiographic quality.	IS: 814-04	EB 5326H2X (heavy coated)
4	Application same as A3 above with high deposition efficiency.	IS: 814-04	EB 5326H2JX (heavy coated)
5	For pipe welding or other applications where high penetration of arc is needed.	IS: 814-04	EC 4316X (medium coated)
6	Fabrication of component made of steels to IS : 2062-11 Gr. E300 & E350 all quality, IS : 2002-01 Gr. 1&2, IS : 1875-04 Class 2, 2A and 3 or similar. Also suitable for repair welding of cast steels to IS : 1030-98 Gr. 230-450W. The weld deposit shall be radiographic quality. Also for joining of stainless steels type 3 Cr12, IRS M-44 or its equivalent with mild steel / low alloyed steel / Corten steel.	IS: 814-04	EB5426H3X (heavy coated)
7	Application same as B-1 above with high deposition efficiency	IS: 814-04	EB5426H3JX (heavy coated)
8	Fabrication of components made of steel to ASTM 516 GR. 70 or equivalent where low temperature (at -46^{o}C) impact properties are required. The weld deposit shall be of radiographic quality.	IS: 1395-03	E55BC126 (heavy coated)
9	Application same as B-3 above with high deposition efficiency.	IS: 1395-03	E55BC126J (heavy coated)
10	Fabrication of components made of steel to IS : 2062-11 Gr. E410, 450, IS : 2002-01 GR.3, IS : 1875-04 class 3A or similar. The weld deposit shall be of radiographic quality.	IS: 1395-03	E63BD126 (heavy coated)
11	Application same as C1 above with high deposition efficiency.	IS: 1395-03	E63BD126J (heavy coated)

SL. NO.	USE	IS / AWS SPEC.	IS / AWS CODE
12	For joining weathering steels conforming to IRS M-41 or M-42 with same steel or steels to IS : 2062-11, IS : 2002-01, IS : 1875-92 as mentioned above. This can also be used for combination joint of IRS M-44 & IRS M-41 and IRS M-41 & M-42. The weld deposit shall be of radiographic quality.	AWS A5.5	E8018W2 (heavy coated)
13	For fabrication & repairing of Buckles, Gear cases, Protector Tubes, Door Patches, Side Panels, End Wall Patches etc. of rolling stock & locomotives. The electrodes shall be low heat input type with 350 mm length.	IS: 814-04	ER4211X
14	For repair welding of bogies, both cast & fabricated. The electrodes shall be low heat input type with 350mm length.	IS: 1395-03	E55BG1Ni26 (heavy coated)
15	For reclamation of cast iron with non-machinable deposit.	IS: 5511-03	EFe B26 (medium coated)
16	For welding of cast iron with machinable deposit (Ni-Fe type core wire). Also suitable for joining of cast iron to other ferrous & nonferrous materials.	IS: 5511-03	ENiFeG16 (medium coated)
17	For non-machinable hard facing of ferrous items with hardness range of 55-62 Rc	IS: 7303-03	EFe-IC314 (heavy coated)
18	For machinable hard facing of ferrous items with hardness range of 30-40 HRc like reclamation of equalizing beam etc.	IS: 7303-03	EFe-B314 (heavy coated)
19	For welding of copper, bronze and other copper alloys including gun-metal	IS:8666-03	ECuSn-A (medium coated)
20	For welding of aluminium and aluminium Alloy.	AWS A5.3	AL-43 (medium coated)
21	For fabrication of stainless steels type 18% Cr 8% Ni type or its equivalent.	IS: 5206-03	E19.9R26 (heavy coated)

TABLE – SMAW – IV
WELDING ELECTRODE CLASSIFICATION – COATING, PENETRATION AND CURRENT TYPE

Sl. No.	CLASS	ELECTRODE COATING	PENETRATION	CURRENT TYPE
1	EXXX0	CELLULOSE SODIUM	DEEP	DCEP
2	EXXX1	CELLULOSE POTASSIUM	DEEP	AC, DCEP
3	EXXX2	RUTILE, SODIUM	MEDIUM	AC, DCEN
4	EXXX3	RUTILE, POTASSIUM	LIGHT	AC, DCEP, DCEN
5	EXXX4	RUTILE, IRON POWDER	MEDIUM	AC, DCEP, DCEN
6	EXXX5	LOW HYDROGEN, SODIUM	MEDIUM	DCEP
7	EXXX6	LOW HYDROGEN POTASSIUM	MEDIUM	AC, DCEP
8	EXXX7	IRON POWDER, IRON OXIDE	MEDIUM	AC, DCEN
9	EXXX8	LOW HYDROGEN IRON POWDER	MEDIUM	AC, DCEP
10	EXXX9	IRION OXIDE, RUTILE, POTASIUM	MEDIUM	AC, DCEP, DCEN

TABLE – SMAW – V
ELECTRODE AND WELD CHARACTERISTICS

ELECTRODE	COATING	POSITION	CURRENT	PENETRATION	TENSILE STRENGTH
E-6010	High Cellulose Sodium	All Position	DCEP	DEEP	60,000psi
E-6011	High Cellulose Potassium	All Position	DCEP AC	DEEP	60,000psi
E-6012	High Titania Sodium	All Position	DCEP AC	MEDIUM	60,000psi
E-6013	High Titania Potassium	All Position	DCEP AC	SHALLOW	60,000psi
E-7018	Iron Powder Low Hydrogen	All Position	DCEP AC	SHALLOW TO MEDIUM	70,000psi
E-7028	Iron Powder Low Hydrogen	Flat, Horizontal, Fillets	DCEP AC	SHALLOW TO MEDIUM	70,00psi

TABLE – SMAW – VI
TENSILE STRENGTH OF WELD DEPOSIT (MPa)

SL.NO.	ELECTRODE	WELDING CURRENT (AMP)	TENSILE STRENGTH OF WELD DEPOSIT (MPa)
1	E6013	90	550
2	E6013	100	505
3	E7016	90	617
4	E7016	100	601
5	E7018	90	585
6	E7018	100	567

TABLE – SMAW – VII
HANDLING & STORAGE OF LECTRODES

TYPE OF ELECTRODE	REDRYING TEMP & TIME	REMARK
Rutile E6012 / E6013	100 - 110 C for 1 hr	
Cellulosic E6010 / 6011	Not recommended	If wet 70 C for 30 min
Low hydrogen 10-15 ml H2	250 C for 1 - 2 hrs	Transfer to holding oven at 125 - 150 C
Low hydrogen 5 -10 ml H2	350 C for 1 - 2 hrs	Transfer to holding oven at 125 - 150 C
Low hydrogen below 5 ml H2	400 - 450 C for 1 - 2 hrs	Transfer to holding oven at 125 - 150 C
Stainless steel - Exxx-16/17	250 C for 1 hr	

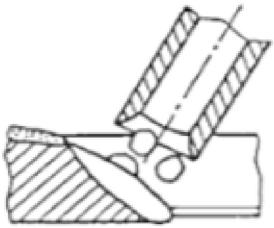
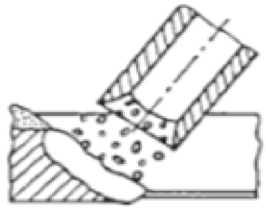
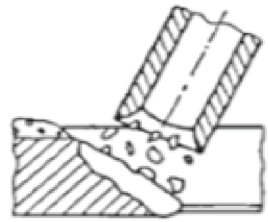
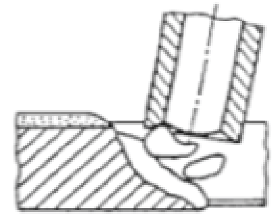
			
Cellulosic Type	**Acid Type**	**Rutile Type**	**Basic Type**
Cellulose 40 Rutile TiO_2 20 Quartz SiO_2 25 Fe - Mn 15 Potassium water glass	Magnetite Fe_3O_4 50 Quartz SiO_2 20 Calcite $CaCO_3$ 10 Fe - Mn 20 Potassium water glass	Rutile TiO_2 45 Magnetite Fe_3O_4 10 Quartz SiO_2 20 Calcite $CaCO_3$ 10 Fe - Mn 15	Fluorspar CaF_2 45 Calcite $CaCO_3$ 40 Quartz SiO_2 10 Fe - Mn 05 potassium water glass
Almost no slag **Droplet Transfer :** medium sized droplets **Toughness Value :** good	Slag solidification time : long **Droplet Transfer :** fine droplets to sprinkle **Toughness Vlaue :** Normal	potassium water glass **Slag solidification time :** Medium **Droplet Transfer :** medium sized to fine droplets **Toughness Value :** good	**Slag solidification time :** Short **Droplet Transfer:** medium sized to big droplets **Toughness Value :** Very Good

TABLE – SMAW – VIII
RECOMMENDATION OF FILTER GLASSES FOR MANUAL METAL ARC WELDING

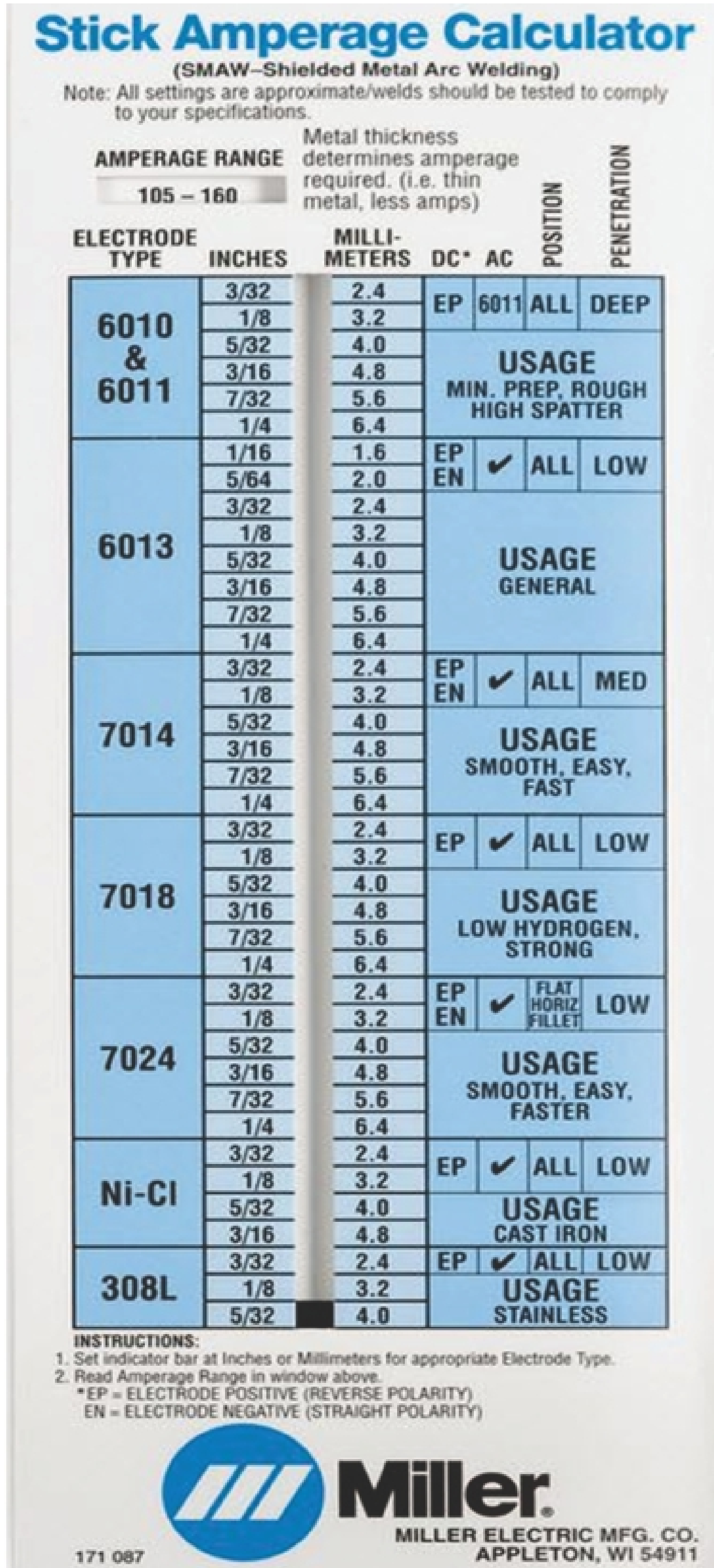
Shade No. of coloured glass	Range of welding current in amperes
8-9	Upto 100
10-11	100 to 300
12-14	Above 300

Electrode Sizes The electrode size refers to the diameter of its core wire.	
Electrode size	Electrode size
1.6mm	5.0mm
2.0mm	6.0mm
2.5mm	6.3mm
3.15mm	8.0mm
4.0mm	10.0mm

TABLE – SMAW – IX
AMPEARAGE SETTING FOR ELECTRODES

		Fast Freeze	Fill Freeze	Fast Fill	Low Hydrogen
	Diameter of	E6010-E6011	E6013-E6014	E7024-E7028	E7018
	Electrodes	Current Setting	Current Setting	Current Setting	Current Setting
Sl.no	Inches --- mm	Amperes	Amperes	Amperes	Amperes
1	3/32-----2.4	40-90	75-105	85-125	70-140
2	1/8------3.2	75-130	100-165	100-175	90-185
3	5/32-----4.0	80-160	135-225	160-270	140-230
4	3/16-----4.8	110-225	185-280	220-330	210-300
5	7/32-----5.6	200-260	235-340	270-410	230-380
6	1 /4------6.4	220-325	260-425	215-520	290-440

TABLE – SMAW – X



Stick Amperage Calculator

(SMAW–Shielded Metal Arc Welding)

Note: All settings are approximate/welds should be tested to comply to your specifications.

AMPERAGE RANGE 105 – 160

Metal thickness determines amperage required. (i.e. thin metal, less amps)

ELECTRODE TYPE	INCHES	MILLIMETERS	DC*	AC	POSITION	PENETRATION	USAGE
6010 & 6011	3/32, 1/8, 5/32, 3/16, 7/32, 1/4	2.4, 3.2, 4.0, 4.8, 5.6, 6.4	EP	6011	ALL	DEEP	MIN. PREP, ROUGH HIGH SPATTER
6013	1/16, 5/64, 3/32, 1/8, 5/32, 3/16, 7/32, 1/4	1.6, 2.0, 2.4, 3.2, 4.0, 4.8, 5.6, 6.4	EP EN	✔	ALL	LOW	GENERAL
7014	3/32, 1/8, 5/32, 3/16, 7/32, 1/4	2.4, 3.2, 4.0, 4.8, 5.6, 6.4	EP EN	✔	ALL	MED	SMOOTH, EASY, FAST
7018	3/32, 1/8, 5/32, 3/16, 7/32, 1/4	2.4, 3.2, 4.0, 4.8, 5.6, 6.4	EP	✔	ALL	LOW	LOW HYDROGEN, STRONG
7024	3/32, 1/8, 5/32, 3/16, 7/32, 1/4	2.4, 3.2, 4.0, 4.8, 5.6, 6.4	EP EN	✔	FLAT HORIZ FILLET	LOW	SMOOTH, EASY, FASTER
Ni-Cl	3/32, 1/8, 5/32, 3/16	2.4, 3.2, 4.0, 4.8	EP	✔	ALL	LOW	CAST IRON
308L	3/32, 1/8, 5/32	2.4, 3.2, 4.0	EP	✔	ALL	LOW	STAINLESS

INSTRUCTIONS:

1. Set indicator bar at Inches or Millimeters for appropriate Electrode Type.
2. Read Amperage Range in window above.

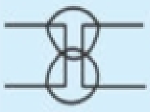
*EP = ELECTRODE POSITIVE (REVERSE POLARITY)
EN = ELECTRODE NEGATIVE (STRAIGHT POLARITY)

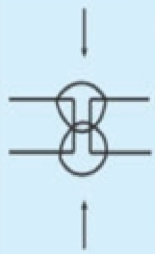
Miller

MILLER ELECTRIC MFG. CO.
APPLETON, WI 54911

171 087

TABLE – SMAW – XI

Position	Plate thickness mm	Gap mm	Volume/ length cc/cm3	Weight/ length weldmetal kg/m
 Flat	1	0	2	0.02
	1.5	0.5	3	0.02
	2	1	4	0.03
	3	1.5	7	0.05
 Flat	4	2	17	0.13
	5	2	21	0.16
	6	2.5	27	0.21
	7	3	36	0.28
 Horizontal-Vertical	1	0	2.5	0.02
	1.5	0.5	4	0.03
	2	1	5	0.04
	3	1.5	9.5	0.07
 Horizontal-Vertical	4	2	22	0.17
	5	2.5	25	0.20
	6	3	32	0.25
	7	3	42	0.33

Position	Plate thickness mm	Gap mm	Volume/ length cc/cm3	Weight/ length weldmetal kg/m
 Overhead	4	2	9	0.07
	5	2	10.5	0.08
	6	2.5	13	0.10
	7	3	16	0.13
	4	2	10.5	0.08
	5	2	16	0.13
	6	2.5	18	0.14
	7	3	21	0.16

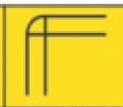
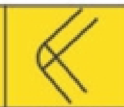
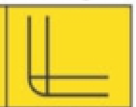
Calculation of Electrode Consumption
Single V-joints : Joint volumes and weld metal weights

Plate thickness mm	Gap mm	 60° Horizontal-Vertical		
		1	2	3
4	1	13	14.5	0.11
5	1	19.5	21	0.16
6	1	27	30	0.24
7	1.5	39	42	0.33
8	1.5	49	56	0.44
9	1.5	60.5	65	0.51
10	2	77.5	81	0.64
11	2	92	96.5	0.76
12	2	107	113	0.89
14	2	141	159	1.17
15	2	160	171	1.34
16	2	180	186	1.46
18	2	223	233	1.83
20	2	271	281	2.21
25	2	411	425	3.34

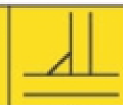
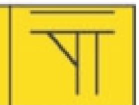
The first run and backing run V-joints :
Weld metal weights

Position	Plate thickness mm	Weight/ length kg/m	Electrode diam mm
Flat	6-12	0.10	3.25
Flat	> 12	0.15	4
Vertical	> 8	0.15	3.25
Horizontal-Vertical	> 8	0.15	3.25
Overhead	> 10	0.10	3.25

Corner Welds : Joint Volumes and weld metal weights

Plate thickness	Section size								
mm	mm2	cm3/m	kg/m	cm3/m	kg/m	cm3/m	kg/m	cm3/m	kg/m
2	2	3.5	0.03	3	0.02	3.5	0.03	3.5	0.03
3	4.5	7	0.05	7	0.05	7	0.05	7.5	0.06
4	8	9	0.07	9	0.07	9.5	0.07	10.5	0.08
5	12.5	13	0.10	13.5	0.11	14.5	0.11	16	0.13
6	18	18.5	0.15	19.5	0.15	21	0.16	22	0.17
7	24.5	22.5	0.20	26.5	0.21	27.5	0.22	31.5	0.25
8	32	33	0.26	34.5	0.27	36	0.28	40.5	0.32
9	40.5	41.5	0.33	43	0.34	45.5	0.36	51	0.40
10	50	51.5	0.40	53.5	0.42	56	0.44	64	0.50
11	60.5	63	0.49	67	0.53	72	0.57	78.5	0.62
12	72	74.5	0.58	79	0.62	84.5	0.66	93	0.73
15	113	1.16	0.91	123	0.97	132	1.04	141	1.11
18	162	167	0.31	174	1.37	190	1.49	204	1.60
20	200	206	1.62	206	1.62	227	1.78	252	1.98
22	242	248	1.95	255	2.00	275	2.16	204	2.39
25	323	329	2.58	331	2.60	370	2.90	405	3.18

Fillet Welds : Joint Volumes and weld metal weights

Plate thickness	Section size								
mm	mm2	cm3/m	kg/m	cm3/m	kg/m	cm3/m	kg/m	cm3/m	kg/m
2	4	5	0.04	6	0.05	5.5	0.04	5.5	0.04
2.5	6.5	7.5	0.06	8.5	0.07	8	0.06	8.5	0.07
3	9	10.5	0.08	12.5	0.10	11	0.09	12	0.09
3.5	12.5	14	0.11	16	0.13	15	0.12	16.5	0.13
4	16	18	0.14	21	0.16	19.5	0.15	22	0.17
4.5	20.5	22.5	0.18	26	0.20	24.5	0.19	26.5	0.21
5	25	27.5	0.22	31.5	0.25	30.5	0.24	33	0.26
5.5	30.5	33.5	0.26	37	0.29	36	0.28	40.5	0.32
6	36	40	0.31	42	0.33	43	0.34	47.5	0.37
6.5	42.5	46.5	0.37	49.5	0.39	51	0.40	56	0.44
7	49	54.5	0.43	57	0.45	56	0.44	65	0.51
7.5	56.5	60.5	0.47	65	0.51	64	0.50	73.5	0.58
8	64	70	0.55	73.5	0.58	76.5	0.60	82.5	0.65
9	81	88	0.69	94	0.74	95	0.75	109	0.86
10	100	108	0.85	114	0.89	116	0.91	130	1.02
11	121	131	1.03	138	1.08	143	1.12	157	1.23
12	144	155	1.22	162	1.27	169	1.33	188	1.48
13	169	179	1.41	190	1.49	195	1.53	220	1.73
14	196	207	1.62	224	1.76	227	1.78	257	2.02
15	225	237	1.86	248	1.95	264	2.07	294	2.31

Single V-joints : Joint Volumes and weld metal weights

Plate thickness mm	Gap mm	 Flat			 Flat		
		1	2	3	1	2	3
4	1	11.5	11	0.09	13	12.5	0.10
5	1	16.5	16	0.13	19.5	19	0.15
6	1	23	21.5	0.17	27	25.5	0.20
7	1.5	33.5	32.5	0.26	39	38	0.30
8	1.5	42	40	0.31	49	46.5	0.37
9	1.5	51	48	0.38	60.5	56	0.44
10	2	66.5	62	0.49	77.5	72	0.57
11	2	78.5	71.5	0.56	92	83.5	0.66
12	2	91	83	0.65	107	97.5	0.77
14	2	120	110	0.86	141	130	1.02
15	2	135	123	0.97	160	146	1.15
16	2	151	132	1.04	180	157	1.23
18	2	189	170	1.33	223	204	1.60
20	2	227	208	1.63	271	247	1.94
25	2	341	313	2.46	411	375	2.94

Plate thickness mm	Gap mm	 Vertical			 Overhead		
		1	2	3	1	2	3
4	1	15	16.5	0.13	17.5	18	0.14
5	1	22.5	24.5	0.19	26	28	0.22
6	1	31	37	0.29	36	38.5	0.30
7	1.5	45	49	0.38	51.5	56	0.44
8	1.5	57	59.5	0.47	65.5	70	0.55
9	1.5	70	75.5	0.59	81.5	87.5	0.69
10	2	90	96.5	0.76	104	109	0.86
11	2	107	113	0.89	124	130	1.02
12	2	125	134	1.05	146	157	1.23
14	2	165	171	1.34	193	204	1.60
15	2	188	197	1.55	219	231	1.81
16	2	211	223	1.75	247	257	2.02
18	2	263	276	2.17	308	320	2.51
20	2	320	334	2.62	376	396	3.11
25	2	488	510	4.00	577	606	4.76

TABLE – SMAW – XII

Welding Rod size, amps to part thickness, no gap, fillet weld, flat position, 70F, ...test rod max amps, burn rod down to 3" in one use, stop arc, if rod chery red hot full length (lower 10 amps) or flux coating on rod smoking full 3" length , (lower 10 amps). some machines burn hotter or colder if using short arc length

Lean rod to compensate for magnetic arc blow or use AC or use smaller rod and amps (Easier)

Stick rod type	Part Material Thickness	Easy		Moderate Difficult		Very Difficult on DC		welding rod amp range (arc force, volt fine adjust can effect 40 amps)				6010 some Inverters short arc only
		+/-15 Amp	Rod size	+/-15 Amps	Rod size	+/-15 Amp	Rod size		Lincoln 180	Hobart	Lincoln 5P+	
Arc force set medium to high (arc length 0.5-1.5 dia)									6011	6011	6010	6010
6011	0.062	49	3/32					3/32	40-70	50-90	50-85	50-60
6011	0.093	60	3/32	70	1/8			1/8	55-110	70-125	75-135	75-100
6011	0.125	71	3/32	83	1/8	95	5/32	5/32	85-145	100-160	100-175	100-130
6011	0.188	90	1/8	105	5/32	120	3/16	3/16	110-200		140-225	
6011	0.250	115	1/8	134	5/32	154	3/16	Vertical Up use thinner thickness amps				
6011	0.312	144	5/32	161	3/16			Butt joint use thinner thickness amps				
6011	0.375	164	5/32	184	3/16			Vert down use rod dia near max amps				
Stick rod	Material Thickness	+/-15 Amp	Rod size	+/-15 Amps	Rod size	+/-15 Amp	Rod size	welding rod amp range (arc force, crisp/soft, volt fine adjust can effect readings 40 amps)				
Arc force set low (arc length 0.5-1.0 dia)								6013 some run hotter		6013 slag inclusions in weld use more amps and or bigger rod , avoid cold arc start do circle weave, reduce circle weave and or later oval long in direction of travel to maintain equal weld width as part gets hot		
6013	0.049	59	3/32	49	1/16			1/16	30-60			
6013	0.062	63	3/32	73	1/8			5/64	35-70			
6013	0.093	74	3/32	83	1/8			3/32	40-80			
6013	0.125	80	3/32	90	1/8			1/8	70-120			
6013	0.188	95	1/8	109	5/32			5/32	110-160			
6013	0.250	119	1/8	137	5/32	149	3/16	3/16	140-220			
Stick rod	Material Thickness	+/-15 Amp	Rod size	+/-15 Amps	Rod size	+/-15 Amp	Rod size	welding rod amp range (arc force, crisp/soft, volt fine adjust can effect readings 40 amps)				
Arc force set low if adjustable (arc length <0.5 dia)								7018	Lincoln AC	Hobart	Lincoln	
7018	0.093	67	3/32					3/32	65-110	70-110	70-115	
7018	0.125	74	3/32	96	1/8			1/8	90-145	90-165	90-160	
7018	0.188	90	3/32	116	1/8	130	5/32	5/32	120-190	125-220	130-210	
7018	0.250	105	3/32	135	1/8	151	5/32	3/16			180-300	
7018	0.312	142	1/8	163	5/32	229	3/16	Vertical Up use thinner thickness amps				
7018	0.375	171	5/32			240	3/16	Butt joint use thinner thickness amps				

TABLE – SMAW – XIII
COVERED (STICK) ELECTRODES (SMAW): E6010

Typical Tensile Properties			
Condition	Yield Strength	Tensile Strength	Elongation
As Welded	480 MPa (69 ksi)	560 MPa (81 ksi)	22 %

Typical Charpy V-Notch Properties		
Condition	Testing Temperature	Impact Value
As Welded	-29 °C (-20 °F)	39 J (29 ft-lb)
As Welded	-46 °C (-50 °F)	35 J (26 ft-lb)

Typical Weld Metal Analysis %						
C	Mn	Si	S	P	Ni	Mo
0.10	0.30	0.20	0.02	0.01	0.50	0.24

TABLE – SMAW – XIV
E 7018 CLASSIFICATIONS: AWS A5.1:E7018 H4R, ASME SFA 5.

7018 is an all-position low hydrogen moisture resistant electrode. The wider operating ranges and smooth weld metal transfer minimizes post weld clean up. This premium quality electrode meets a multitude of codes and welding specifications.

Typical Tensile Properties				
Condition	Yield Strength	Tensile Strength	Reduction in Area	Elongation
As Welded	470 MPa (68 ksi)	540 MPa (78 ksi)	75 %	30 %
Stress Relieved	8 hr 621 °C 1150 °F)			
	395 MPa (57 ksi)	485 MPa (70 ksi)	77 %	33 %

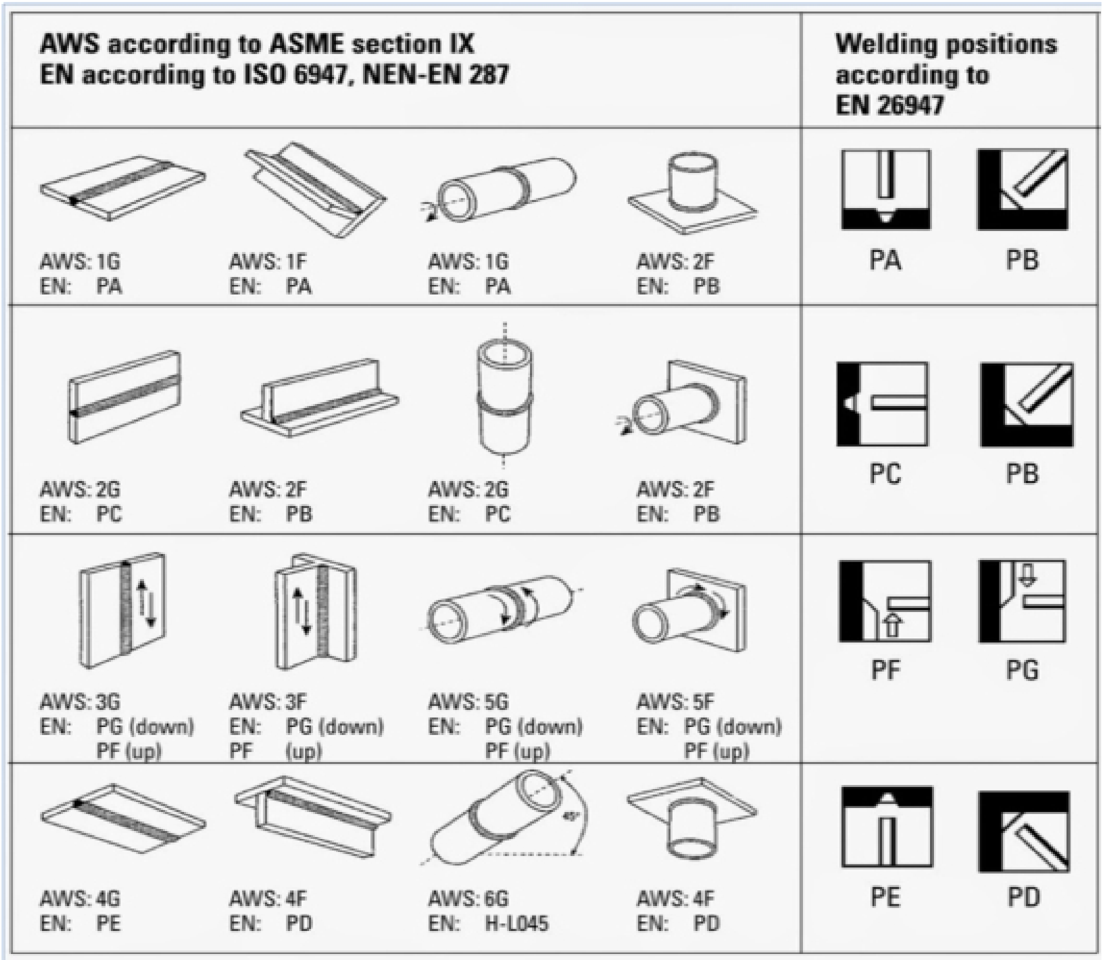
Typical Charpy V-Notch Properties		
Condition	Testing Temperature	Impact Value
As Welded	-29 °C (-20 °F)	225 J (168 ft-lb)
Stress Relieved 8 hr 621 °C (1150 °F))	-29 °C (-20 °F)	260 J (193 ft-lb)

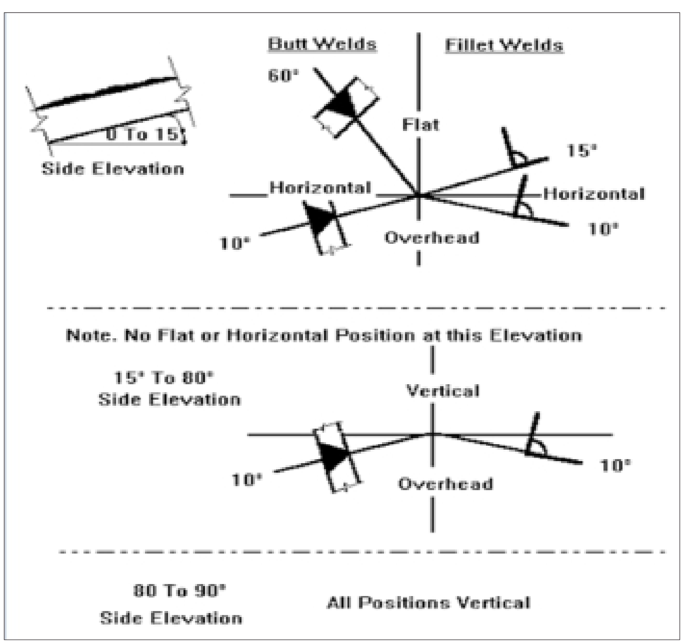
Typical Weld Metal Analysis %				
C	Mn	Si	S	P
0.045	1.10	0.40	0.014	0.015

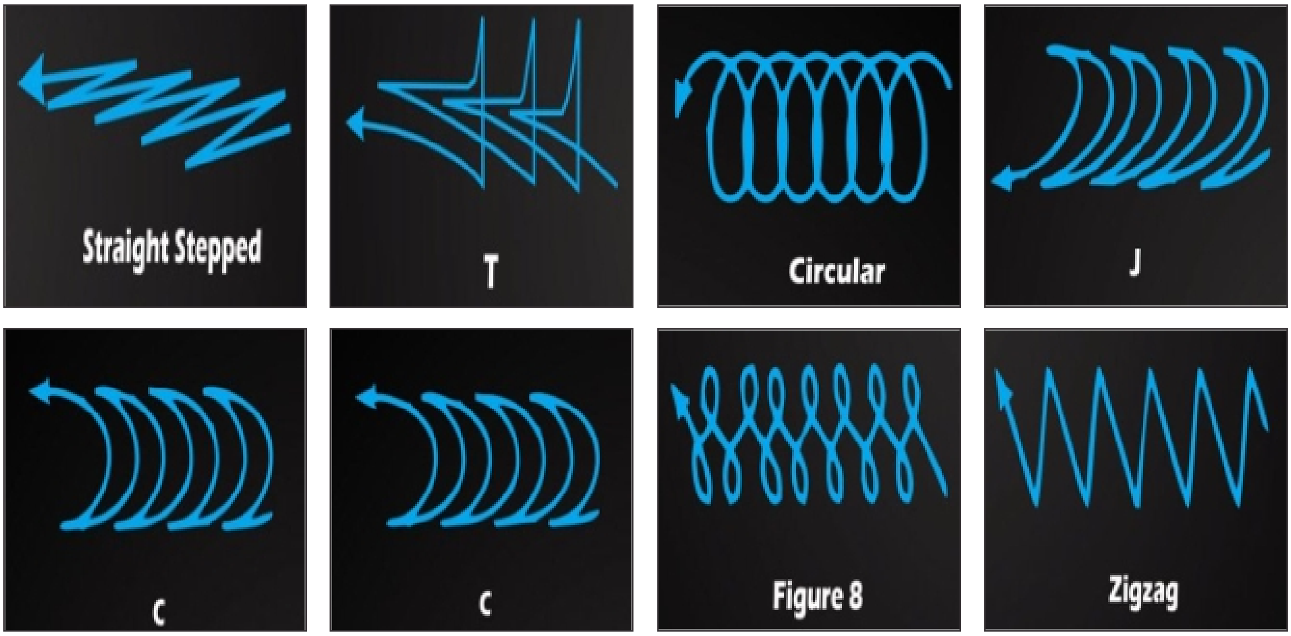
TABLE – SMAW – XV
DEPOSITION DATA.

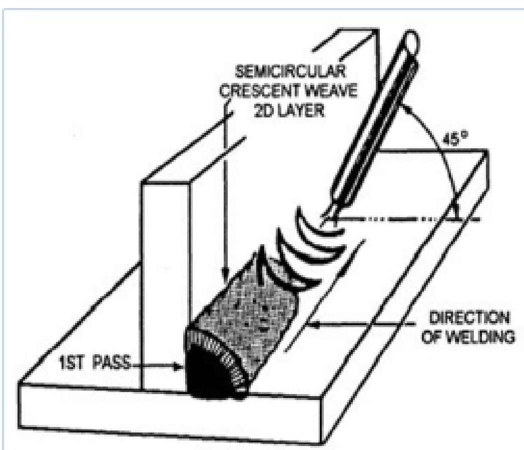
Diameter	Optimal Amps	Amps	Deposition Rate	Efficiency (%)
2.4 mm (3/32 in.)	90 A	70-100 A	0.8kg/h(1.7 lb/h)	66.3 %
3.2 mm (1/8 in.)	120 A	90-160 A	1.2 kg/h (2.6 lb/h)	71.6 %
3.2 mm (1/8 in.)	140 A	90-160 A	1.2 kg/h (2.7 lb/h)	70.9 %
4.0 mm (5/32 in.)	140 A	130-220 A	1.4 kg/h (3.1 lb/h)	75 %
4.0 mm (5/32 in.)	170 A	130-220 A	1.7 kg/h (3.8 lb/h)	73.5 %
4.8 mm (3/16 in.)	200 A	200-300 A	2.2 kg/h (4.9 lb/h)	76.4 %
4.8 mm (3/16 in.)	250 A	200-300 A	2.4 kg/h (5.4 lb/h)	74.6 %
5.6 mm (7/32 in.)	300 A	250-350 A	3.3 kg/h (7.2 lb/h)	74 %
6.4 mm (1/4 in.)	300 A	300-400 A	3.5 kg/h (7.7 lb/h)	78 %
6.4 mm (1/4 in.)	350 A	300-400 A	3.9 kg/h (8.7 b/h)	77 %

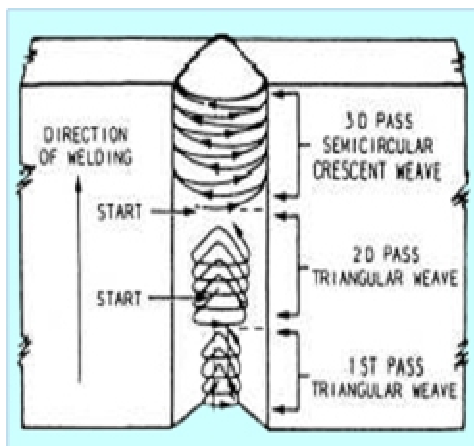
POSITIONAL WELDING

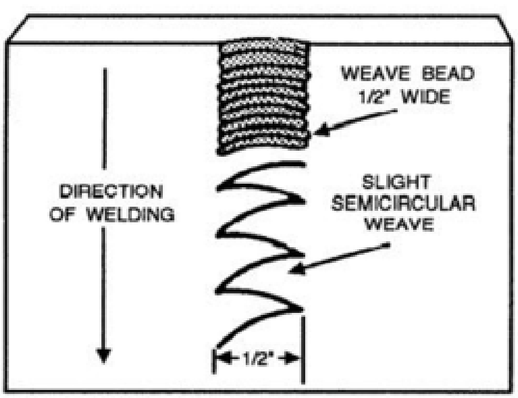












VERTICAL WEAVE BEAD WELD,
WELDING DOWN

D

TABLE – SMAW – XVI
TYPICAL WELDING PARAMETERS OF M.S & LOW ALLOY ELECTRODES.

Sl. No.	DIAMETER OF ELECTRODES Inches -- mm	VOLTAGE (V)	AMPERE FLAT POSITION	AMPERE VERTICAL & OVERHEAD POSITION
1	3/32-----2.4	21-25	65-80	65-75
2	1/8------3.2	21-25	90-110	80-95
3	5/32-----4.0	21-26	135-160	120-140
4	3/16-----4.8	22-26	160-210	140-160
5	7/32-----5.6	22-26	200-260	160-180
6	1 /4------6.4	23-27	220-325	180-200

WEAVING FOR THICKER WELDING BEAD FORMATION

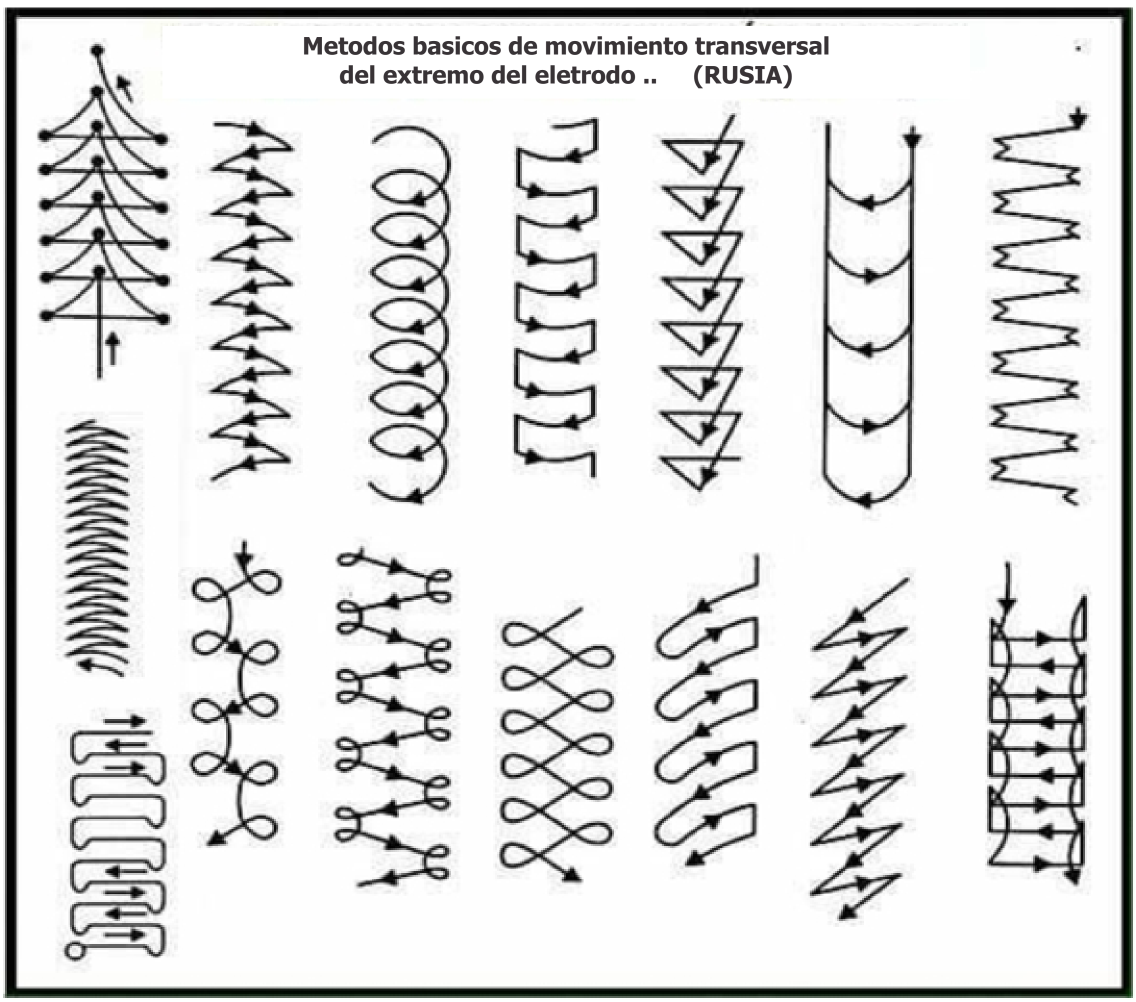


TABLE – SMAW – XVII
ELECTRODE CLASSES, CURRENT TYPE, POSITIONS AND RESULTS

Type	AWS Class	Current Type	Welding Position	Weld Results
Mild Steel	E 6010 E 6011	DCR DCR AC	F,V.OH,H F,V,OH,H	Fast Freeze, Deep Penetrating, Flat Beads, All purpose welding
	E 6012 E 6013 E 6014	DCS, AC DCR,DCS,AC DCS, AC	F,V,OH,H F,V,OH,H F,V,O,H	Fill-freeze, Low Penetration, For poor Fit-up, Good Bead Contour, Minimum Spatter.
	E 6020 E 6024	DCR,DCS,AC DCR,DCS,AC	F,H F,H	Fast Fill High Deposition, Deep Groove weld, Single Pass
Low Hydrogen	E 6015 E 6016 E 6018 E 7016 E 7018 E 7028	DCR DCR, AC DCR, AC DCR, AC DCR, AC DCR, AC	F,V,OH,H FV,OH,H F,V,OH,H F,V,OH,H F,V,OH,H F,H	Welding of High Sulphur and High Carbon steels that tend to develop Porosity and Crack under Weld Deposit.
Stainless Steels	E308-15, 16	DC, AC	F,V,OH,H	Welding Stainless Steels, 301,302,303m 304 and 308
	E 309-15,16	DC, AC	F, V, OH,H	Welding 309 Alloys at elevated Temperature applications and Dissimilar Metals
	E 310-15, 16	DC, AC	F,V,OH,H	Welding type 310 and 314 Stainless Steels where High Corrosion and Elevated Temperatures are required
	E-316-15-16	DC, AC	F,V,OH,H	Welding type 316 Stainless Steels and Welds of Highest quality. Contains less Carbon to minimum Carbon transfer in the weld. Type 316 reduces pitting corrosion
	E347-15, 16	DC, AC	F,V,OH,H	For Welding all grades of Stainless Steels.
Low Alloy	E-7011-A1 E-7020-A1	DCR, AC DCR, DCS, AC	F,V,OH,H F	For welding carbon Moly Steels
	E-8018-CD	DCR, AC	F,V,OH,H	For low alloy high tensile strength
	E10013-G	DCS, AC	F,V,OH,H	For low alloy high tensile strength

DCR – Direct Current Reverse Polarity. DCS – Direct Curent Straight Polarity.
F – Flat. V – Vertical, OH – Overhead, H - Horizontal

CONCLUSION

SMAW is still widely used in industry for its low cost of equipment, consumables and ease of operations. In this Part relevant data for Shielded Manual Arc Welding / Manual Metal Arc Welding Process (SMAW / MMAW) for Computer Storage and necessary retrieval are systematically arranged in Tabular form. In some Tables duplication of data of some parameters will be observed, but along with different parameters to avoid and minimise searching time for connected data requirement.