

Introduction to Shielded Metal Arc Welding (SMAW)

1. Welding Terms

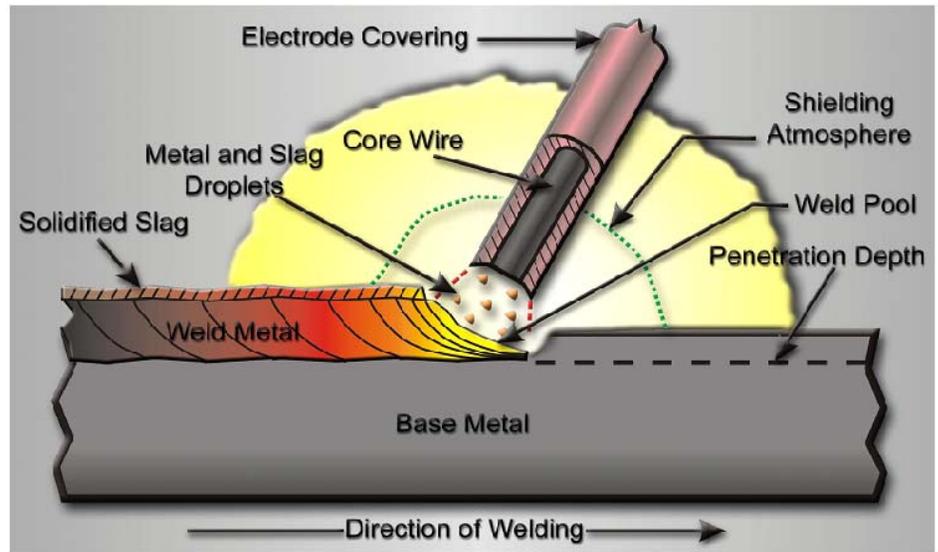
- a. **Fusing;** Heating two or more metals or nonmetals until they become liquid, then allowing them to join and solidify.
- b. **Fusion Welding;** Welding that uses fusion or melting of the base metals to make a weld.
- c. **Welding;** A process in which metal pieces are joined by heating them to a temperature high enough to cause them to melt and fuse together into a single piece. Welding always happens above 800 degrees F.
- d. **Weld pool or puddle;** Molten area during a welding process.
- e. **Electrical Circuit:** A path taken by an electrical current flowing from one terminal of the welding machine, through a conductor, and to the other terminal.
- f. **Conductor:** Any material through which electricity will flow _____.
- g. **Ampere:** (Amp) Unit of measure for electricity that expresses the _____ or number of electrons flowing through a conductor per unit of time. 6.3 Quintillion (billion billions) electrons/ second. Amount of water through water hose.
- h. **Voltage:** (Volt) The amount of electrical pressure (_____) in a circuit. Pressure in a water hose.
- i. **Resistance:** (Ohm) Opposition of the material to conduct electron flow. Measured in Ohms. (1 Ohm = 1 _____ forcing 1 Amp to flow) Closing down the end of a water hose.
- j. **Frequency:** (Hz) Number of positive/negative cycles per second in an _____ sine wave. Measured in Hertz. United States = 60 Hz.

2. Personal Protection

- a. **Safety glasses;** ANSI Z87.1
- b. **Clothing;** Fire resistant materials, Leather, cotton – no synthetics like polyester. No turned up or frayed cuffs. Long sleeves and collars buttoned.
- c. **Boots;** Leather, steel toes, slip on best, no exposed opening.
- d. **Gloves;** Gauntlet, flexible but heavy enough for heat protection.
- e. **Welding Helmet;** _____ shaded lens. (ultraviolet/ infrared light)
- f. **Ear protection;** muffs, plugs, (out of position welding/ cutting)
- g. **Never have a pressurized butane lighter on your person while in the shop.**

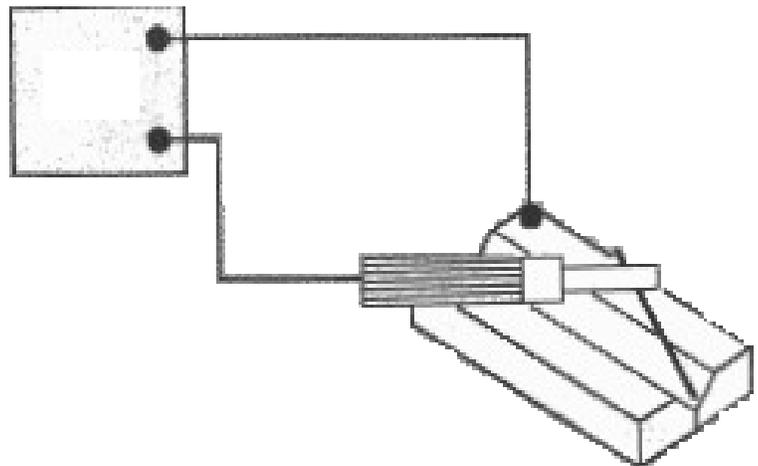
3. SMAW Process

- a. Machine produces electric current to produce an electric _____.
- b. Metals are joined together by creating an electric arc between a coated metal electrode and a _____.
- c. The heat of the electric arc (6000°F to _____ F) melts the metal which mixes with the molten deposits of the coated electrode.
- d. The coating of the electrode produces a _____ that shields the weld from the atmosphere and helps to maintain the weld shape.
- e. Coating is later removed in the form of slag.
- f. The slag coating over the weld insulates the hot weld from contaminants in the atmosphere during _____.



4. SMAW Equipment

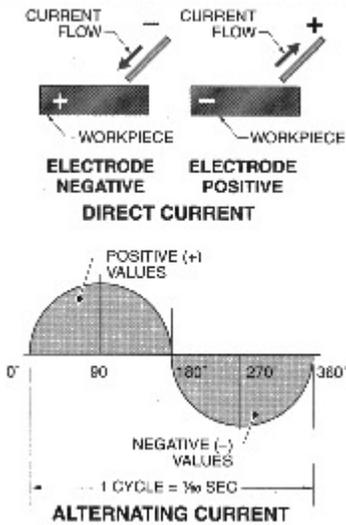
- Power Source
- Work Clamp
- Ground Lead
- Electrode Lead
- Electrode Holder
- Work
- Electrode



5. Electrical Welding Current

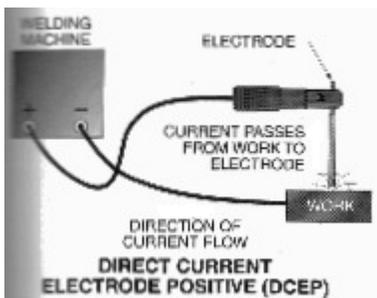
- a. **Alternating Current (AC)**; current alternates flow in positive and _____ direction.
- b. **Direct Current (DC)**; Current flows in _____ direction. Maybe positive or negative.
- c. **Polarity**: Positive or negative state of an object. Determines the _____ of the flow of electrons in a DC circuit.

6. Alternating Current



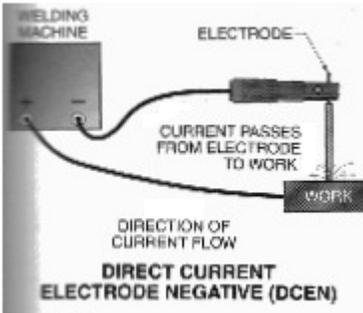
- a. Electrons change direction every 1/120 of a second (___cycles per second = 60 Hz)
- b. Rapid reversal causes the welding heat to be evenly distributed on both the work and the _____.
- c. Less stable arc (not smooth) as arc extinguishes and re-ignites through each _____.
- d. Agitates puddle. Helps _____ electrode metal and the flux.
- e. Helps float slag and impurities to the top of the weld _____.
- f. Less penetration than _____.

7. Direct Current Electrode Positive (DCEP)



- a. Electrons flow from negative work piece to _____ electrode.
- b. Formerly called _____ Polarity.
- c. **70%** of heat located in the electrode – _____ in work piece.
- d. Forceful, digging arc. Deeper penetration than _____ and AC.
- e. Used for most SMAW operations.
- f. Obtained by switching the leads or changing a polarity _____ on the welding machine.
- g. Susceptible to magnetic _____ _____. Magnetic field that causes arc to wander.

**8. Direct Current
Electrode Negative
(DCEN)**



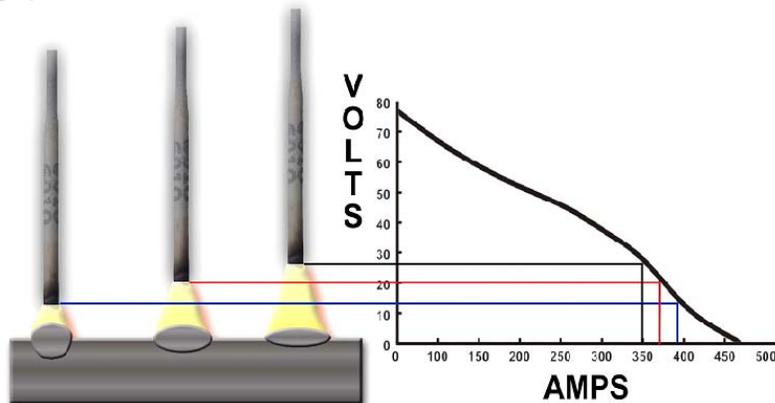
- a. Electrons flow from negative electrode to _____ work piece.
- b. Formerly called _____ Polarity.
- c. _____ of heat located in the electrode – _____ in work piece.
- d. Less forceful arc. More shallow penetration than _____ and AC.
- e. Used for _____ metals (sheet metal)
- f. Obtained by switching the leads or changing a polarity switch on the welding machine.

**9. Power Source/
Welding Machines**

- a. Supply power to produce the _____.
- b. Transformer or Rectifier; use electricity from the power _____.
- c. Engine driven generator. _____
- d. Rated by Duty cycle. (amount of weld time within a ____ min. period at a specific amperage)
- e. Ex. 60% duty cycle at 150 amps = ____ minutes of welding time during a 10 period at 150 amps. Machine must cool ____ minutes out of the 10 minutes.
- f. Uses constant current (____) power source (SMAW, GTAW) –vs- constant voltage (____) power source (GMAW, FCAW)
- g. Light Duty Machine; 150 amps – _____amps.
- h. Medium Duty Machine; 250 amps – _____amps.
- i. Heavy Duty Machine; 400 amps – _____amps.

**10. Constant Current
Welding Machines**

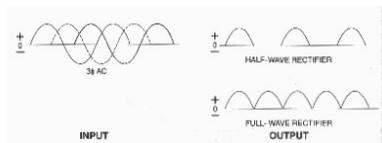
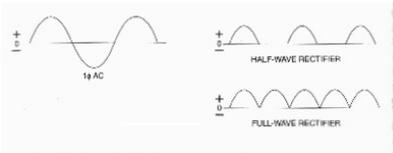
- a. Also called a _____.
- b. _____ Volt/Amp curve.
- c. Produces a _____ current over a wide range of voltages.
- d. Voltage/Amperage changes with length of _____.
- Larger = higher voltage, _____ amperage.
- e. Makes it possible to control puddle characteristics by changing the arc gap. Good for SMAW – bad for _____.



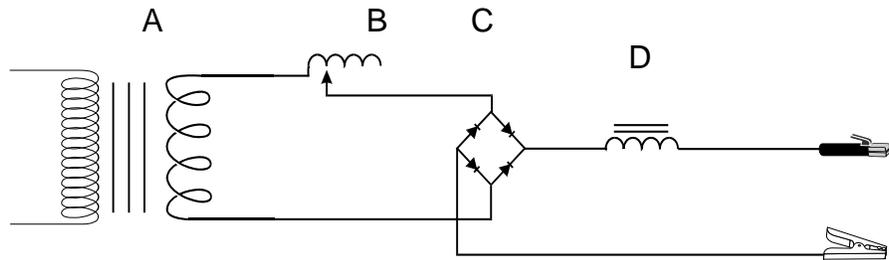
11. Transformer Machines

- a. Generally the cheapest to purchase and run on a _____ phase circuit.
- b. Transforms _____ voltage (120, 230, 460, 600 volts) to low voltage (18 – 36 working volts) and _____ amperage to higher welding amperages.
- c. Over-all _____ electrical efficiency.
- d. Larger, heavy coils, large fans for cooling, draw high amps compared to _____ machines

12. Transformer/ Rectifier Machines

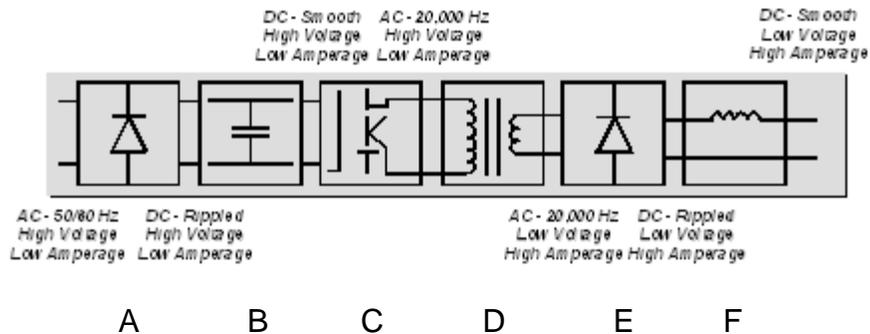


- a. **Transformer:** Single/3 phase input; high volts, low amps to low volts, _____ amps. AC
- b. **Reactor:** selects amount of _____ welding current.
- c. **Bridge Rectifier:** changes AC to DC. Full _____ Rectifier.
- d. **Inductance Coil:** smoothes and filters _____ output.
- e. Larger, heavy coils, large fans for cooling, draw high amps compared to Inverter machines.



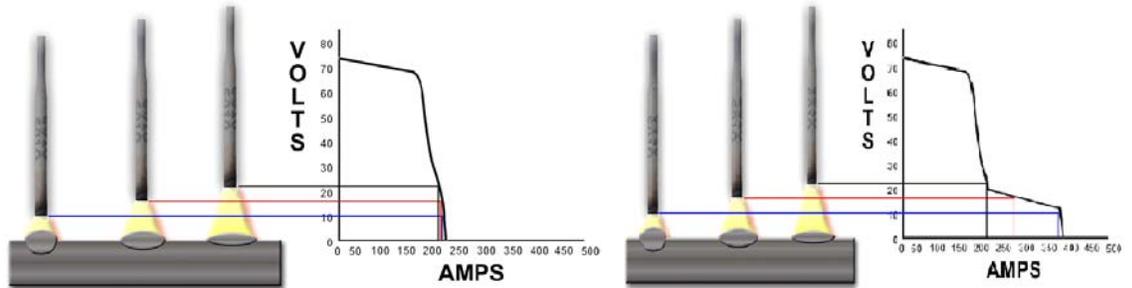
13. Inverter Machines

- a. **Rectifier:** 60 Hz AC to 60 Hz _____. High Voltage, Low Amperage.
- b. **Filter:** **Smooths** DC current.
- c. **Integrated Circuit:** Changes DC current to high frequency _____. Lincoln; (IGBT) Insulated Gate Bipolar Transistor Miller; (SCR) Silicon Controlled Rectifier
- d. **Transformer:** High frequency, high voltage, low amperage AC to high frequency, low voltage, _____ amperage AC.
- e. **Rectifier:** High frequency AC to _____ rippled.
- f. **Choke:** Smooths DC high frequency rippled current.
- g. Require much less electricity to operate. _____ cooling fans.
- h. Smaller _____ windings – more expensive.
- i. _____ response time. Controlled Volt/Amp curve.
- j. Some models can accommodate _____ or _____ welding operations.



**14. Arc Control
Arc Force
Dig**

- a. Solid state welding machines (_____) volt/amp curves are different than traditional machines.
- b. GTAW; _____ volt/amp curve preferred
- c. Increasing Arc Control or Force _____ volt/amp curve allowing amperage control through arc length. Better for SMAW.
- d. Provides additional amperage if voltage drops below preset limit. (____ - ____ volts)

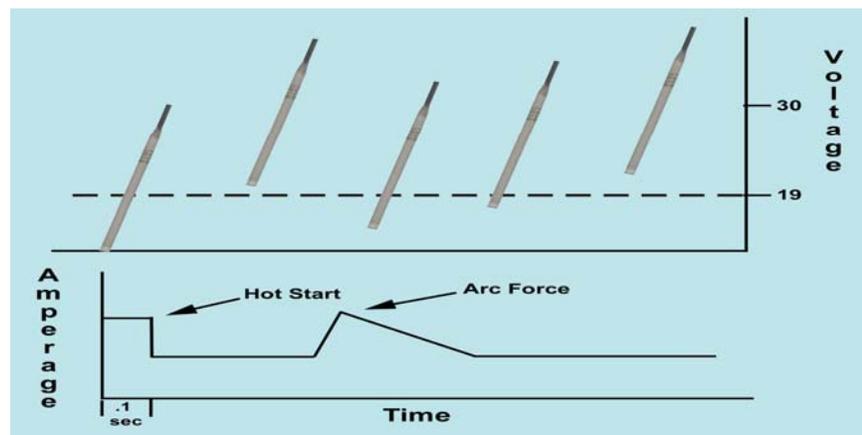


Zero Arc Force

75% Arc Force

**15. Hot Start
Adaptive Hot
Start & Arc
Force**

- a. **Hot Start:** Preset higher amperage for _____ of a second when striking an arc.
- b. **Adaptive Hot Start:** Additional _____ amps above set current only when needed. Determined by time electrode is in contact with the base metal.
- c. Allows for better arc starting and more controlled bead.



16. Welding Leads & Connections

- a. Conduct current to and from the _____.
- b. Correct size diameter lead must be used. Too _____ for current will overheat, resulting in lost power.
- c. Larger diameters are needed for _____ runs. Added resistance will cause voltage drop.
- d. Connections: Quick connect – _____ tight or loose.
Lug – clamp with a nut to the machine.
- e. Connections must be tight. Loose connections will cause overheating, _____, _____, and possible arcing.

17. Electrode Holder

- a. Insulated handle and clamp to hold electrode. (called a _____)
- b. Different styles and sizes. Need to match _____ requirements of the machine.
- c. Keep lead connection _____.

18. Electrodes

- a. Support electric arc and provide _____ metal.
- b. Covered with _____ coating.
- c. Different electrode names by different manufactures but all fall under _____ and ASTM classifications. (Groups F1, F2, F3, F4)
- d. Fall into three groups: Fast Freeze, Fill Freeze, and Fast _____.
- e. Iron Powder Electrodes; contain iron powder in flux for increased deposition rates. (6027, 7014, _____)
- f. Low Hydrogen; welding high sulfur and medium to high carbon steels. Prevent cracking due to hydrogen absorption in Heat Affect Zone (HAZ). _____ (7016, 7018, 7028)

19. Electrode Diameter

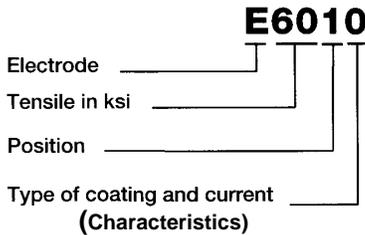
- a. Diameter determined by the metal _____ not the flux coating.
- b. Common diameters from 3/32" to 5/16" in _____" length.
- c. Generally, never use an electrode with a _____ diameter than the thickness of the base metal.
- d. Larger diameter electrodes require _____ amperage.

20. Selecting Electrodes

- a. **Type of material;** have approximately the same metallurgical properties as the _____ metal. Minimum Tensile strength of the deposited filler metal.
- b. **Type of electrode coating;** deposition rate - Some have _____ mix in w/ flux.
- c. **Weld Position;** Look at _____ digit.
- d. **Type of welding current;** designed for a single polarity or a **combination** of polarities. AC, DCEP, DCEN
- e. **Metal Thickness:** Thick; _____" root pass then larger diameters.
Thin; smaller diameter, fill freeze.
- f. **Type of Joint;** deep penetration on root pass.
- g. **Welding Code requirements;** _____ rod.

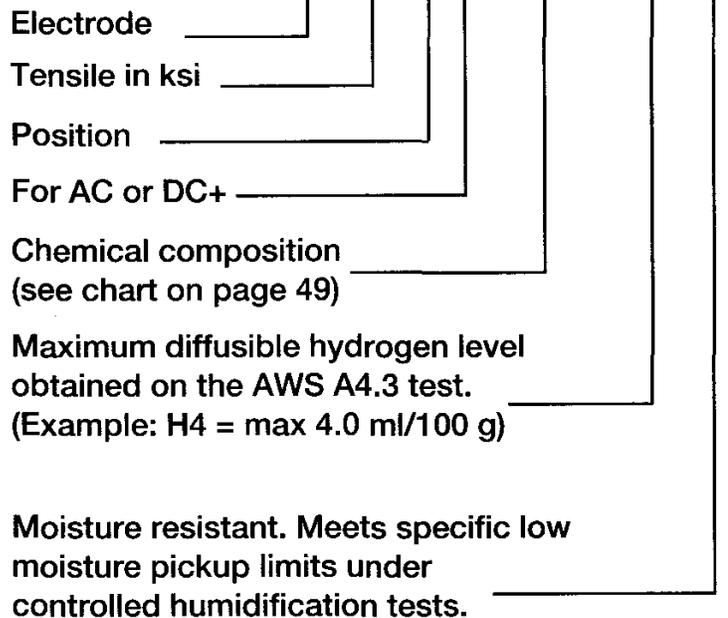
21. AWS Electrode Classification System

AWS A5.1 CARBON STEEL ELECTRODE



AWS A5.5 LOW ALLOY STEEL ELECTRODE

E8018-B1 H4R



22. Position

- 1 — Flat, Horizontal, Vertical, Overhead
- 2 — Flat and Horizontal only
- 4 — Flat, Horizontal, Vertical Down, Overhead, Position

23. Flux Coating

Types of Coating and Current

Digit	Type of Coating	Current
0	Cellulose sodium	DC+
1	Cellulose potassium	AC, DC±
2	Titania sodium	AC, DC-
3	Titania potassium	AC, DC+
4	Iron powder titania	AC, DC±
5	Low hydrogen sodium	DC+
6	Low hydrogen potassium	AC, DC+
7	Iron powder iron oxide	AC, DC±
8	Iron powder low hydrogen	AC, DC±

- Cleans the surface being welded.
- Releases gases (CO₂) that shields the molten weld area from atmosphere. (_____, nitrogen)
- Gas helps conduct electricity.
- Produces _____ to insulate and slow the rate of weld bead cooling. (helps reduce residual stress in bead)
- Reduces _____.
- Makes easier electrode _____.
- Helps insure even distribution of the filler metal with the parent (_____) metal.
- Adds alloy materials to the weld bead.
- Stabilizes the _____.
- Provides better _____.

Chemical Composition of Weld Deposit

Suffix	%Mn	%Ni	%Cr	%Mo	%V
A1				.50	
B1			.50	.50	
B2			1.25	.50	
B3			2.25	1.00	
C1		2.50			
C2		3.25			
C3		1.00	.15	.35	
D1/D2	1.25-.200			.25-.45	
G ⁽¹⁾		.50 min.	.30 min.	.20 min.	.10 min.

⁽¹⁾ Only one of the listed elements is required.

24. Common Electrodes

ELECTRODE CLASSIFICATIONS				
AWS Class	Current Type	Welding Position	Weld Results	Electrode Group
E-6010	DCEP	ALL	Deep penetration, flat beads	Fast-freeze
E-6011	DCEP, DCEN, AC			
E-6012	DCEN AC	ALL	Shallow penetration, good bead contour, minimum spatter, for poor fit-up	Fill-freeze
E-6013	DCEP, DCEN, AC			
E-6020	DCEP DCEN AC	FLAT, HORIZONTAL	High deposition, deep groove single-pass welds	Fast-fill
E-6027	DCEN AC	FLAT, HORIZONTAL	High deposition, deep penetration	Fast-fill
E-7014	DCEP DCEN AC	ALL	Low penetration, high speed	Fill-freeze
E-7024	DCEP DCEN AC	FLAT, HORIZONTAL	High deposition, single and multiple passes	Fast-fill
E-7016	DCEP AC	ALL	Welding of high-sulfur and high-carbon steels that tend to develop porosity and crack under weld bead	Fill-freeze
E-7018	DCEP AC	ALL		
E-7028	DCEP AC	FLAT, HORIZONTAL		Fast-fill

25. Common Electrodes & Current Settings

MILD STEEL ELECTRODE CURRENT SETTINGS		
Electrode	Diameter ^a	Ampere [†]
E-6010	1/32	60 - 90
	1/16	80 - 120
	1/8	110 - 160
	3/16	150 - 200
	1/4	175 - 250
	5/16	225 - 300
E-6011	1/32	50 - 90
	1/16	80 - 130
	1/8	120 - 180
	3/16	140 - 220
	1/4	170 - 250
	5/16	225 - 325
E-6012	1/32	40 - 90
	1/16	80 - 120
	1/8	120 - 190
	3/16	140 - 240
	1/4	180 - 315
	5/16	225 - 350
E-6013	1/32	20 - 40
	1/16	25 - 50
	1/8	30 - 80
	1/4	80 - 120
	3/8	120 - 190
	1/2	140 - 240

IRON POWDER ELECTRODE CURRENT SETTINGS		
Electrode	Diameter ^a	Ampere [†]
E-6027	1/8	225 - 300
	1/4	275 - 375
	3/8	350 - 450
E-7014	1/32	80 - 110
	1/16	110 - 150
	1/8	140 - 190
	3/16	180 - 260
	1/4	250 - 325
	5/16	300 - 400
E-7024	1/32	90 - 120
	1/16	120 - 150
	1/8	180 - 230
	3/16	250 - 300
	1/4	300 - 350
	5/16	350 - 400

LOW-HYDROGEN ELECTRODE CURRENT SETTINGS		
Electrode	Diameter ^a	Ampere [†]
E-7016	1/8	75 - 105
	1/4	100 - 150
	3/8	140 - 190
	1/2	190 - 250
	5/8	250 - 300
	1	300 - 375
E-7018	1/8	70 - 120
	1/4	100 - 150
	3/8	120 - 200
	1/2	200 - 275
	5/8	275 - 350
	1	300 - 400
E-7028	1/8	175 - 250
	3/8	250 - 325
	1/2	300 - 400
	1	375 - 475