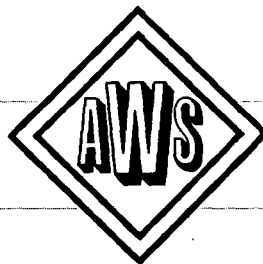


The Professional's Advisor on Resistance Welding



Edited by
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NOTE: Although care was taken in choosing and presenting the data in this guide, AWS cannot guarantee that it is error free. Further, this guide is not intended to be an exhaustive treatment of the topic and therefore may not include all available information, including with respect to safety and health issues. By publishing this guide, AWS does not insure anyone using the information it contains against any liability or injury to property or persons arising from that use.

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Basic Safety Precautions

Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit.

A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support. Do not weld on cylinders.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

AWS also recommends a personal copy of "Arc Welding Safely," "Fire Safety in Welding and Cutting," and "Safety in Welding, Cutting, and Allied Processes."

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Chapter 1—Definitions

Resistance Welding

Acceptable weld—A weld that meets all the requirements and the acceptance criteria prescribed by the welding specifications.

Contact resistance—Resistance to the flow of electric current between two workpieces or an electrode and a workpiece.

Cool time—The time interval between successive heat times in multiple-impulse welding or in the making of seam welds. (See Figures 1 and 2.)

Electrode force—The force applied to the electrodes in making spot, seam or projection welds by resistance welding.

Electrode indentation—The depression formed on the surface of workpieces by electrodes.

Electrode pickup—Contamination of the electrode tips or wheel faces by the base metal or its coating during spot, seam, or projection welding.

Electrode skid—The sliding of a resistance welding electrode along the surface of the workpiece when making spot, seam, or projection welds.

Faying surface—The mating surface of a member that is in contact with or in close proximity to another member to which it is to be joined.

Follow-up—The ability of the moveable electrode to maintain proper electrode force and contact with the workpiece as metal movement occurs, especially in projection welding.

Forge-delay time—The time elapsing between a preselected point in the welding cycle and the initiation of the forge force. (See Figure 1.)

Forge force—A compressive force applied to the weld after the heating portion of the welding cycle is essentially complete.

Heat-affected zone (HAZ)—The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding. It should be noted that with resistance welding processes the HAZ is usually much narrower than with arc welding processes, but the metallurgical characteristics are the same.

High-strength low-alloy steel (HSLA)—A general term for low-carbon steel having higher yield strength than standard low yield strength, low-carbon steels. It can be furnished as either a hot or cold rolled product.

High-strength steels (HSS)—A general group of steels with greater tensile and yield strengths than low strength, low-carbon steel. *NOTE:* I-F steels are low-carbon steels with improved formability having less than 0.02 percent carbon (C) with niobium (Nb) or titanium (Ti) additions.

Impulse—A group of pulses occurring on a regular frequency separated only by an inter-pulse time. (See Figures 1 and 2.)

Indentation—In a spot, seam, or projection weld, the depression on the exterior surface of the workpieces.

Indirect welding—A resistance welding secondary variation in which the welding current flows through the workpieces in locations away from, as well as at, the welds for resistance spot, seam, or projection welding. (See Figure 3.)

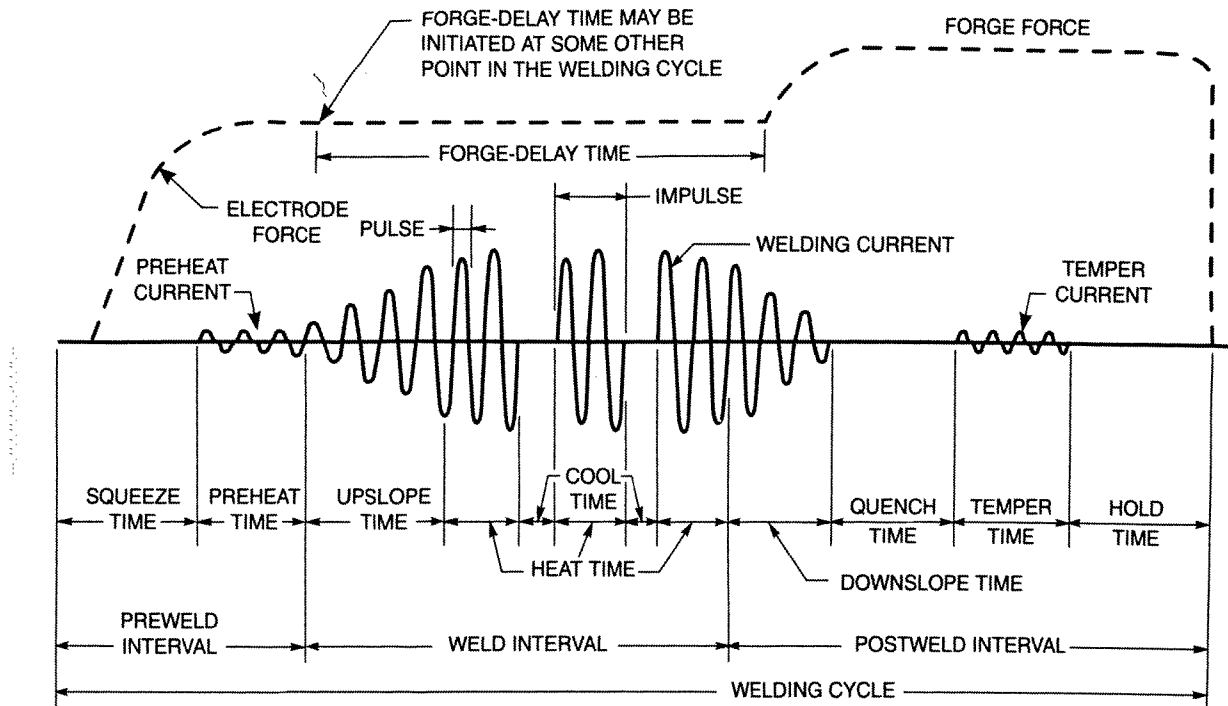


Figure 1—Multiple Impulse Resistance Spot Welding Schedule

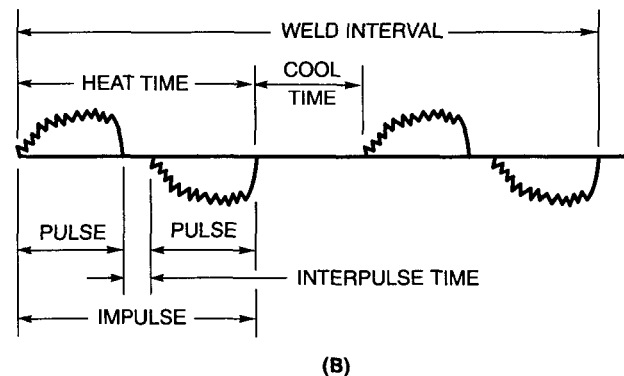
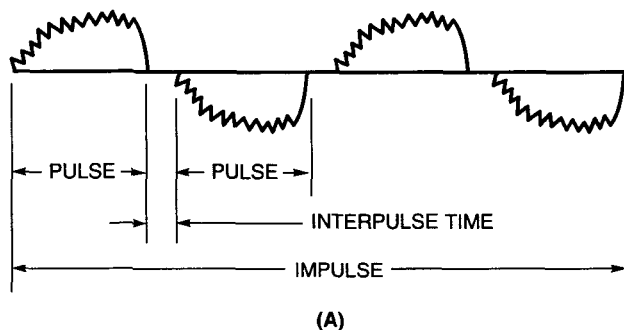


Figure 2—Resistance Welding Current Characteristics for Frequency Converter Equipment

Mushrooming—The deformation of an electrode, initiated at the contact surface as a result of the various actions occurring during welding.

Off time—The time during which the electrodes are off the workpieces. This term is generally used when the welding cycle is repetitive. (See Figure 4.)

Penetrator—A non-metallic oxide inclusion in a flash weld.

Phase shift control—A control commonly used in resistance welding machines to adjust the initiating point allowing only a portion or percentage of each alternating current half cycle to pass to the welding transformer.

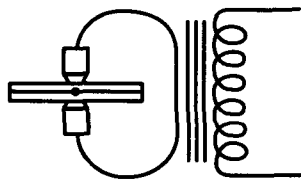
Platen—A member with a substantial flat surface to which dies, fixtures, backups, or electrode holders are attached, and which transmits the electrode force or upset force. One platen usually is fixed and the other moveable.

Postweld interval—The total elapsed time from the end of the weld interval to the end of hold time. (See Figure 1.)

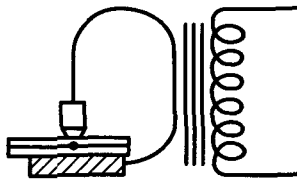
Preheat current—An impulse or series of impulses that occur prior to and are separated from the welding current. (See Figure 1.)

Preheat time—The duration of preheat current flow during the preweld interval. (See Figure 1.)

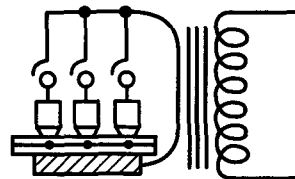
Preweld interval—The elapsed time between the initiation of the squeeze time and the beginning of the weld time or weld interval time. (See Figure 1.)



(A)

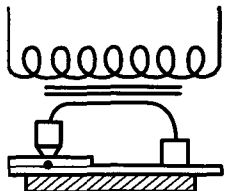


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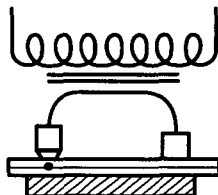


(C)

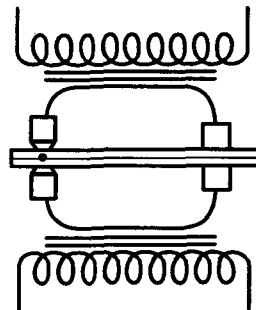
DIRECT WELDING



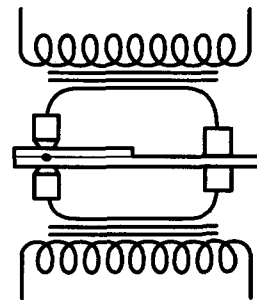
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INDIRECT WELDING

Figure 3—Typical Arrangements for Single Spot Welds

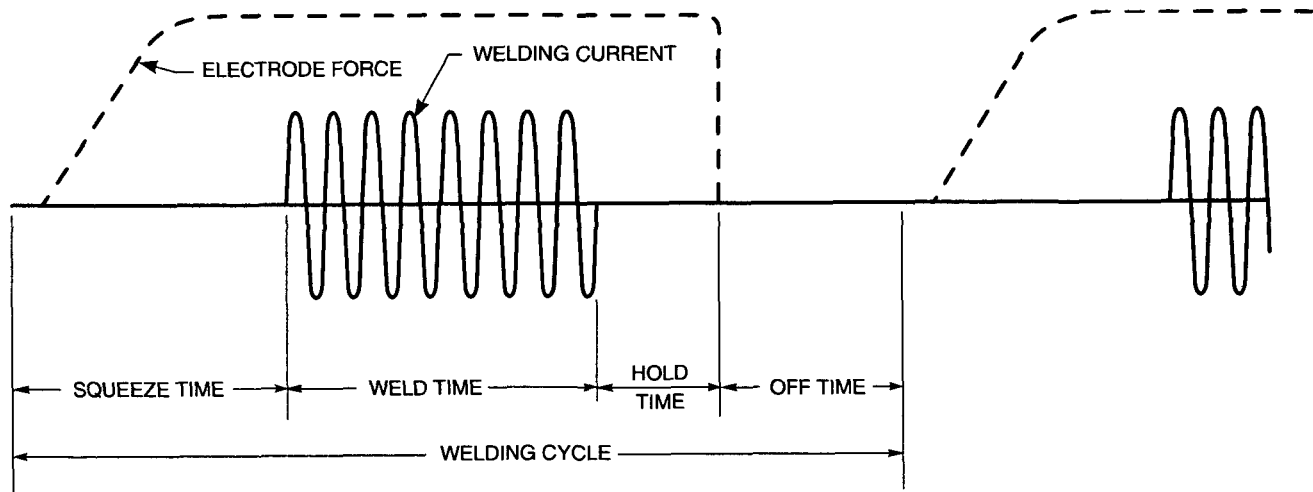


Figure 4—Single Impulse Resistance Spot Welding Schedule

Pulse—A current of controlled duration of either polarity through the welding circuit. (See Figures 1 and 2.)

Pulse time—The duration of a pulse. (See Figure 2.)

Push welding—A resistance welding process variation in which spot or projection welds are made by manually applying force to one electrode and using the workpiece or a support as the other electrode.

Quench time—The time from the end of the weld, weld interval, or downslope time to the beginning of the temper time, during which no current flows through the workpieces and the weld is rapidly cooled by the electrodes. (See Figure 1.)

Resistance Welding (RW)—A group of welding processes that produces coalescence of the faying surfaces with the heat obtained from resistance of the work pieces to the flow of the welding current in a circuit of which the workpieces are a part, and by the application of pressure.

Resistance welding control—The device, usually electronic, that determines the welding sequence and timing with regard to the welding current pattern, electrode or platen force or movement, and other operational conditions of a resistance welding machine.

Resistance welding current—The current in the welding circuit during the making of a weld, but excluding preweld or postweld current. (See Figures 1 and 4.)

Resistance welding die—A resistance welding electrode usually shaped to the workpiece contour to clamp the workpieces and to conduct the welding current.

Resistance welding downslope time—The time during which the welding current is continuously decreased. (See Figure 1.)

Resistance welding electrode—The part of a resistance welding machine through which the welding current and, in most cases, force are applied directly to the workpiece. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck, or modification thereof.

Resistance welding upslope time—The time during which the welding current continuously increases from the beginning of the welding current. (See Figure 1.)

Resistance welding time—The duration of welding current flow through the workpieces in making a weld by single-impulse welding or flash welding. (See Figure 4.)

Secondary current path—The electrical path through which the welding current passes.

Series welding—A resistance welding secondary circuit variation in which the secondary current is conducted through the workpieces and electrodes or wheels in a series electrical path to simultaneously form multiple resistance spot, seam, or projection welds. (See Figure 5.)

Single impulse welding—A resistance welding process variation in which spot, projection, or upset welds are made with a single impulse.

Squeeze time—The time between the initiation of the welding cycle and first application of current in spot, seam, or projection and some types of upset welds. (See Figures 1 and 4.)

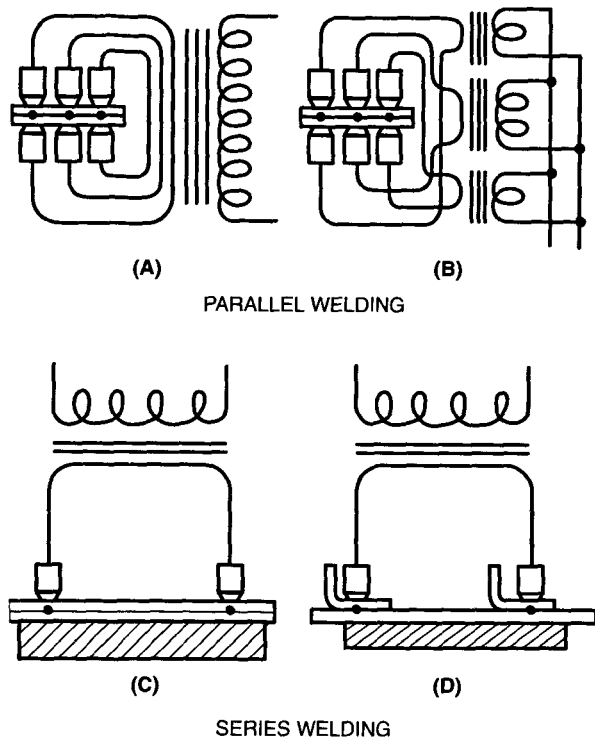


Figure 5—Typical Arrangements for Multiple Spot Welding

Static electrode force—The force exerted by electrodes on the workpieces in making spot, seam, or projection welds by resistance welding under welding conditions, but with no current flowing and no movement in the welding machine.

Synchronous timing—The initiation of each half cycle of welding transformer primary current on an accurately timed delay with respect to the polarity reversal of the power supply.

Temper time—The time following quench time during which a current is passed through the weld for heat treating. (See Figure 1.)

Weld discrepancy—A weld condition that deviates from the applicable standard, specification or engineering drawing.

Weld interval—The total of all heat and cool times, and upslope time, used in making one multiple impulse weld. (See Figure 1.)

Weld lobe—The current, time, and force ranges which produce acceptable welds.

Spot Welding

Button—That part of a weld, including all or part of the nugget, that tears out in the destructive testing of spot, seam or projection welded specimens.

Electrode cap—A replaceable electrode tip used for resistance spot welding.

Electrode tip life—The number of resistance spot welds that can be made with an electrode before redressing of the electrode is required.

Nugget—The weld metal joining the workpieces in spot, seam or projection welding.

Resistance spot welding (RSW)—A resistance welding process that produces a weld at the faying surfaces of a joint by the heat obtained from resistance to the flow of welding current through the workpieces from electrodes that serve to concentrate the welding current and pressure at the weld area. (See Figures 1–6.)

Seam Welding

Heat time—The duration of any one impulse in multiple impulse welding or resistance seam welding. (See Figures 1 and 2.)

Mash seam welding—A resistance seam welding process variation that makes a lap joint primarily by high temperature plastic working and diffusion as opposed to melting and solidification. The joint thickness after welding is less than the original assembled thickness.

Overlap—The portion of the preceding weld nugget remelted by the succeeding weld.

Resistance seam welding (RSEW)—A resistance welding process that produces a weld at the faying surfaces of overlapped parts progressively along a length of a joint. The weld may be made with overlapping weld nuggets, a continuous weld nugget, or by forging the joint as it is heated to the welding temperature by resistance to the flow of welding current. (See Figure 6.)

Roll spot welding—A resistance welding process variation that makes intermittent spot welds using one or more rotating circular electrodes. The rotation of the electrode may or may not be stopped during the making of a weld.

Projection Welding

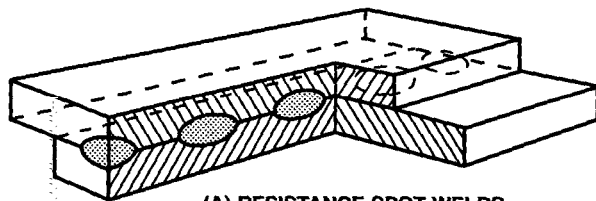
Projection welding (PW)—A resistance welding process that produces a weld by the heat obtained from the resistance to the flow of the welding current. The resulting welds are localized at predetermined points by projections, embossments, or intersections.

Flash Welding

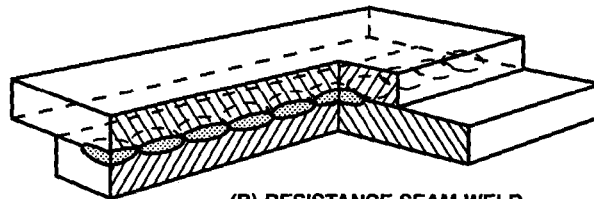
Flash welding (FW)—A resistance welding process that produces a weld at the faying surfaces of a butt joint by a flashing action and by the application of pressure after heating is substantially completed. The flashing action, caused by the very high current densities at the small contact points between the workpieces, forcibly expels the material from the joint as the workpieces are slowly moved together. The weld is completed by a rapid upsetting of the workpieces. (See Figure 7.)

Flashing action—The phenomenon in flash welding wherein points of contact, formed by light pressure across faying surfaces, are melted and explosively ejected because of the extremely high current density at contact points.

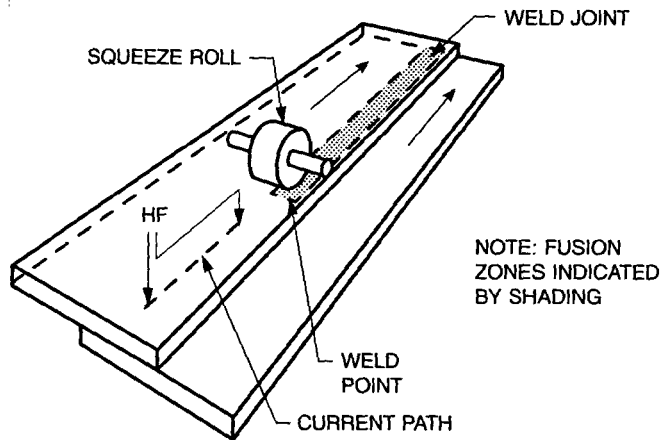
Flash—Material that is expelled from a flash weld prior to the upset portion of the welding cycle.



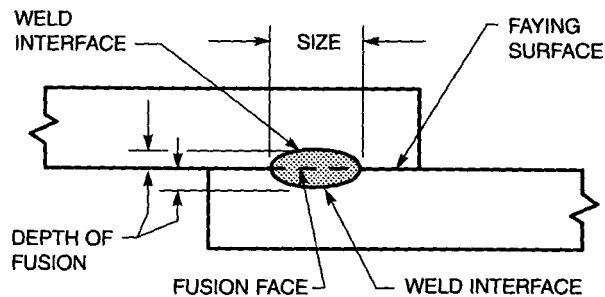
(A) RESISTANCE SPOT WELDS



(B) RESISTANCE SEAM WELD



(C) LAP JOINT MADE BY HIGH FREQUENCY SEAM WELDING



(D) RESISTANCE SPOT OR SEAM WELD

Figure 6—Seam Welds and Spot Welds

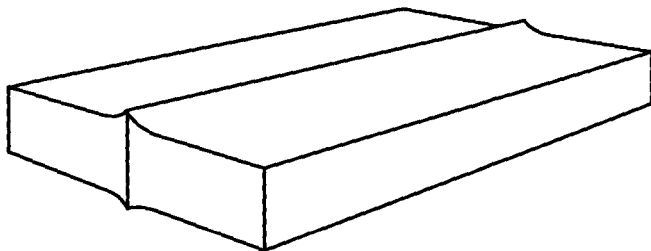


Figure 7—Flash Weld

Flash time—The duration of flashing action during flash welding.

Upset—Bulk deformation resulting from the application of pressure in welding (notably flash welding). The upset may be measured as a percent increase in interface area, a reduction in length, a percent reduction in lap joint thickness, or a reduction in cross wire weld stack height.

Upset distance—The total reduction in the axial length of the workpieces from the initial contact to the completion of the weld. In flash welding the upset distance is equal to the platen movement from the end of flash time to the end of upset.



Chapter 2—Resistance Welding Electrodes

A. Electrode Materials—Resistance Welder Manufacturers' Association (RWMA) Group A, Class 2 electrodes (see Table 1) are generally recommended for low-carbon steels because this group of electrodes maintains relative high strengths at elevated temperatures. Industry uses several electrode materials for the resistance welding of coated steels. These electrode materials are selected for the following characteristics and properties:

- *RWMA Group A, Class 1*—Materials are relatively weak electrode material, but they exhibit the highest conductivity. They can conduct the increased currents associated with coated steels and cool the face quicker, which can retard alloying between the coating and the electrode.
- *RWMA Group A, Class 2*—These materials are used for welding coated steel because of their higher strength, which better matches the strength of steel than Class 1.
- *RWMA Group C, Class 20*—Dispersion strengthened copper electrode usage has increased with the introduction of new coatings and expanded the use of traditional galvanized coatings.
- *RWMA Group A, Class 1*—These electrodes are the most commonly used for resistance welding aluminum and its alloys. RWMA Group A, Class 2 may be used but the lower electrical and thermal conductivities of this alloy makes it less suitable for welding aluminum except in those cases where higher strength is required.

B. Electrode Geometries—The shapes shown in Figure 8 are used in various situations depending on the specific requirements of the job. The tables of welding parameters (as given in Chapter 3) indicate the recommended shape for each thickness of material to be joined.

Table 1—Electrode Materials for Resistance Welding

Group A—Copper Base Alloys		RWMA Designation
Class 1	Cadmium copper	1.16200
	Chromium copper	1.18200
	Zirconium copper	1.15000
Class 2	Chromium copper	2.18200
	Chromium zirconium copper	2.18150
Class 3	Beryllium copper (Co)	3.17500
	Beryllium copper (Ni)	3.17510
	Beryllium free	3.18000
Class 4	Beryllium copper	4.17200
Class 5	Aluminum bronze	5.95300
Group B—Refractory Metal or Refractory Metal Composites		
Class 10	Copper tungsten (45% Cu/55% W)	10.74450
Class 11	Copper tungsten (25% Cu/75% W)	11.74400
Class 12	Copper tungsten (20% Cu/80% W)	12.74350
Class 13	Tungsten	13.74300
Class 14	Molybdenum	14.42300
Group C—Specialty Materials		
Class 20	Dispersion strengthened copper	20.15760

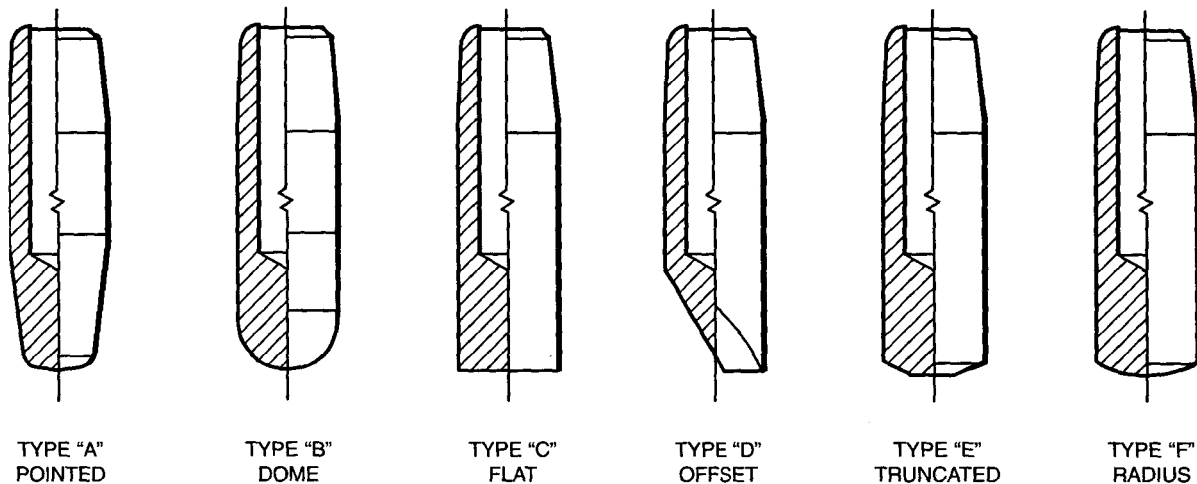


Figure 8—Standard RWMA Nose or Tip Geometries of Spot Welding Electrodes



Chapter 3—Spot and Seam Welding Parameters

The following tables of recommended welding parameters are arranged in the following order:

A. Low-Carbon Steel (Uncoated)

- Table 2—Spot Welding Parameters for Low-Carbon Steel
- Table 3—Pulsation Spot Welding Parameters for Low-Carbon Steel
- Table 4—Spot Welding Parameters for Low-Alloy and Medium-Carbon Steel
- Table 5—Seam Welding Parameters for Low-Carbon Steel

B. Low-Carbon Steel (Coated)

- Table 6—Spot Welding Parameters for Galvanized Low-Carbon Steel
- Table 7—Spot Welding Parameters for Galvannealed Low-Carbon Steel
- Table 8—Seam Welding Parameters for Galvanized Low-Carbon Steel

C. High-Strength Low-Alloy Steel (Uncoated)

- Table 9—Spot Welding Parameters for HSLA Steel (Min. Y.S.—50 ksi)
- Table 10—Spot Welding Parameters for HSLA Steel (Min. Y.S.—55 ksi)
- Table 11—Spot Welding Parameters for HSLA Steel (SAE J1392)

D. High-Strength Low-Alloy Steel (Coated)

- Table 12—Spot Welding Parameters for Galvanized HSLA Steel (50, 60, 70, 80, and 90 ksi Grades)

E. Aluminum and Aluminum Alloys

(These schedules are for various Machine configurations)

- Table 13—Spot Welding Parameters for Aluminum Alloys on Standard Single-Phase AC Type Equipment
- Table 14—Spot Welding Parameters for Aluminum Alloys on Single-Phase AC Slope Control Type Machine
- Table 15—Spot Welding Parameters for Aluminum Alloys on Three-Phase Rectifier Type Equipment
- Table 16—Spot Welding Parameters for Aluminum Alloys on Three-Phase Frequency Converter Type Equipment (Single-Impulse Welds)
- Table 17—Recommended Spot Weld Spacing, Edge Distance, Overlap, and Distance Between Rows of Welds for Aluminum and its Alloys

NOTE: The values given in the following tables should not be considered as the only possible conditions for welding the materials and thicknesses shown; they are rather starting conditions for setting up welding schedules to be followed in any particular welded fabrication. They may be modified accordingly to obtain optimum conditions for the specific conditions and production requirements.

Table 2—Spot Welding Parameters for Low-Carbon Steel

Metal Thickness in.	Electrode* Face Dia. in.	Net Electrode Force lb.	Weld Time Cycles	Welding Current (Approx.) Amps	Minimum Contact Overlap in.	Minimum Weld Spacing in.	Minimum Shear Strength** lb.	Nugget Dia. in.	
								Minimum Satisfactory	Set-up
0.020	0.188	400	7	8500	0.44	0.38	320	0.12	0.180
0.025	0.188	450	8	9500	0.47	0.50	450	0.12	0.180
0.030	0.250	500	9	10500	0.51	0.62	550	0.14	0.250
0.035	0.250	600	9	11500	0.53	0.75	750	0.16	0.250
0.040	0.250	700	10	12500	0.56	0.85	925	0.18	0.250
0.045	0.250	750	11	13000	0.59	0.94	1150	0.19	0.250
0.050	0.312	800	12	13500	0.61	1.00	1350	0.20	0.312
0.055	0.312	900	13	14000	0.63	1.06	1600	0.21	0.312
0.060	0.312	1000	14	15000	0.65	1.12	1850	0.23	0.312
0.070	0.312	1200	16	16000	0.68	1.25	2300	0.25	0.312
0.080	0.312	1400	18	17000	0.72	1.44	2700	0.26	0.312
0.090	0.375	1600	20	18000	0.78	1.56	3450	0.27	0.375
0.105	0.375	1800	23	19500	0.84	1.68	4150	0.28	0.375
0.120	0.375	2100	26	21000	1.02	1.81	5000	0.30	0.375

*Shapes that can be used are:

E = Truncated Cone (45° Bevel)

A = Pointed

B = Domed

F = Radius Tip

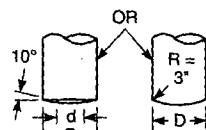
Also see Figure 1.

Notes:

1. For intermediate thicknesses, force, weld time, and current may be interpolated.
2. Electrode material: RWMA Class 2.
3. Minimum weld spacing is measured from centerline to centerline.
4. The data within this table was supplied by committee members and represents an average of typical parameters used in industry.
5. Based on single-phase AC 60 (Hz) equipment.
6. **Based on 30000 psi yield strength material.

Table 3—Pulsation Spot Welding Parameters for Low-Carbon Steel

Electrode Diameter and Shape



Min. d = 1/4"

Weld Time

On 20
Cycles

Off 5
Cycles

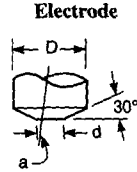
Number of Positions

Combination of Thicknesses to be Welded in.	"D" Min. in.	"d" Max. in.	Net Electrode Force lb.	Adjacent Welds			Current Approx. Amps	Minimum Contact Overlap in.	Minimum Shear Strength* in.	Nugget Dia. in.	
				Single Welds	1 in. to 2 in.	2 in. to 4 in.				Minimum Satisfactory	Set-up
0.125 to 0.125	1.00	0.44	1800	3	5	4	18000	0.88	5000	0.38	0.45
0.125 to 0.188	1.00	0.44	1800	3	5	4	18000	0.88	5000	0.38	0.45
0.125 to 0.250	1.00	0.44	1800	3	5	4	18000	0.88	5000	0.38	0.45
0.188 to 0.188	1.25	0.50	1950	6	20	14	19500	1.12	10000	0.50	0.60
0.188 to 0.250	1.25	0.50	1950	6	20	14	19500	1.12	10000	0.50	0.60
0.188 to 0.312	1.25	0.50	1950	6	20	14	19500	1.12	10000	0.50	0.60
0.250 to 0.250	1.25	0.56	2150	12	24	18	21500	1.38	15000	0.56	0.70
0.250 to 0.312	1.25	0.56	2150	12	24	18	21500	1.38	15000	0.56	0.70
0.312 to 0.312	1.50	0.62	2400	15	30	23	24000	1.50	20000	0.62	0.70

Notes:

1. Type of steel—Y.S. less than 70 ksi.
2. Electrode material: RWMA Class 2.
3. For the 3-in. radius face electrodes, the face diameter is the same as the electrode diameter.
4. Based on single-phase AC 60 (Hz) equipment.
5. *Based on material with less than 70,000 psi tensile strength.
6. Adjacent welds are measured as to distance between spots.

Table 4—Spot Welding Parameters for Low-Alloy and Medium-Carbon Steels



Material			Electrode			Net Electrode Weld and Temper Force	Weld Time Cycles	Quench Time Cycles	Temper Time Cycles	Weld Current (Approx.) Amps	Temper Current % of Weld Current	Min. Contacting Overlap in.	Min. Weld Spacing in.	Min. Shear Strength lb.	Satis- factory Nugget Dia. in.
Type	Condition*	Thickness in.	"D" Min. Dia. in.	"d" Face Dia. in.	"R" Face Radius in.										
SAE 1020	Hot Rolled	0.040	5/8	1/4	6	1475	6	17	6	16000	90	1/2	1	1360	0.23
SAE 1035	Hot Rolled	0.040	5/8	1/4	6	1475	6	20	6	14200	91	1/2	1	1560	0.22
SAE 1045	Hot Rolled	0.040	5/8	1/4	6	1475	6	24	6	13800	88	1/2	1	2000	0.21
SAE 4130	Hot Rolled	0.040	5/8	1/4	6	1475	6	18	6	13000	90	1/2	1	2120	0.22
SAE 4340	N & D	0.031	5/8	3/16	6	900	4	12	4	8250	84	7/16	3/4	1084	0.16
SAE 4340	N & D	0.062	3/4	5/16	6	2000	10	45	10	13900	77	5/8	1-1/2	3840	0.27
SAE 4340	N & D	0.125	1	5/8	10	5500	45	240	90	21800	86	7/8	2-1/2	13680	0.55
SAE 8630	N & D	0.031	1/2	3/16	6	800	4	12	4	8650	88	7/16	3/4	1220	0.16
SAE 8630	N & D	0.062	5/8	5/16	6	1800	10	36	10	12800	83	5/8	1-1/2	4240	0.27
SAE 8630	N & D	0.125	1	5/8	10	4500	45	210	90	21800	84	7/8	2-1/2	13200	0.55
SAE 8715	N & D	0.018	1/2	1/8	6	350	3	4	3	3900	85	7/16	5/8	400	0.10
SAE 8715	N & D	0.062	5/8	5/16	6	1600	10	28	10	12250	85	5/8	1-1/2	3300	0.27
SAE 8715	N & D	0.125	1	5/8	10	4500	45	180	90	22700	85	7/8	2-1/2	12760	0.55

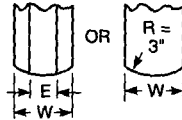
*N & D = Normalized & Drawn.

Notes:

1. Material should be pickled or otherwise cleaned to obtain a surface contact resistance not exceeding 200 microhms.
2. Electrode Material: RWMA Class 2.
3. Electrode diameter and shape are the same for both upper and lower electrodes.
4. Minimum spacing is that spacing for which no special precautions need to be taken to compensate for shunted current effect of adjacent welds.
5. Based on single-phase AC 60 (Hz) equipment.
6. Data obtained from steel companies.

Table 5—Seam Welding Parameters for Low-Carbon Steel

Electrode Width and Shape



Metal Thickness in.	W Min. in.	E W Max. in.	Net Electrode Force lb.	On Time Cycles	Off Time Cycles	Weld Speed Min. in.	Welds Per in.	Current Amps	Minimum Contact Overlap in.
0.010	0.38	0.18	400	2	1	80	15	8000	0.38
0.021	0.38	0.19	550	2	2	75	12	11000	0.44
0.031	0.50	0.25	900	3	2	72	10	13000	0.50
0.040	0.50	0.25	980	3	3	67	9	15000	0.50
0.050	0.50	0.31	1050	4	3	65	8	16500	0.56
0.062	0.50	0.31	1200	4	4	63	7	17500	0.62
0.078	0.62	0.38	1500	6	5	55	6	19000	0.69
0.094	0.62	0.44	1700	7	6	50	5.5	20000	0.75
0.109	0.75	0.50	1950	9	6	48	5	21000	0.81
0.125	0.75	0.50	2200	11	7	45	4.5	22000	0.88

Notes:

1. Type of steel—SAE 1010.
2. Material should be free from scale, oxides, paint, grease and oil.
3. For the electrodes with a radius face, the face width is the same as the electrode width.
4. Electrode materials: RWMA Class 2.
5. For large assemblies, minimum contacting overlap indicated should be increased by 30%.
6. Based on single-phase AC 60 (Hz) equipment.
7. Welding speeds noted do not give a leak-tight seam.

Table 6—Spot Welding Parameters for Galvanized Low-Carbon Steel

Metal Thickness in.	Electrode		Net Electrode Force lb.	Weld Time Cycles	Weld Current (Approx.) A	Minimum Contact Overlap in.	Minimum Weld Spacing in.	Nugget Diameters		Minimum Shear Strength lb.
	Face Dia. in.	Shape						Minimum Satisfactory in.	Set-up in.	
0.020	0.188	A, B, E	475	10	10900	0.44	0.38	0.12	0.18	320
0.025	0.188	A, B, E	525	11	11500	0.47	0.62	0.13	0.18	450
0.030	0.250	A, B, E	575	12	12300	0.47	0.62	0.14	0.25	575
0.035	0.250	A, B, E, F	625	13	13500	0.53	0.75	0.16	0.25	750
0.040	0.250	A, B, E, F	700	13	14100	0.53	0.75	0.17	0.25	925
0.045	0.250	A, B, E, F	750	14	14800	0.59	0.94	0.19	0.25	1150
0.050	0.312	A, B, E, F	800	16	15600	0.59	0.94	0.20	0.31	1350
0.055	0.312	A, B, E, F	1000	17	16200	0.63	1.06	0.21	0.31	1600
0.060	0.312	A, B, E, F	1025	18	17000	0.63	1.06	0.22	0.31	1850
0.070	0.312	A, B, E, F	1225	22	18800	0.66	1.18	0.24	0.31	2300
0.080	0.312	A, B, E, F	1375	25	19600	0.72	1.38	0.26	0.31	2700
0.090	0.375	A, B, E, F	1500	31	20400	0.78	1.56	0.27	0.38	3450
0.105	0.375	A, B, E, F	1725	35	22000	0.84	1.68	0.28	0.38	4150
0.120	0.375	A, B, E, F	2100	42	24000	0.88	1.81	0.30	0.38	5000

Notes:

1. Welding parameters are applicable to welding 2 stack joints of one-side or two-side galvanized low-carbon steel.
2. Welding parameters are based on single-phase AC 60 (Hz) equipment.
3. Welding parameters are applicable when using electrode materials included in RWMA Classes 1, 2, and 20.
4. Metal thicknesses represent the actual thickness of the sheets being welded. In the case of welding two sheets of different thicknesses, use the welding parameters for the thinner sheet.
5. Nugget diameters are listed as:
 - the minimum diameter that is recommended to be considered a satisfactory weld.
 - the initial aim set-up nugget diameter that is recommended in setting up a weld station to produce weld nuggets that consistently surpass the satisfactory weld nugget diameter for a given number of production welds.
6. Electrode shapes listed include: A—pointed, B—domed, E—truncated, F—radiused.
7. These recommendations are based on available weld schedules representing recommendations from resistance welding equipment suppliers and users.

Table 7—Spot Welding Parameters for Galvannealed Low-Carbon Steel

Metal Thickness in.	Electrode		Net Electrode Force lb.	Weld Time Cycles	Weld Current (Approx.) A	Minimum Contact Overlap in.	Minimum Weld Spacing in.	Nugget Diameters		Minimum Shear Strength lb.
	Face Dia. in.	Shape						Minimum Satisfactory in.	Set-up in.	
0.020	0.200	A, B, E	375	6	8000	0.44	0.38	0.10	0.20	320
0.025	0.200	A, B, E	400	7	9000	0.47	0.62	0.12	0.20	450
0.030	0.200	A, B, E	450	8	10500	0.47	0.62	0.14	0.20	575
0.035	0.250	A, B, E, F	600	9	11500	0.53	0.75	0.16	0.25	750
0.040	0.250	A, B, E, F	650	10	12500	0.53	0.75	0.19	0.25	925
0.045	0.250	A, B, E, F	750	11	13000	0.59	0.94	0.20	0.25	1150
0.050	0.312	A, B, E, F	800	12	14000	0.59	0.94	0.22	0.31	1350
0.055	0.312	A, B, E, F	900	13	14500	0.63	1.06	0.24	0.31	1600
0.060	0.312	A, B, E, F	1000	14	15000	0.63	1.06	0.26	0.31	1850
0.070	0.312	A, B, E, F	1200	16	16500	0.66	1.18	0.28	0.31	2300
0.080	0.312	A, B, E, F	1300	18	17500	0.72	1.38	0.29	0.31	2700
0.090	0.375	A, B, E, F	1500	20	19000	0.78	1.56	0.32	0.38	3450
0.105	0.375	A, B, E, F	1800	23	20000	0.84	1.68	0.33	0.38	4150
0.120	0.375	A, B, E, F	2100	26	21000	0.88	1.81	0.34	0.38	5000

Notes:

1. Welding parameters are applicable to welding 2 stack joints of one-side or two-side galvannealed sheets of low-carbon steel.
2. Welding parameters are based on single-phase AC 60 (Hz) equipment.
3. Welding parameters are applicable when using electrode materials included in RWMA Classes 1, 2, and 20.
4. Metal thicknesses represent the actual thickness of the sheets being welded. In the case of welding two sheets of different thicknesses, use the welding parameters for the thinner sheet.
5. Nugget diameters are listed as:
 - the minimum diameter that is recommended to be considered a satisfactory weld.
 - the initial aim set-up nugget diameter that is recommended in setting up a weld station to produce weld nuggets that consistently surpass the satisfactory weld nugget diameter for a given number of production welds.
6. Electrode shapes listed include: A—pointed, B—domed, E—truncated, F—radiused.
7. These recommendations are based on available weld schedules representing recommendations from resistance welding equipment suppliers and users.

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