

AWS D17.2/D17.2M:2007
An American National Standard

Specification for Resistance Welding for Aerospace Applications



American Welding Society



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An American National Standard

Approved by the
American National Standards Institute
January 4, 2007

Specification for Resistance Welding for Aerospace Applications

1st Edition

Prepared by the
American Welding Society (AWS) D17 Committee on Welding in the Aircraft and Aerospace Industry

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification provides the general resistance welding requirements for aerospace hardware. It includes, but is not limited to, resistance spot and resistance seam welding of aluminum, magnesium, iron, nickel, cobalt, and titanium-based alloys. There are requirements for machine and procedure qualification, production witness samples, and inspection and acceptance criteria for aerospace hardware.



American Welding Society

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American Welding Society

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Foreword

This foreword is not part of AWS D17.2/D17.2M:2007, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

In the mid 1990s, the AWS D17 Committee on Welding in the Aircraft and Aerospace Industries decided it was necessary to form a subcommittee to write a resistance spot and seam welding specification.

This specification is a new document and is intended to replace the following documents:

MIL-W-6858D *Welding, Resistance: Spot and Seam*, March 28, 1978

AMS-W-6858A *Welding, Resistance Spot and Seam*, April 1, 2000

MIL-W-6858D or AMS-W-6858A, or both, take precedence over this specification only when they are cited by the contract documents.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D17 Committee on Welding in the Aircraft and Aerospace Industries, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Specification for Resistance Welding for Aerospace Applications

1. Scope

This specification covers requirements for resistance spot and seam welding of the following metals and their alloys.

1.1 Material Groups

- (1) Group 1—Aluminum and magnesium
- (2) Group 2—Steel, nickel, and cobalt
- (3) Group 3—Titanium

1.2 Classification. Classification is based on the following:

- (1) *Class A.* A welded joint, whose failure during any operating condition would cause loss of the equipment or system or one of its major components.
- (2) *Class B.* A welded joint whose failure would reduce the overall strength of the equipment or system or limit the intended functioning or use of equipment.
- (3) *Class C.* A welded joint for which no stress analysis is required and whose failure would not affect the performance of the equipment or system.

1.3 Standard Units of Measure. This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets [] or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system shall be used independently.

1.4 Safety and Health. Safety and health issues and concerns are beyond the scope of this standard, and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

2. Normative References

The following standard contains provisions which, through reference in this text, constitute provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

- (1) AWS A3.0, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.¹

3. Terms and Definitions

All of the terms listed in this clause are used in various parts of this document and require definition for correct interpretation of the instructions. Most of these terms are not contained in AWS A3.0, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*. Some of the terms are listed in AWS A3.0, but their definitions have been enhanced to clarify their use in this document.

For the purposes of this document, the following definitions apply:

close spaced welds. Spot welds on sheet placed less than two diameters apart, center to center. Such proximity may require more power than other spot welds.

Engineering Authority. The contracting agency or corporation that acts for and in behalf of the customer on all matters within the scope of this standard. The Engineering Authority has responsibility for the structural integrity or maintenance of airworthiness of the hardware and compliance with all contract documents.

¹ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

foil. A thickness of 0.008 in [0.02 mm] or less.

metallographic section. A transverse cut on the diameter of a spot weld or across a seam weld, or a longitudinal cut down the center of a seam weld, polished down to near the center of the weld and etched to accentuate the metallographic structure.

nugget. The weld (fused) metal joining the parts in spot, seam, or projection welds.

resistance spot weld size. The diameter of a spot weld nugget or the width of a seam weld nugget measured at the plane of the faying surfaces.

peel test. A mechanical test in which the corners (or sides) of seam or spot welded foil or sheet members are gripped and pulled apart to determine if the joint fails by delamination, by fracture of a cleaved surface, or by tearing of a button (plug) out of the parent material. Delamination, in contrast to fracture, is a sign of no fusion between the two adjacent members. A button or plug, which is pulled out of the removed member, is not necessarily equal in size to the cast nugget underlying it.

penetration. The extent of the nugget or fusion zone into the thickness of a joined member.

production witness specimens. Welds of specimens made in production setups and destructively tested to provide data on the qualities of production welds which cannot be tested.

resistance seam welding (RSEW). A resistance welding process which produces coalescence at the faying surfaces by the heat obtained from resistance to electric current through the work parts held together under pressure by electrodes. The resulting weld is a series of overlapping resistance spot welds made progressively along a joint by turning wheel electrodes or indexing the part under fixed electrodes.

resistance spot welding (RSW). A resistance welding process which produces coalescence at the faying surfaces in one spot by heat obtained from the resistance to electric current through the work parts held together under pressure by electrodes. The size and shape of the individually formed welds are a function of the size and contour of the electrodes, current, and weld time.

sheet. A thickness, for the purpose of this specification, of more than 0.008 in through 0.250 in [0.20 mm through 6.35 mm].

weld conditions. All circumstances surrounding the making of a given weld, including material, configuration, material preparation, electrode shape, machine

number, and all weld parameters. Weld conditions that are relevant require documentation. A suggested form for documentation is found in Annex A.

weld parameters. Machine settings or adjustments, such as, but not limited to, weld current, weld time, and electrode force.

4. Requirements

4.1 Design Requirements

4.1.1 Definition of terms used in this specification shall be in accordance with AWS A3.0, and as shown in Clause 3 herein. In the event of any conflict between the requirements of this specification and those requirements specified on the engineering drawing, the engineering drawing shall prevail.

4.1.2 The class of welding shall be designated on the item specification or drawing.

4.1.3 Spot Weld Certification. There shall be two methods of certification for spot welds.

4.1.3.1 Standard Certification. The standard certification method shall be for a weld schedule that certifies to the requirements of Tables 1 through 3 (sheet) or Table 4 (foil), and all other applicable weld property requirements listed in this specification have been met.

4.1.3.2 Design Allowable Certification. The design allowable certification method shall be used for a weld schedule that certifies a guaranteed minimum strength value or nugget size, specified on the engineering drawing, has been met. Conditions where design allowable certification shall be permitted are: Where available space, equipment or material conditions and design stress permits the use of smaller or lower strength welds; where weld conditions and design stress require larger or higher strength weld; or where unusual conditions exist (such as welding through adhesives or surface coatings). When design allowable certification is used, the guaranteed strength value or nugget size and weld class shall be specified on the engineering drawing.

4.2 Materials and Methods of Preparation

4.2.1 Surface Conditions. The surface of the parts to be welded shall be free from objectionable films such as heavy oxides, scale, ink, grease, dirt, or other substances, or surface conditions detrimental to the welding process.

4.2.1.1 Cleaning Requirements. These cleaning requirements shall be used to prepare test material and production parts:

Table 1
Shear Load Requirements for Spot Weld Sheet Specimens
Group 1 Alloys—Aluminum and Magnesium Alloys

Nominal Thickness of Thinner Sheet		Ultimate Strength				Ultimate Strength				Ultimate Strength				Ultimate Strength			
		56 000 psi and above lb per spot		386 MPa and above N per spot		35 000 psi to 55 999 psi lb per spot		240 MPa to 385.9 MPa N per spot		19 500 psi to 34 999 psi lb per spot		135 MPa to 239.9 MPa N per spot		Below 19 500 psi lb per spot		Below 135 MPa N per spot	
in	mm	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.010	0.25	60	75	265	335	50	65	225	290	—	—	—	—	—	—	—	—
0.012	0.30	75	95	335	425	65	85	290	380	30	40	135	175	20	25	90	110
0.016	0.40	110	140	490	625	100	125	445	555	70	90	310	400	50	65	225	290
0.018	0.45	125	160	555	710	115	145	510	645	85	110	380	490	65	85	290	380
0.020	0.50	140	175	625	780	135	170	600	755	100	125	445	555	80	100	355	445
0.022	0.55	160	200	710	890	155	195	690	865	120	150	535	665	95	120	425	535
0.025	0.65	185	235	825	1045	175	200	780	890	145	185	645	825	110	140	490	625
0.028	0.70	215	270	995	1200	205	260	910	1155	175	220	780	980	135	170	600	755
0.032	0.80	260	325	1155	1445	235	295	1045	1310	210	265	935	1180	165	210	735	935
0.036	0.90	305	385	1355	1710	275	345	1225	1535	255	320	1135	1425	195	245	865	1090
0.040	1.00	345	435	1535	1935	310	390	1380	1735	300	375	1335	1670	225	285	1000	1270
0.045	1.10	405	510	1800	2270	370	465	1645	2070	350	440	1555	1955	260	325	1155	1445
0.050	1.30	465	585	2070	2600	430	540	1910	2400	400	500	1780	2225	295	370	1310	1645
0.056	1.40	555	670	2470	2980	515	645	2290	2870	475	595	2110	2645	340	425	1510	1890
0.063	1.60	670	840	2980	3635	610	765	2715	3400	570	715	2535	3180	395	495	1755	2200
0.071	1.80	825	1035	3670	4605	720	900	3200	4005	645	810	2780	3600	450	565	2000	2515
0.080	2.00	1025	1285	4560	5715	855	1070	3805	4760	765	960	3400	4270	525	660	2335	2935
0.090	2.30	1255	1570	5580	6985	1000	1250	4450	5560	870	1090	3870	4850	595	745	2645	3315
0.100	2.50	1490	1865	6630	8295	1170	1465	5205	6515	940	1175	4180	5225	675	845	3000	3660
0.112	2.80	1780	2225	7915	9895	1340	1675	5960	7450	1000	1255	4450	5580	735	920	3270	4090
0.125	3.20	2120	2650	9430	11 785	1625	2035	7228	9050	1050	1315	4670	5850	785	985	3490	4380
0.140	3.60	2525	3160	11 230	14 055	1920	2400	8540	10 675	—	—	—	—	—	—	—	—
0.160	4.10	3120	3900	13 880	17 345	2440	3050	10 585	13 565	—	—	—	—	—	—	—	—
0.180	4.60	3725	4660	16 570	20 730	3000	3750	13 345	16 680	—	—	—	—	—	—	—	—
0.190	4.80	4035	5045	17 950	22 440	3240	4050	14 410	18 015	—	—	—	—	—	—	—	—
0.250	6.40	7350	9200	32 695	40 920	6400	8000	28 465	35 585	—	—	—	—	—	—	—	—

Note: N = newtons.

(1) Oxide coatings may be removed by mechanical treatment or by chemical treatment.

(2) The cleaning procedure used to prepare Group 1 materials for certification shall be specified on the weld procedure for production welding. Establishing minimum and maximum surface resistance values for test and production parts shall be used to ensure conformity is achieved between test and production material and compliance to this specification is maintained.

(3) The maximum time span that is permitted between cleaning and welding shall be demonstrated such that all the quality requirements of this standard can consistently be met within those time limits. Production welding shall be performed within those limits.

(4) When a cleaning procedure is changed, if it can be demonstrated that the new procedure produces the same results as the old procedure, recertification of weld schedules shall not be required as long as the weld parameters meet the requirements of 5.1.5. This conformity shall be shown by producing the same weld results (nugget and strength ranges) as made during machine qualification tests (using procedure certification quantities) and, for Group 1 alloys, showing a surface resistance (microohms) average that is no more than 1.05 times that achieved by the replaced procedure.

4.2.1.2 Surface Coatings. Coatings which improve the corrosion resistance or sealing characteristics without affecting the weld properties may be applied

Table 2
Shear Load Requirements for Spot Weld Sheet Specimens
Group 2 Alloys—Steel, Nickel, and Cobalt Alloys

		Ultimate Strength				Ultimate Strength				Ultimate Strength				Ultimate Strength			
Nominal Thickness of Thinner Sheet		Above 185 000 psi lb per spot		Above 1275 MPa N per spot		150 000 psi to 185 000 psi lb per spot		1034 MPa to 1275 MPa N per spot		90 000 psi to 149 999 psi lb per spot		620 MPa to 1033.9 MPa N per spot		Below 90 000 psi lb per spot		Below 620 MPa N per spot	
in	mm	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.
0.009	0.22	200	245	890	1090	175	210	780	935	130	160	580	710	100	125	440	555
0.010	0.25	245	305	1090	1355	205	255	910	1135	160	195	710	865	115	140	510	625
0.012	0.30	350	410	1555	1825	275	340	1225	1510	200	245	890	1090	150	185	665	825
0.016	0.40	480	595	2135	2645	400	495	1780	2200	295	365	1310	1625	215	260	955	1155
0.018	0.45	590	725	2625	3225	490	600	2200	2670	340	415	1510	1845	250	305	1110	1355
0.020	0.50	635	785	2825	3490	530	655	2355	2915	390	480	1735	2135	280	345	1245	1535
0.022	0.55	730	905	3245	4025	610	755	2715	3360	450	550	2000	2445	330	405	1470	1800
0.025	0.65	870	1075	3870	4780	725	895	3225	3980	530	655	2355	2915	400	495	1780	2200
0.028	0.70	1025	1260	4560	5605	855	1055	3805	4690	635	785	2825	3400	465	575	2070	2555
0.032	0.80	1250	1545	5560	6870	1045	1280	4650	5695	775	955	3445	4250	565	695	2515	3090
0.036	0.90	1500	1850	6670	8230	1255	1545	5580	6870	920	1140	4090	5070	690	860	3070	3825
0.040	1.00	1750	2150	7785	9565	1460	1800	6495	8005	1065	1310	4735	5825	815	1000	3625	4450
0.045	1.10	2100	2600	9340	10 895	1795	2210	7985	9830	1285	1585	5715	7050	1005	1240	4470	5515
0.050	1.30	2450	3000	10 900	13 345	2125	2620	9450	11 655	1505	1855	6695	8250	1195	1475	5315	6560
0.056	1.40	2880	3550	12 810	15 790	2550	3145	11 340	13 990	1770	2185	7875	9720	1460	1800	6495	8005
0.063	1.60	3550	4375	15 790	19 460	3090	3815	13 745	16 970	2110	2595	9385	11 545	1760	2170	7830	9650
0.071	1.80	4200	5150	18 680	22 905	3730	4595	16 590	20 440	2535	3125	11 275	13 900	2080	2560	9250	11 385
0.080	2.00	4850	6000	21 575	26 690	4410	5440	19 615	24 195	3005	3705	13 365	16 480	2455	3025	10 920	13 455
0.090	2.30	5600	6900	24 910	30 690	5090	6275	22 640	27 910	3515	4335	15 635	19 280	2885	3560	12 830	15 835
0.100	2.50	6300	7750	28 020	34 470	5720	7050	25 445	31 360	4000	4935	17 790	21 680	3300	4070	14 680	18 105
0.112	2.80	7000	8600	31 135	38 255	6365	7855	28 310	34 940	4545	5610	20 215	24 955	3795	4675	16 880	20 795
0.125	3.20	7785	9600	34 630	42 700	7080	8730	31 490	38 830	5065	6250	22 530	27 800	4300	5310	19 125	23 620

Note: N = newtons.

prior to welding. Such finishes shall be considered as final steps of the cleaning procedure and necessary conditions shall be specified on the certified weld procedure.

4.2.2 Fitup. Mating parts assembled for welding shall be processed to fit so that before the first and each successive weld is made the surfaces to be joined by the weld are in contact with each other or can be made to contact each other. If the parts are not in contact, use the minimum force necessary to achieve contact but not exceeding the control adjustment requirements of 5.1.5.

4.3 Equipment Requirements

4.3.1 Welding Machines. The welding machine shall consist of a suitable source of electrical energy, a means of adequately cooling the electrodes, and a means of reliably controlling and indicating the relative magnitude of

the current, the welding force, and the time of current flow, to fulfill the requirements specified herein. The force and current controls shall operate so that no current can flow until the welding force is applied by the welding electrodes. Electrode force shall be maintained until weld current is terminated.

4.3.2 Shear Testing Machines. All shear testing machines shall be accurate within $\pm 2\%$ of the indicated reading. The maximum shear testing rate shall not exceed 0.5 in [13 mm] per minute.

4.3.2.1 Stationary Shear Testing Machines. Stationary shear test machines shall be calibrated for accuracy at intervals not to exceed one year.

4.3.2.2 Portable Shear Testing Machines. Portable shear test machines shall be calibrated for accuracy at intervals not to exceed two months.

Table 3
Shear Load Requirements for Spot Weld Sheet Specimens
Group 3 Alloys—Titanium Alloys

Nominal Thickness of Thinner Sheet		Ultimate Strength				Ultimate Strength			
		Above 100 000 psi lb per Spot		689.5 MPa and Above N per Spot		100 000 psi and Below lb per Spot		Below 689.5 MPa N per Spot	
in	mm	Min	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.	Min.	Min. Avg.
0.010	0.25	205	265	910	1180	160	210	710	935
0.012	0.30	275	360	1225	1600	200	260	890	1155
0.016	0.40	400	520	1780	2310	295	385	1310	1710
0.018	0.45	490	635	2180	2825	340	445	1510	1980
0.020	0.50	530	690	2355	3070	390	510	1735	2270
0.022	0.55	610	795	2715	3535	450	585	2000	2600
0.025	0.65	725	945	3225	4205	530	690	2355	3070
0.028	0.70	855	1110	3805	4940	635	825	3380	3670
0.032	0.80	1045	1360	4515	6050	775	1000	3445	4450
0.036	0.90	1255	1630	5580	7250	920	1200	4090	5340
0.040	1.00	1460	1900	6495	8450	1065	1385	4735	6160
0.045	1.10	1795	2340	7985	10 410	1285	1670	5715	7430
0.050	1.30	2125	2760	9450	12 275	1505	1910	6695	8495
0.056	1.40	2550	3320	11 340	14 765	1770	2300	7875	10 230
0.063	1.60	3000	3900	13 345	17 345	2110	2730	9385	12 145
0.071	1.80	3380	4400	15 035	19 570	2395	3115	10 625	13 855
0.080	2.00	3810	4960	16 945	22 060	2700	3510	12 010	15 610
0.090	2.30	4290	5570	19 080	24 775	3040	3955	13 520	17 590
0.100	2.50	4760	6170	21 170	27 445	3380	4395	15 035	19 550
0.112	2.80	5320	6800	23 665	30 245	3785	4925	16 835	21 905
0.125	3.20	5950	7700	26 465	34 250	4220	5490	18 770	24 420

Note: N = newtons.

4.3.3 Jigs and Fixtures. Jigs and fixtures shall be so designed that no welding current can shunt through them instead of passing through the workpieces. All tooling that is required to locate welds or assist in the assembly of welded parts that passes through the magnetic field during the welding operation, should be made of non-magnetic materials insofar as possible.

4.3.4 Maintenance of Equipment. Unless otherwise specified, each item of equipment shall be inspected periodically as recommended by the manufacturer or per RWMA Bulletin 14, *Maintenance Manual for Resistance Welding Machines*. A preventative maintenance procedure shall be established and maintenance records kept.

4.4 Qualification of Welding Machines

4.4.1 Qualification Approval. Qualification shall be performed on each resistance spot or seam welding machine to determine its ability and consistency of operation. The purpose of qualification is to identify and ver-

ify the range of welding for which a machine may be considered capable. Weld conditions shall be documented on a Machine Qualification Test Report. Typical examples of report forms are given in AWS C1.1M/C1.1, *Recommended Practices for Resistance Welding*. Such forms may be modified or expanded as required. After approval is obtained, these reports shall be posted near the machine. Existing machine qualifications made under previous revisions of this specification shall be honored. Existing weld machine qualifications (made to superseded welding specifications) may be accepted as equivalent to this specification at the sole discretion of the Engineering Authority (see Annexes A and B).

4.4.2 Machine Qualification Scope. Machines shall be qualified to meet the weld requirements for the highest classification in a metal group for which it is intended to be used in production. A machine qualified to weld to the requirements of one weld classification in a group shall be automatically considered qualified for lower weld classifications. A spot weld machine qualified for

Table 4
Shear Load Requirements for Spot Welds in Foil

Thickness of Outer Sheet		Standard Number of Spots per inch [25 mm]	Acceptable Range Spots per inch [25 mm] ¹	Group 1 Alloys with an Ultimate Strength of				Group 2 and 3 Alloys with an Ultimate Strength of							
				Minimum Shear Load: Pounds per Linear inch [Newtons (N) per Linear millimeter (mm)]: (S _o) ^{2,3}											
in	mm	(N _o)	R	Up to	Up to	Above	Above	Up to	Up to	90 ksi	620	1034	1034	Above	Above
				56	386	56	386	90	620	to 149	MPa to 150	1034	1034	1034	1034
				ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
0.001	0.03	40	1–50	20	3.5	30	5.3	45	7.9	65	11.3	80	14.0	90	15.8
0.002	0.05	20	1–30	40	7.0	60	10.5	90	15.8	130	22.8	160	28.0	180	31.5
0.003	0.08	12	1–17	65	11.3	100	17.5	150	26.3	205	35.9	260	45.5	300	52.5
0.004	0.10	10	1–14	90	15.8	135	23.6	190	33.3	285	49.9	350	61.3	405	70.9
0.005	0.13	9	1–13	115	20.1	165	28.9	235	41.1	340	59.5	425	74.4	490	85.8
0.006	0.15	7	1–10	125	21.9	185	32.4	275	48.2	380	66.5	475	83.2	540	94.6
0.007	0.18	6	1–8	140	24.5	210	36.8	320	56.0	440	77.0	550	96.3	630	110.3
0.008	0.20	5	1–7	160	28.0	235	41.2	355	62.2	490	85.8	610	106.8	690	120.8

Notes:

1. When the number of spots per linear inch [spots per 25 millimeters] in a production sample or test sample (N_p) is greater than the number specified in the range (R) listed in the table above, the minimum shear load shall remain constant at the value obtained at the top of the range.

The following is given as an example to help calculate the modified minimum shear load requirements:

If the Group 2 (110 ksi) material thickness is 0.002 in [0.05 mm], what would the (S_x) be for various (N_p).

N₀ = 20 spot welds 0.85 N₀ = 17 spot welds 1.15 N₀ = 23 spot welds S₀ = 130 lbs/in [22.8 N/mm]

If N_p is less than 15% of N₀, then S_x = N_p/20 × 1.15 × 130 lbs/in [N_p/20 × 1.15 × 22.8 N/mm]

If N_p is greater than 15% of N₀, then S_x = N_p/20 × 0.90 × 130 lbs/in [N_p/20 × 0.90 × 22.8 N/mm]

N _p	S _x [lbs per inch (in)]	S _x [newtons (N) per millimeter (mm)]	N _p	S _x [lbs per inch (in)]	S _x [newtons (N) per millimeter (mm)]
17	127.1	22.3	23	134.6	23.6
16	119.6	21.0	24	140.4	24.6
15	112.1	19.7	25	146.3	25.7
14	104.7	18.4	26	152.1	26.7
13	97.2	17.0	27	158.0	27.7
12	89.7	15.7	28	163.8	28.7
10	74.8	13.1	29	169.7	29.8
9	67.3	11.8	30	175.5	30.8
8	59.8	10.5	31	175.5*	30.8*
7	52.3	9.2	32	175.5*	30.8*
6	44.9	7.9	33	175.5*	30.8*
5	37.4	6.6	34	175.5*	30.8*

*See Note 1 above.

2. When the actual number of spots per linear inch [number of spots per 25 millimeters] (N_p) is within 15% of the standard spots per inch [spots per 25 millimeters] (N₀), the tabulated minimum shear loads as noted shall apply.
3. When the actual number of spots per linear inch [spots per 25 millimeters] (N_p) differs from the standard spots per inch [spots per 25 millimeters] (N₀) by 15% or greater, but do not exceed the above noted spots per inch range [spots per 25 millimeter range] (R), the applicable modified minimum shear load (S_x) shall be determined by using the formula below.

$$S_x = (S_0) \times (K) \times (N_p/N_0)$$

Where:

(N₀) is defined as the recommended (standard) number of spots per linear inch [spots per 25 millimeters].

(S₀) is defined as the minimum shear load in pounds per linear inch [newtons (N) per millimeter (mm)] of test coupon in the table above.

(N_p) is the actual number of spots per linear inch [spots per 25 mm] on a production part or representative specimen or coupon.

(S_x) is the modified minimum shear load in pounds per linear inch [newtons (N) per millimeter (mm)] of test coupon when the difference of (N_p) is greater than 15% of (N₀).

(K) is the constant shown below:

K = 1.15 when the number of spots per linear inch [spots per 25 mm] in the production weld or test sample (N_p) is less than 15% (0.85N₀) of the standard number of spots per linear inch [spots per 25 mm] required by the table above (i.e., see Note 2). If N_p is less than 0.85N₀, then the modified minimum shear load (S_x) is obtained by using the following formula:

$$S_x = S_0 \times (1.15) \times (N_p/N_0)$$

K = 0.90 when the number of spots per linear inch [spots per 25 mm] in the production weld or test sample (N_p) is greater than 15% (1.15N₀) of the standard number of spots per inch [spots per 25 mm] required in the table above (i.e., see Notes 1 and 2). If N_p is greater than 1.15N₀, then the modified minimum shear load (S_x) is obtained by using the following formula:

$$S_x = S_0 \times (0.90) \times (N_p/N_0)$$

spot welding is also qualified for overlap spot welding. Machines used for Class C foil welding are qualified by establishing a weld procedure certification. Machines qualified to a class for seam welding shall be considered qualified for roll spot welding to the same class.

4.4.2.1 Test Conduct. No maintenance work and no control adjustments are permitted during the welding of a set of test specimens.

4.4.2.2 Test Materials. The test materials for a Group 1 qualification shall be any aluminum alloy commonly used in resistance welded products. For Groups 2 and 3, qualification test material shall be any steel or titanium alloy commonly used in resistance welded products.

4.4.2.3 Test Specimen Requirements. Weld tests listed in Table 5 shall be performed and shall meet applicable acceptance criteria. For each group of alloys, two test sets shall be required—one at the highest (thickest to thickest) end of the thickness range and one at the lowest

(thinnest to thinnest) end of the thickness range for which the qualification is desired.

4.4.2.4 Weld Machine Requalification. Requalification shall be required if the machine is rebuilt or if significant operational changes are made. When machine requalification is required, all procedures shall meet applicable acceptance criteria of 4.7. Changes that do not require requalification of weld machine are:

(1) Change of location within a plant, which maintains the same electrical circuit.

(2) General machine maintenance.

(3) Parts replacement such as electrodes and electrode holders that do not affect the pressure or power characteristics.

4.5 Weld Procedure Certification

4.5.1 Procedure Certification. Tests shall be conducted to determine if a particular machine, in

Table 5
Machine Qualification Test Specimen Requirements

Alloy Group	Class	Specimen	Amount per Set	Visible	Radiographic	Mechanical	Metallographic
Spot Welds—Sheet							
1	A	Figure 1(B)	105 welds	All	All	100 shear	5 microsections
1	B, C	Figure 1(B)	105 welds	All	None	100 shear	5 microsections
2, 3	A	Figure 1(A) or (B)	105 welds	All	All	100 shear	5 microsections
2, 3	B, C	Figure 1(A) or (B)	105 welds	All	None	100 shear	5 microsections
Spot Welds—Foil							
1, 2, 3	A	Figure 3	12 in [300 mm] continuous length of weld	All	All	10 shear	2 microsections
	C	Figure 4			see 4.4.2		
Seam Welds—Sheet							
1, 2, 3	A	Figure 5	24 in [600 mm] continuous length of weld	All	All	None	8 microsections (4 transverse, 4 longitudinal)
	B, C	Figure 5	24 in [600 mm] continuous length of weld	All	None	None	8 microsections (4 transverse, 4 longitudinal)
Seam Welds—Foil							
1, 2, 3	A	Figure 6	12 in [300 mm] continuous length of weld	All	All	Pressure Test	2 microsections (1 transverse, 1 longitudinal)
	C	Figure 4			see 4.4.2		

combination with a specific weld procedure and other specific conditions, will on a given set of materials produce resistance welds that conform to the requirements of this specification. Documentation of these tests will be contained in a completed Certified Weld Procedure Test Report that will be available to the Quality Assurance (QA) personnel. In addition, the weld procedure shall be posted near the machine and be available to machine operators and QA. The following shall be included in the procedure certification and any changes of these critical items outside the allowable limits of 5.1.5 shall require recertification:

- (1) Pressure
- (2) Electrode type (geometry and material class)
- (3) Weld settings (time, current, number of cycles)
- (4) Surface preparation
- (5) Weld overlap (RSEW)
- (6) Travel speed (RSEW)

4.5.2 Procedure Certification Test Reports. For each machine and each combination of relevant material conditions (such as alloy, temper, surface conditions, and thickness combinations), the contractor will determine the effective weld machine settings for test and production parts. The conditions and parameters shall be formally entered on a weld procedure before the test welding. Typical examples of report forms are given in Annexes A and B. These shall be modified or expanded as required. After acceptance, production setups shall be made to the certified procedure, with the variation of 5.1.5 allowed.

4.5.2.1 Examination Data. Certification test report shall include the shear strength data on each weld, their average, the numbers of specimens with shear values outside of the set limits, and the nugget diameters and penetration of each metallographic specimen. The examination page shall have a formal indication of the success or failure to meet the certification criteria applicable to the subject material combination.

4.5.3 Test versus Production Conditions. The purpose of certification is to replicate the results expected on production components; therefore, test conditions for certification shall correspond with expected production conditions. These conditions include, but are not limited to: Welding over or adjacent to existing resistance or fusion welds, minimum edge distance, overlap distance, surface preparation (including shot peening, chemical milling, or other surface preparation), and heat treatment.

4.5.4 Procedure Certification Test Specimen Configuration and Examination Requirements. Tests shall be as specified in Tables 6 through 9 and as shown in Figures 1 through 6. Welds shall be located within ± 0.060 in [± 1.5 mm] of specimen centers. Specimen size tolerance shall be ± 0.060 in [± 1.5 mm].

4.5.5 Thickness Latitudes. Thickness combinations falling within the following limits shall not require separate certified weld procedures provided that the certified nugget size average can be reproduced with a weld heat (current) setting that lies within $\pm 10\%$ of the value established by the original certification procedure; all other conditions being the same.

Table 6
Procedure Certification Specimen and Examination Requirements
Spot Welds—Sheet

Type	Alloy Group	Class	Specimen	Number of Welds	Examination			
					Visible 4.7.1	Radiographic 4.7.2	Mechanical 4.7.4	Metallographic 4.7.3
Isolated or Roll Spot	1	A	Figure 1(A) or (B)	25	All	All	20 Shear	5 microsections
		B	Figure 1(A) or (B)	15	All	None	10 Shear	5 macrosections
		C	Figure 1(A) or (B)	5	All	None	3 Shear	2 macrosections
	2, 3	A	Figure 1(A) or (B)	13	All	All	10 Shear	3 microsections
		B	Figure 1(A) or (B)	8	All	None	5 Shear	3 macrosections
		C	Figure 1(A) or (B)	5	All	None	3 Shear	2 macrosections
Close Space	1, 2, 3	A	Figure 2	20	All	All	None	10 microsections
		B	Figure 2	10	All	None	None	5 macrosections
		C	Figure 2	3	All	None	None	3 macrosections

Table 7
Procedure Certification Specimen and Examination Requirements
Spot Welds—Foil

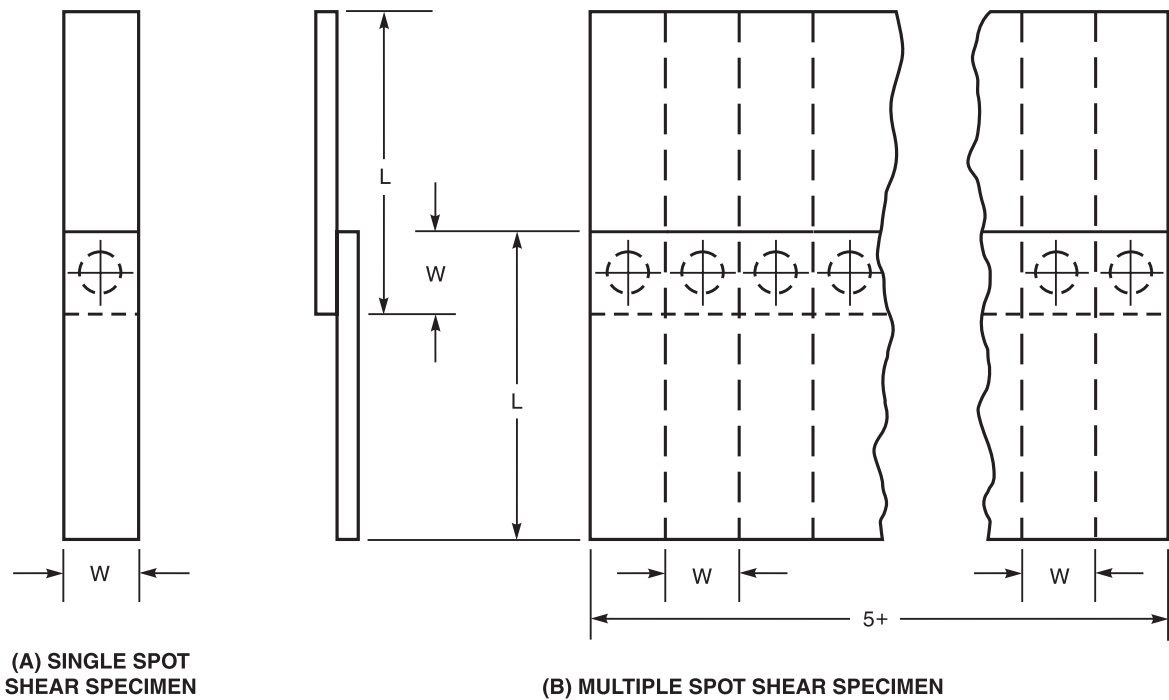
Alloy Group	Class	Specimen Configuration	Length of Weld	Examination			
				Visible	Radiographic	Mechanical	Metallographic
1, 2, 3	A	Figure 3	12 in [300 mm] continuous length of weld	All	All	5 Shear and Peel 3 in [75 mm]	2 in [50 mm]
	C	Figure 4	12 in [300 mm] continuous length of weld	All	None	Peel (10 in [250 mm] minimum length)	None

Table 8
Procedure Certification Specimen and Examination Requirements
Seam Welds—Sheet

Alloy Group	Class	Specimen Configuration	Length of Weld	Examination		
				Visible 4.7.1	Radiographic 4.7.2	Metallographic 4.7.3
1, 2, 3	A	Figure 5	12 in [300 mm] continuous length of weld	All	All	4 transverse microsections (Tr) 4 longitudinal microsections (Lo)
	B	Figure 5	12 in [300] mm continuous length of weld	All	None	4 transverse microsections (Tr) 4 longitudinal microsections (Lo)
	C	Figure 5	12 in [300 mm] continuous length of weld	All	None	1 transverse macrosections (Tr) 2 longitudinal macrosections (Lo)

Table 9
Procedure Certification Specimen and Examination Requirements
Seam Welds—Foil

Alloy Group	Class	Specimen Configuration	Length of Weld	Examination			
				Visible 4.7.1	Radiographic 4.7.2	Mechanical 4.7.4	Metallographic 4.7.3
1, 2, 3	A	Figure 6(A)	12 in [300 mm] continuous length of weld	All	All	Pressure Test 4.7.4.5(1)(a)	1 in [25 mm]
	C	Figure 4	12 in [300 mm] continuous length of weld	All	None	Peel 4.7.4.4 (10 in [250 mm] minimum length)	1 in [25 mm]

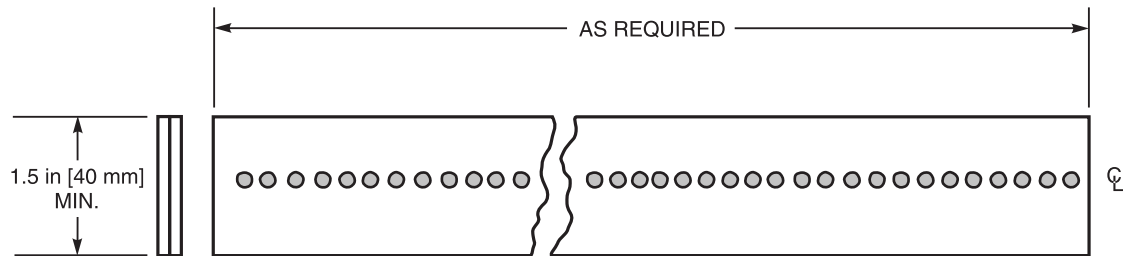


Notes:

1.	Nominal Thickness of Thinner Sheet, in	W in, min.	Nominal Thickness of Thinner Sheet, mm	W mm, min.
	Over 0.008 to 0.030	0.68	Over 0.20 to 0.75	17.0
	Over 0.030 to 0.100	1.00	Over 0.75 to 2.50	25.0
	Over 0.100 to 0.130	1.25	Over 2.50 to 3.20	32.0
	Over 0.130	1.50	Over 3.20	38.0

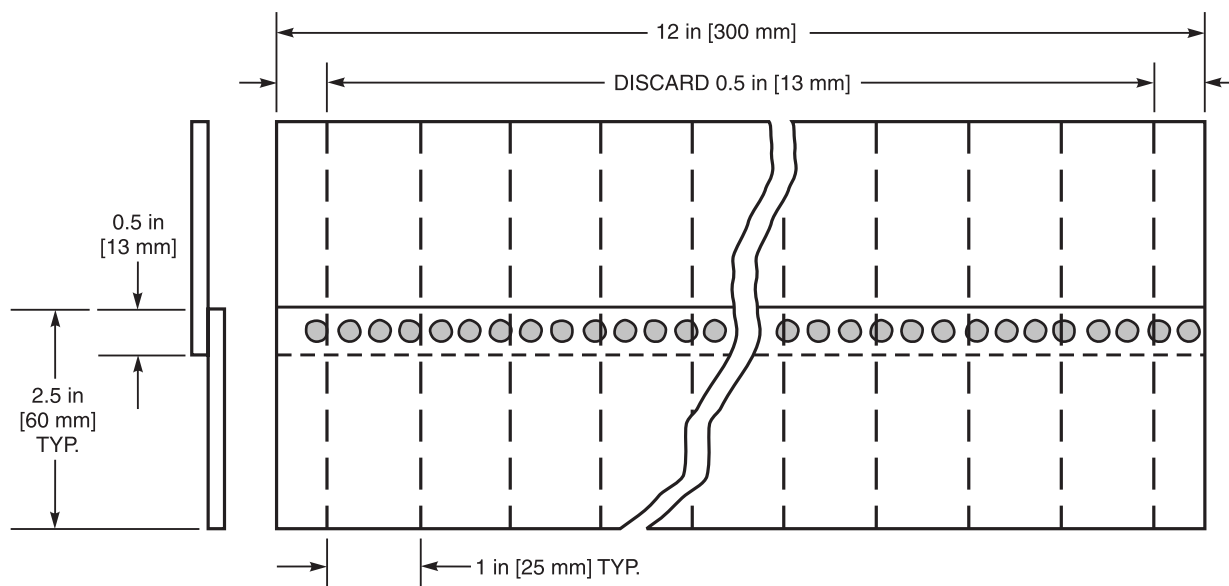
2. L shall not be less than 4W.
3. Figure 1(B) shall be made of 5 specimens or more

Figure 1—Spot Welds in Sheet



- Notes:
- 1. Spot spacing shall be in accordance with the subject production part.
 - 2. Specimen lengths shall be as required.
 - 3. See Clause 3, Terms and Definitions for definition of close spaced welds.

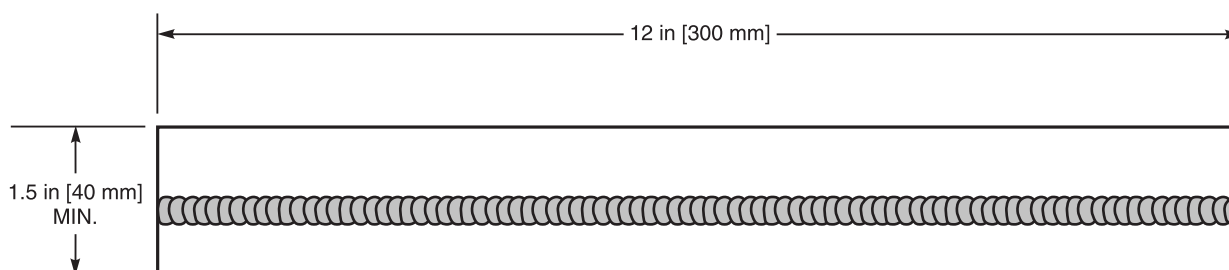
Figure 2—Close Spaced Spot Welds in Sheet



Notes:

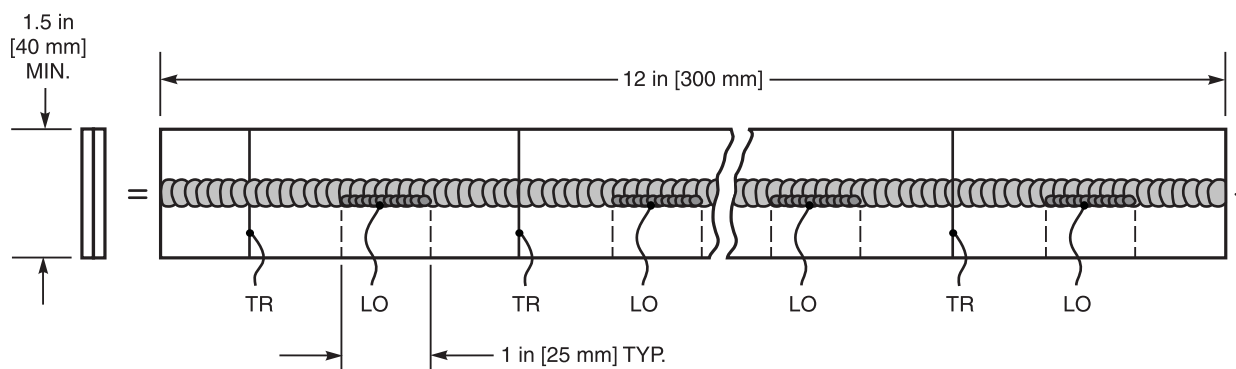
1. Spot spacing shall be in accordance with Table 4 (Standard Spots per in or mm) for qualification, and in accordance with the subject production part of certification.
2. For Class A, select at random five 1 in or 25 mm specimens for mechanical shear tests, three specimens for peel tests, and two specimens for metallographic examination.

Figure 3—Spot Welds in Foil for Class A Welds



Note: Spot spacing shall be in accordance with subject production parts.

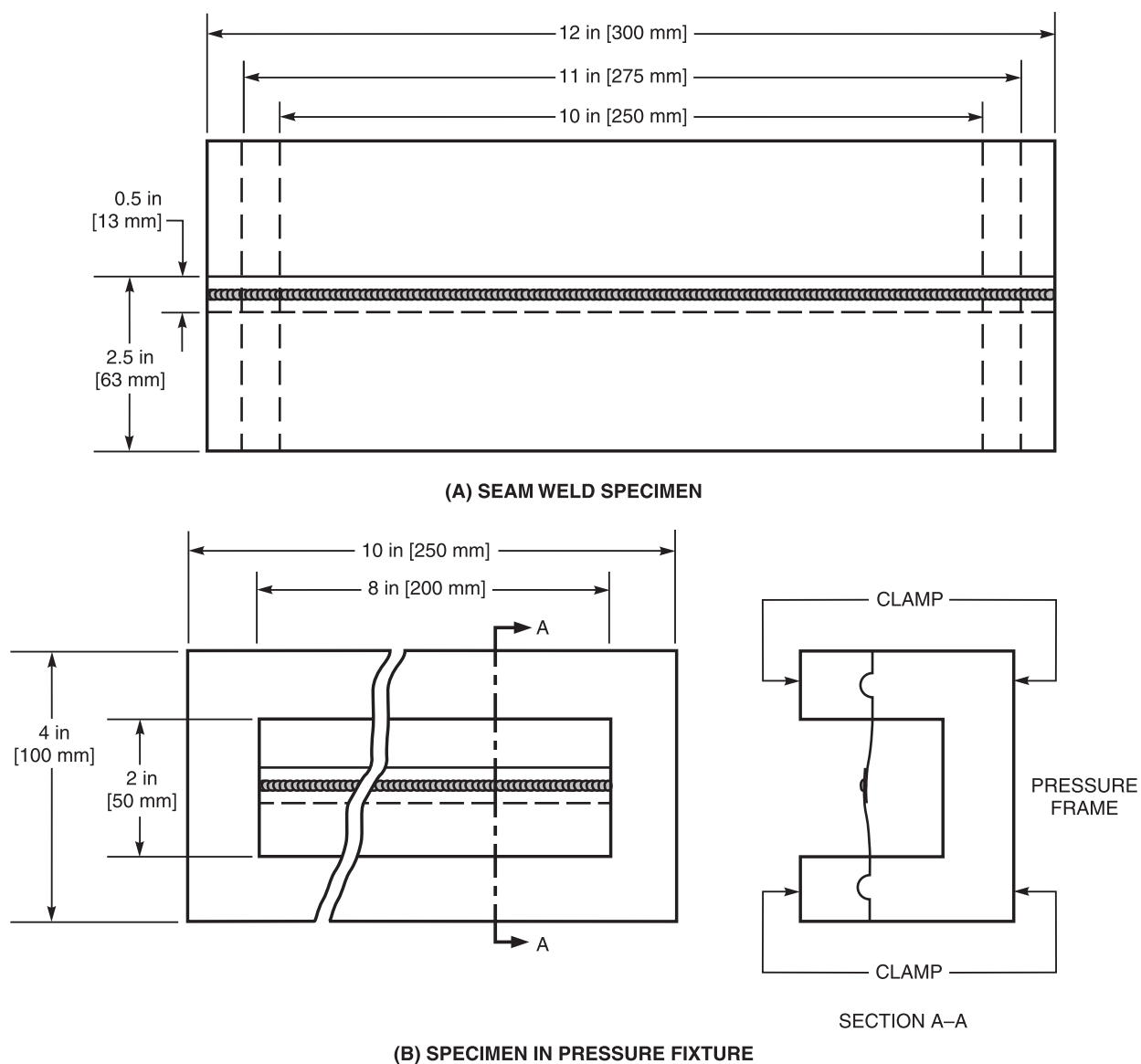
Figure 4—Spot and Seam Welds in Foil, Peel Specimen for Class C Welds



Note: Remove metallographic sections in the order above, but examine from random positions.

Lo—Longitudinal section
Tr—Transverse section

Figure 5—Seam Welds in Sheet



Note: After welding, discard the outside 0.5 in [12 mm] strips. Take a longitudinal metallographic section from the next 0.5 in or 13 mm strip on one end and a transverse section from the other end. Then mount the 10 in [250 mm] remainder in the pressure fixture and test.

Figure 6—Pressure Test of Seam Welds in Foil for Class A Welds

(1) *Foil*. The variation in thickness (with regard to the original procedure) of either outer sheet is within ± 0.001 in [± 0.03 mm] and the variation in summed thickness (with regard to the original procedure) of the combination is within ± 0.003 in [± 0.08 mm].

(2) Sheet (outer) up to 0.040 in [1.02 mm], inclusive:

(a) The variation in thickness of either outer sheet is within ± 0.004 in [± 0.10 mm].

(b) The variation in the summed thickness of the combination is within ± 0.006 in [± 0.15 mm].

(3) Sheet (outer) over 0.040 in [1.02 mm]:

(a) The variation in thickness of either outer sheet is within $\pm 10\%$ for Group 1 alloys, or $\pm 20\%$ for Groups 2 and 3 alloys and

(b) The variation in the summed thickness of the combination is within $\pm 10\%$.

4.5.6 Design Allowable Certification. A weld procedure shall be certified to produce the minimum strength, nugget size or quality requirement specified on the engineering drawing and this specification. This certification method is limited to spot welds in sheet, except for close spaced spot welds. Certification results shall be entered on the test report, which includes the settings used to weld the coupons. Weld settings shall not be adjusted during the welding of the certification coupons. After certification acceptance, production setups shall be allowed to deviate from the weld procedure as allowed by 5.1.5.

4.5.6.1 Design Allowable Certification for Strength. When a minimum strength is specified on the engineering drawing, the following shall be used to complete the weld procedure certification: The certification report shall state: "These conditions certify a strength value of ____." The number entered shall be the value of the lowest strength specimen in 300 welds for Class A, 180 welds for Class B, and 50 welds for Class C. As reliability requirements warrant, the required number (e.g., 300) may be changed by the cognizant engineering authority through drawing notes or design specifications. Weld coupon configuration shall be as specified for standard certification method.

4.5.6.2 Design Allowable Certification for Nugget Size. When a minimum nugget size is specified on the engineering drawing, the following shall be used to complete the weld procedure certification: The certification report shall state: "These conditions certify a nugget value of ____." The number entered shall be the value of the smallest nugget size measured in 30 welds for Class A, 20 welds for Class B, and 10 welds for Class C. As reliability requirements warrant, the required number (e.g., 30) may be changed by the cognizant engineering authority through drawing notes or design specifications. Weld coupon configuration shall be as specified for standard certification method.

4.5.7 Procedure Recertification. Recertification shall be required if the machine is rebuilt or if significant operational changes are made to it as specified in 4.5.1. An existing weld schedule need not be recertified for another contract or designs provided all material conditions are equal. Existing certifications made under superseded revisions of this specification shall be honored. However, recertification of a specification may be required at any time if the procuring activity doubts for any reason the ability of a machine to make welds satisfactorily with the original certification conditions. Changes that do not require recertification of weld procedure are:

(1) Change of location within a plant, which does not involve a change in electrical circuit

(2) General machine maintenance

(3) Electrode replacement

4.5.8 Existing Procedure Certifications. Existing procedure certifications may be accepted as equivalent to the requirements of this specification at the sole discretion of the Engineering Authority.

4.6 Production Verification Testing. Periodic tests shall be conducted to determine if a particular machine, in combination with a specific weld procedure and other specific conditions used during production, produces resistance welds that conform to the requirements of this specification. These tests shall conform to 5.2 of this specification. Documentation of these tests shall be contained in an individual register (logbook) for each resistance welding machine. In addition, the register shall be located in the resistance welding work area and be available for review.

4.7 Acceptance Criteria. This subclause defines weld acceptance criteria for machine qualification, procedure certification, and production conducted under the standard certification method. For design allowable certification, the engineering authority shall specify on the engineering drawing which tests to perform and appropriate acceptance criteria.

4.7.1 Visible Criteria

4.7.1.1 Visual Discontinuities in Test Specimens. Qualification, certifications, and production witness test specimens shall be smooth, free of cracks, tip-pickup, pits, and other flaws that indicate that the welds were made with dirty electrodes, improperly prepared surfaces, or excessive heat and undue force.

4.7.1.2 Visual Discontinuities in Parts or Lot. Visual discontinuities are limited in quantity by Table 10. Parts or lots with discontinuities exceeding the quantity specified in Table 10 shall be rejected.

4.7.1.3 Sheet Separation. Separation between members is excessive when it exceeds (1) or (2) (see below) measured at a distance as shown in Figure 7. Excessive separation is not acceptable on test specimens. Excessive separation of welds sampled shall not exceed 3% for Class A or 10% for Class B and C of production parts or lots.

(1) Greater than 15% of the summed thickness of the outer sheet and the one adjacent to it, or 0.006 in [0.15 mm], whichever is greater; or

(2) Greater than 0.003 in [0.08 mm] between foil and the member adjacent to it.

4.7.1.4 Surface Indentation. Indentations (see Figure 8) are not acceptable if their depth exceeds the

Table 10
Visible External Imperfections for Production Parts

Nature of Weld Imperfections	Acceptable Percentage of Welds Exhibiting Imperfection		
	Class A	Class B	Class C
Cracks open to surface	0%	0%	5%
Edge bulge cracks ^a	0%	0%	10%
Surface pits over 0.063 in [1.60 mm] dia.	0%	0%	10%
Surface pits under 0.063 in [1.60 mm] dia.	3%	5%	10%
Flash and surface fusion	3%	5%	10%

^a Not acceptable on any test specimens.

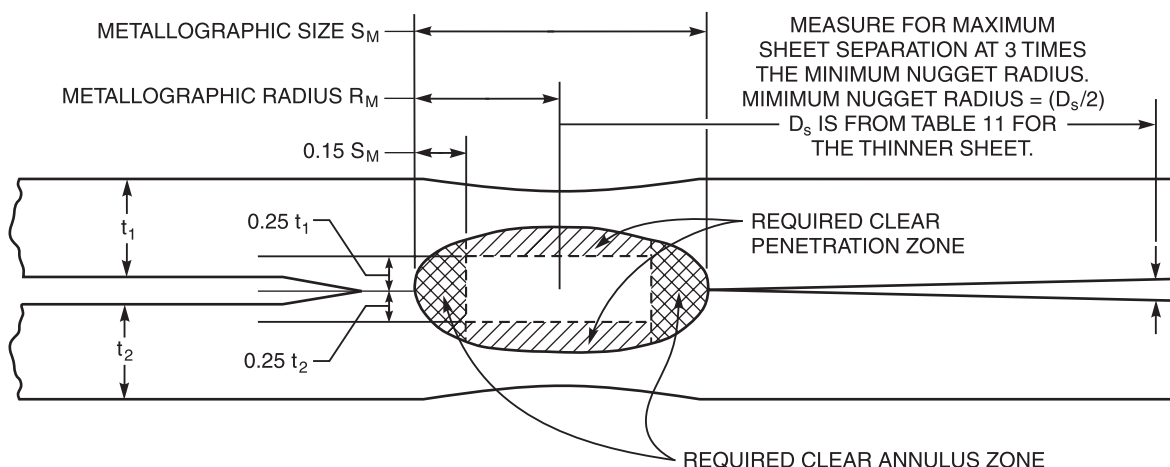
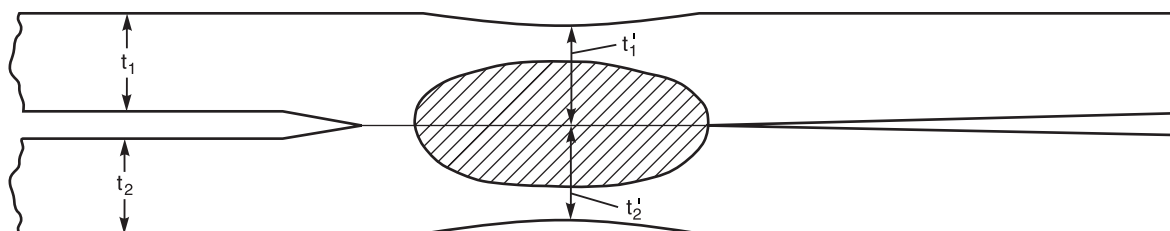


Figure 7—Nomenclature for Metallographic Spot Weld Sections and Seam Weld Transverse Sections



INDENTATION = $t_1 - t_1'$ FOR SHEET WITH THICKNESS OF t_1 OR $t_2 - t_2'$ FOR SHEET WITH THICKNESS t_2

Figure 8—Surface Indentation

following limitations (where t is the thickness of the indented outer member). Excessive indentation is not acceptable on test specimens. Excessive indentation of welds sampled shall not exceed 3% of measured welds for Class A or 10% for Class B and C of production parts or lots.

(1) Sheet; Class A and B: 10% t or 0.005 in [0.13 mm]; whichever is greater.

(2) Sheet; Class C: 20% t or 0.005 in [0.13 mm]; whichever is greater

(3) Foil; Class A: 30% t

(4) Foil; Class C: 40% t

(5) When aerodynamic smoothness is a requirement, the outside indentation shall not exceed 0.004 in [0.10 mm] on sheet and 20% of foil thickness.

4.7.2 Radiographic Acceptance Criteria. All Class A test welds shall be examined for compliance with the following:

4.7.2.1 All welds shall be free of cracks and expulsion.

4.7.2.2 No pore or instance of incomplete fusion shall have a linear dimension greater than 15% of the minimum nugget size as specified in Table 11.

4.7.2.3 No pore or instance of incomplete fusion shall extend into the outer 15% of the nugget radius which is the required clear annulus as shown in Figure 9.

4.7.2.4 Porosity or incomplete fusion in the nugget shall not have an aggregate area of greater than 5% in Group 1 alloys, or 10% in Group 2 and Group 3 alloys.

4.7.2.5 The nuggets shall be consistent in size and generally round in shape. Welds that exhibit incomplete fusion shall not be acceptable.

4.7.3 Metallographic Criteria. The metallographic examination and acceptance criteria are applicable to qualification, standard certification, and production witness specimens. Examination and acceptance criteria apply to production parts in the event of a test. Metallographic nomenclature is shown in Figure 7 and Figure 10. Test specimens shall be cross sectioned, polished, and etched as closely as possible through the center of the weld for metallurgical examination. Class A welds shall be examined as a microsection at a magnification of 20X to a maximum of 50X. Classes B and C welds shall be examined as a macrosection at 10X magnification.

4.7.3.1 Internal Discontinuities. Inclusions, porosity, and instances of incomplete fusion are acceptable within the nugget of metallographic sections, unless the nugget contains:

(1) A discontinuity within 15% of the nugget's radius from the edge of the nugget.

(2) A discontinuity extending into an outer sheet more than 25% of the sheet thickness for Class A and Class B welds.

Table 11
Nugget Size (All Groups)

Nominal Thickness of Thinner Sheet		Nugget Size (D_s)		Nominal Thickness of Thinner Sheet		Nugget Size (D_s)	
in	[mm]	in	[mm]	in	[mm]	in	[mm]
0.001	[0.03]	0.010	[0.25]	0.036	[0.90]	0.150	[3.81]
0.002	[0.05]	0.015	[0.38]	0.040	[1.00]	0.160	[4.06]
0.003	[0.08]	0.020	[0.50]	0.045	[1.10]	0.170	[4.32]
0.004	[0.10]	0.030	[0.76]	0.050	[1.20]	0.180	[4.57]
0.005	[0.12]	0.035	[0.89]	0.056	[1.40]	0.190	[4.82]
0.006	[0.16]	0.040	[1.02]	0.063	[1.60]	0.200	[5.08]
0.007	[0.18]	0.045	[1.14]	0.071	[1.80]	0.210	[5.33]
0.008	[0.20]	0.050	[1.27]	0.080	[2.00]	0.225	[5.72]
0.010	[0.25]	0.060	[1.52]	0.090	[2.30]	0.240	[6.10]
0.012	[0.30]	0.070	[1.78]	0.100	[2.50]	0.250	[6.35]
0.016	[0.40]	0.085	[2.16]	0.112	[2.80]	0.260	[6.60]
0.018	[0.45]	0.090	[2.29]	0.125	[3.20]	0.280	[7.11]
0.020	[0.50]	0.100	[2.54]	0.140	[3.60]	0.300	[7.62]
0.022	[0.55]	0.105	[2.68]	0.160	[4.10]	0.320	[8.13]
0.025	[0.65]	0.120	[3.05]	0.180	[4.60]	0.340	[8.64]
0.028	[0.70]	0.130	[3.30]	0.190	[4.80]	0.350	[8.89]
0.032	[0.80]	0.140	[3.56]	—	—	—	—

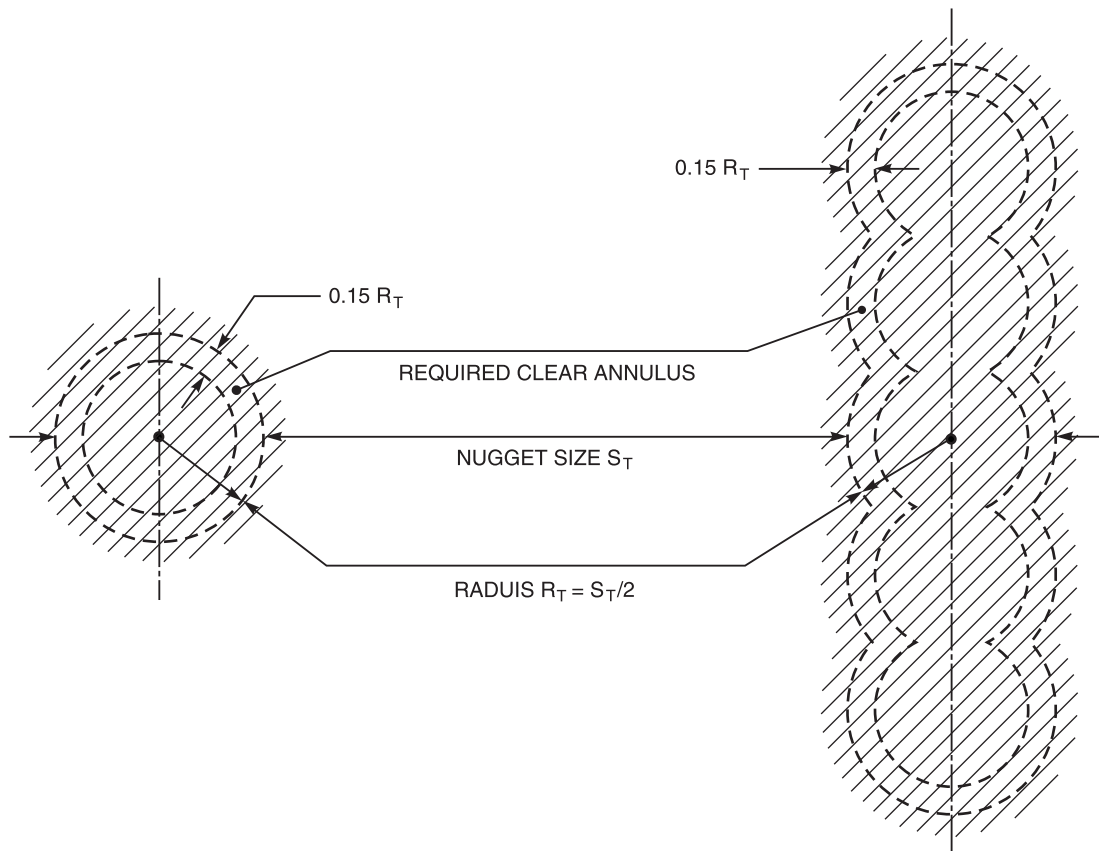


Figure 9—Nomenclature Diagram of Spot and Seam Weld Radiographs

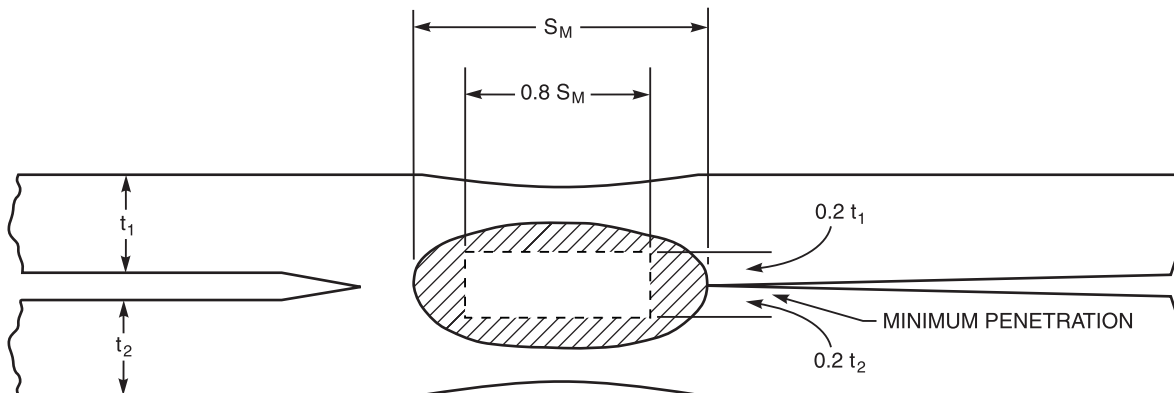


Figure 10—Minimum Penetration

(3) A discontinuity extending into an outer sheet more than 50% of the sheet thickness for Class C welds.

(4) A discontinuity with its largest dimension exceeding 10% for Class A welds, 15% for Class B welds, and 25% for Class C welds of the nugget diameter.

(5) All welds shall be free of cracks.

(6) For certification and qualification, Class A and Class B weld test specimens shall not exhibit expulsion or the unacceptable discontinuities of 4.7.3.1(1), (2), (3), (4), and (5).

4.7.3.2 Excessive Discontinuities. For production witness specimens or parts sectioned for routine or post production tests, if the discontinuities, insufficient penetration or excessive penetration exceed the percentage of the test lot permitted by Table 12, then all work completed since the most recent acceptance test or through the end of the shift, whichever occurs first, shall be rejected. The provisions of 5.1.5, 5.3.3, and 5.3.4 shall be continuously applied as a referee.

4.7.3.3 Incomplete Fusion. Whenever a metallographic section of a production witness specimen or part reveals incomplete fusion, welding shall be stopped and parts made after the last acceptable group of witness specimens shall be subjected to material review procedures.

4.7.3.4 Penetration. At least 80% of the measured nugget diameter shall exceed the minimum penetration requirement. Maximum penetration shall be measured at the maximum extent into the outer sheets (see Figure 10).

(1) *Minimum Penetration.* Penetration shall comply with the following:

(a) In two equal-thickness members, penetration shall exceed 0.2 times the thickness of each member into each member.

(b) In two unequal-thickness members, penetration shall exceed 0.2 times the thickness into each respective member.

(c) In three or more thicknesses, penetration into the outer members shall exceed 0.2 times the thickness of each outer member.

(2) *Maximum Penetration.* Penetration shall not exceed:

(a) *Group 1 Materials.* 80% for Class A and Class B welds, 90% for Class C welds.

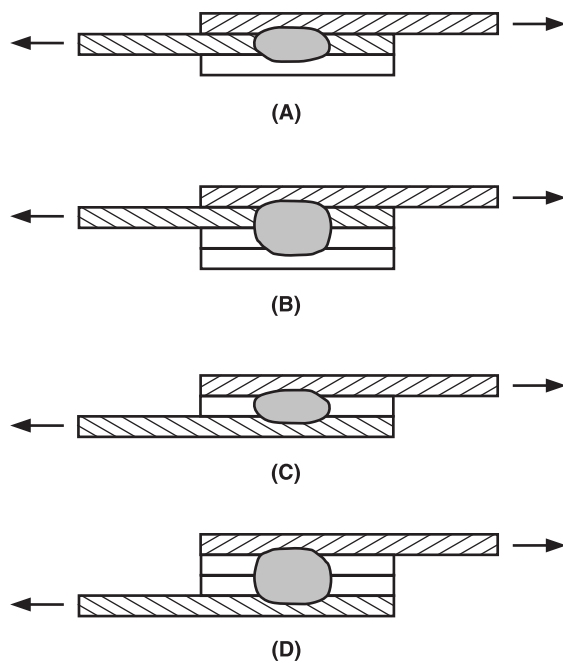
(b) *Group 2 and 3 Materials.* 90% for all classes.

4.7.3.5 Nugget Size. The minimum nugget size for spot welds shall be those specified in Table 11. In welds of two members of unequal thickness, the thinner member shall determine the required minimum nugget size at the faying surface. In three or more thickness welds, the thinner of the two outer members shall determine the minimum nugget size from Table 11, unless load-carrying members are identified for the certification combinations, such as in Figures 11(C) and 11(D). In this case, the lesser thickness of the two load carrying members shall identify and be the determinant of minimum nugget size for each interface lying between them. Each nugget shall be measured at the subject interface plane on the metallographic section through the center of the nugget. Class A foil weld size may be measured by the size of the fractured peel specimen instead of a metallographic section, when the foil is an outer member.

(1) *Seam and Intermittent Welds.* Seam and intermittent weld nugget size shall be determined by transverse sections and shall comply with the spot weld size requirements listed in Table 11. Seam and intermittent welds shall exhibit uniform overlap in a longitudinal section of not less than 25% of the nugget size as measured in a transverse section.

Table 12
Internal Metallographic Imperfections for Production Witness Samples or Sectioned Parts

Nature of Weld Imperfections	Acceptable Percentage of Welds Exhibiting Imperfection		
	Class A	Class B	Class C
Porosity, Cracks, Incomplete-Fusion (4.7.3.1)	0%	6%	N/A
Insufficient Penetration [4.7.3.4(1)]	0%	3%	N/A
Excessive Penetration [4.7.3.4(2)]	0%	3%	N/A
Insufficient Size (4.7.3.5)	0%	3%	N/A



Note: Arrows indicate loaded members.

Figure 11—Shear Tests of Three or More Thicknesses

(2) *Machine Qualification and Procedure Certification.* The nugget size of all required metallographic sections will be measured for each interface plane and recorded. From the values of each plane the average size and the lowest size in the test group will be entered on the test record form. The peel test of Class A foils, in addition to Table 11, also requires that the largest nugget size not be more than 120% of the smallest nugget size.

(3) *Production Witness Specimens*

(a) Nugget size measurement shall be the process control method for close spaced spot welds, as defined in Table 13, and for seam welds and may be an alternate method to spot shear tests of sheet [shear tests of production witness specimens, 4.7.4.1(2)]. Size shall be measured on metallographic sections. Nugget size can also be measured on peel specimens when approved by the Engineering Authority.

(b) Class A welds shall be within $\pm 10\%$ of the average nugget size recorded for procedure certification or no more than 0.020 in [0.50 mm] smaller than the certification average, when the average is larger than 0.200 in [5.08 mm]. Class B welds shall be within $\pm 20\%$ of the procedure certification nugget size average.

(c) All welds shall meet the minimum nugget requirements as specified in Table 11.

4.7.4 Mechanical Criteria

4.7.4.1 Spot Welds—Sheet

(1) Procedure Certification and Machine Qualification

(a) *Minimum.* Each and every shear test specimen, such as Figure 1(A) or Figure 1(B) (see 4.5.4), shall equal or exceed the minimum strength required by Tables 1 through 3.

(b) *Average.* The average shear strength shall equal or exceed the applicable minimum average strength specified in Tables 1 through 3.

(c) *Consistency—Group 1 Materials.* For Class A and Class B welds, 90% of the number of welds tested shall have shear strength values within 12.5% of the lot average. Each of the remaining 10% of the welds shall have shear strength values within 25% of the lot average. All Class C welds shall be within 35% of the lot average.

(d) *Consistency—Group 2 and 3 Materials.* For Class A and Class B welds, each of 90% of the number of welds tested shall have shear strength values within 10% of the lot average. Each of the remaining 10% of the welds shall have shear strength values within 20% of the lot average. All Class C welds shall be within 33% of the lot average.

(2) *Production Witness Specimens.* The spread between the lowest and highest specimen shall be less than 35% of the applicable production test lot average.

(a) *Class A.* The test lot average shall be not less than 90% of the certification average and no weld shall be less than the applicable minimum value shown in Tables 1 through 3.

(b) *Class B and Class C.* The test lot average shall be not less than the applicable value shown in Tables 1 through 3.

4.7.4.2 Design Allowable Certification for Sheet

(1) *Minimum.* The value of the lowest specimen in the test lot shall exceed the specified design minimum.

(2) *Average.* The test lot average (A_c) shall be recorded on the certification report form.

(3) *Consistency.* 95% of the number of specimens tested shall have values greater than 0.875 times the test lot averages (A_c).

Table 13
Production Witness Welds, Test Lots

Class	Specimen	Amount of Weld in Test Lot ^c	Examination		
			Mechanical ^{a, c}		Metallographic Requirement ^b
			Test	Requirement	
Spot Welds—Sheet					
A	Figure 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
B	Figure 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
C	Figure 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
Spot Welds—Sheet—Close Space					
A	Figure 2	3 Weld		None	4.7.3
B	Figure 2	3 Weld		None	4.7.3
C	Figure 2	3 Weld		None	4.7.3
Spot Weld—Foil					
A	Figure 3	3 weld	Peel	4.7.4.4(2)(a)	4.7.3
C	Figure 4	1 in [75 mm]	Peel	4.7.4.4(2)(b)	4.7.3
Seam Welds—Sheet					
A	Figure 5	3 in [75 mm]		None	4.7.3
B	Figure 5	3 in [75 mm]		None	4.7.3
C	Figure 5	3 in [75 mm]		None	4.7.3
Seam Welds—Foil					
A	Figure 4	3 in [75 mm]	Peel	4.7.4.5(2)(a)	4.7.3
C	Figure 4	3 in [75 mm]	Peel	4.7.4.5(2)(b)	4.7.3

^a See 5.2.1 and 5.2.2.

^b Seam welds shall require metallographic evaluation of 2 transverse and 1 longitudinal sections.

^c Default examination for production witness welds is metallographic, but when mechanical tests are used for examination of witness production weld compliance of spot welds established by the standard certification procedure, then three welds will be added for metallographic examination (4.7.3) to the preproduction lot for Class A and Class B welding, and three welds for metallographic examination will be added every fourth routine lot for Class A.

4.7.4.3 Production Witness Specimens—Design Allowable Certification for Sheet

(1) *Average.* The average strength or nugget size of the production test lot shall be not less than 0.94 times Ac for Class A welds, and not less than 0.90 times Ac for Class B and Class C welds, without consideration of the provisions of 5.3.4.

(2) *Consistency.* No specimen in a group of three consecutive test lots (nine specimens) for Class A welds or two consecutive test lots (six specimens) for Class B and Class C welds may be less than 0.88 times Ac for Class A welds, 0.83 times Ac for Class B welds, and 0.80 times Ac for Class C welds.

4.7.4.4 Spot Welds—Foil (Less Than or Equal to 0.008 in [0.20 mm])

(1) Procedure Certification and Machine Qualification

(a) *Class A.* Each shear specimen shall equal or exceed the applicable values in Table 4. In addition, the peel test run shall cause a button (plug) pull-out failure in at least 95% of the welds tested. The remaining 5% may fail at the interface plane, but the cleavage in each case shall be of a fused zone that is at least 80% of the average button size.

(b) *Class C.* Peel tests shall cause a button pull-out failure in at least 85% of the welds tested. The

remaining 15% may fail at the interface plane, but there shall be evidence of fusion at the interface in each case.

(2) **Production Witness Specimens.** The required test lot shall be tested for compliance with the peel requirements only of 4.7.4.4(1)(a) for Class A welds or 4.7.4.4.(1)(b) for Class C welds.

(a) *Class A.* The weld specimen shall be tested in peel. Failure shall be by tearing of the metal adjacent to the weld nugget for more than 95% of the weld length. The remaining portion of the weld length may fail by fracture across the faying plane, but the smallest nugget size (fusion) shall be not less than 0.80 times the average nugget size.

(b) *Class C.* The weld specimen shall be tested in peel and shall meet the requirements of 4.7.4.4 (1)(b).

4.7.4.5 Seam Welds—Foil

(1) **Procedure Certification and Machine Qualification Requirements (Acceptance Criteria)**

(a) *Class A.* A pressure test specimen as shown in Figure 6 (see 4.5.4) shall show no evidence of leakage through the joint while under a pressure greater than (1) 25% of the specimen burst pressure for qualification, or (2) the greatest pressure to be experienced by the weld in its assigned service, as noted on the applicable drawing for certification. Examination for leaks shall begin not less than one minute after the specimen has reached its specified load. After the leak test, the specimen shall be loaded to destruction. Failure shall occur in the metal adjacent to the weld. Failure by cleavage fracture through the weld shall be cause for rejection.

(b) *Class C.* The weld specimen shall be tested in peel. Failure shall occur by tearing of the metal adjacent to the weld nugget for more than 85% of the weld length. The remaining portion of the weld length may fail by fracture across the weld in the faying plane, but continuous fusion shall be evident.

(2) **Production Witness Specimens (Acceptance Criteria)**

(a) *Class A.* The weld specimen shall be tested in peel. Failure shall be by tearing of the metal adjacent to the weld nugget for more than 95% of the weld length. The remaining portion of the weld length may fail by fracture across the faying plane, but the smallest nugget size (fusion) shall be not less than 0.80 times the average nugget size

(b) *Class C.* The weld specimen shall be tested in peel and shall meet the requirements of 4.7.4.5(1)(b).

4.7.4.6 Unusual Specimen Configuration. Specimens of unusual configuration shall be tested so as to stress the load carrying members, as specified on the

applicable drawing or part specification. Some examples of joints with three or more members are shown in Figure 11. The strength requirements of such combinations shall be determined from Tables 1 through 3 and Table 4 based upon the requirement for the thinner loaded member unless otherwise specified on the applicable drawing or part specification. Test specimen members not loaded (unshaded) may be coupons laid crosswise or parallel to the load, may be short pieces, or may be positioned out of the way of the test fixture. The minimum width of the specimen and overlap shall be based on the thickness of the thinnest loaded member.

5. Quality Assurance Provisions

5.1 Production Quality Control

5.1.1 Procedures. Qualified personnel in each plant shall be responsible for the control of machine settings and all welding procedures. Certified procedures shall be available for examination by any authorized inspector at any time.

5.1.2 Weld Location. Welds shall be located as specified on the engineering drawing or applicable document.

5.1.3 Test Specimens. Certification and production witness specimens shall conform to the production parts they represent with respect to material, thickness, overlap, configuration, and surface condition or preparation. Production witness specimens shall be run with production weld conditions using either certification specimens or a simulation of the production part. When production conditions exist that were not applied during certification, but cause machine settings to differ from certification settings so as to exceed the permitted latitude (5.1.5), the certification shall be run again with the subject critical production conditions included. Examples of such production conditions are, but are not limited to, magnetic material in the machine throat, curvature of the part, spot spacing and part (overlap) width.

5.1.4 Surface Resistance. A daily check shall be made of the surface resistance in microohms for Group 1 (Class A) welds when running production parts. A minimum of five readings shall be made on samples typical of the material being welded and its surface condition and preparation. The details of the method of obtaining the surface resistance measurement shall be the same as those used for the certification of welding procedures or cleaning procedures and the values of the surface resistance shall not exceed the limits of consistency and maximum values established at that time.

5.1.5 Control Adjustments. The settings may be varied by $\pm 5\%$ from the established certification values, or

by $\pm 10\%$ when only one setting is adjusted. Rounded to the nearest unit this shall be the permitted procedure adjustment. Production welds shall be made within $\pm 5\%$ of the settings used on witness specimens. If satisfactory welding cannot be maintained within these limits of adjustment, welding shall be stopped and the machine shall be checked for faulty operation. If it can be shown that conditions other than those controlled by the certified welding procedure were the cause of the faulty welding and with their correction the original certified welding procedure is capable of producing acceptable welds, the establishment of a new certified welding procedure will not be required. For Class A welds, also see 5.3.4.

5.2 Production Witness Specimens. The following specimens shall accompany the welding of production parts. These specimens will duplicate the production parts in all conditions controlled by the certified welding procedure and the drawing. Results of these tests shall be maintained in an individual register (logbook) by each welding machine.

5.2.1 Test Lots. Test lots of witness specimens for production parts shall be as noted below.

Each test lot shall consist of the number and configuration of test specimens and method of evaluation as specified in Table 13. Any of the quantities specified may be made on a simulation of the production joint or a production part.

(1) Preproduction lot. At the start of each work day or before a new production lot is welded or before welding is resumed after a machine shutdown.

(2) Routine lot. At intervals specified in 5.2.2.1 or 5.2.2.2 during production welding and after an electrode change, or other minor welding equipment change.

(3) Postproduction lot. At the end of each production work day or after the completion of a production lot. The last routine test lot may be entered as the postproduction test lot if the production work lot is finished before half of the required routine time interval has elapsed.

5.2.2 Testing Requirements

5.2.2.1 Class A welds shall be accompanied by the following test lots:

- (1) Preproduction lot
- (2) Routine lot every one hour maximum of weld time
- (3) Postproduction lot. Postproduction lot not required if welding of production lot is completed within 30 minutes of last routine lot.

5.2.2.2 Class B welds shall be accompanied by the following test lots:

- (1) Preproduction lot
- (2) Routine lot every two hours maximum of weld time
- (3) Postproduction lot. Postproduction lot not required if welding of production lot is completed within 60 minutes of last routine lot.

5.2.2.3 Class C welds shall be accompanied by the following test lots:

- (1) Preproduction lot
- (2) Postproduction lot

5.2.2.4 Single Spot Standard Certification. Single spot welds established by the standard certification procedure may be controlled either by mechanical strength [4.7.4.1(2)] or by nugget size with soundness examination (4.7.3).

5.2.2.5 Design Allowable Certification Spot Welds. Spot welds established by the design allowable certification are only required to meet the requirements for visible criteria of 4.7.1 and the strength criteria of 4.7.4.2 and 4.7.4.3 or nugget size of 4.7.3.5.

5.2.2.6 Visual and Radiographic Requirements. All specimens shall be visually examined in accordance with 4.7.1. Radiographic examinations of specimens shall not be required, unless otherwise specified in the applicable drawing or part specification.

5.2.3 Alternate Testing Requirements As an alternate to the testing requirements of 5.2.2(1) real time non-destructive SPC system may be used when approved by the Engineering Authority. As a minimum the SPC system shall address: part fitup, precleaning, electrode monitoring, and in process monitoring of critical process parameters. This system of controls shall include but is not limited to, real time adaptive controls or in-process NDT methods. Destructive testing shall still be used to establish and verify that the capability of this SPC system will identify welds complying with strength or size requirements with 99.5% reliability.

5.3 Inspection of Production Parts

5.3.1 External Imperfections. Welds shall be examined for compliance with the visible criteria by determining the presence and number of discontinuities on the following basis.

- (1) Class A and B parts—All welds
- (2) Class C parts—On sampling basis agreed upon with Engineering Authority.

5.3.2 Internal Imperfections. When required, radiographically inspect per 4.7.2 and metallographically inspect per 4.7.3.

5.3.3 Distribution of Imperfections. Imperfections are instances of external or internal discontinuities or departures from specified dimensions. They begin to affect the weld and welded assemblies when they achieve the dimensions of:

- (1) 4.7.1 for visible
- (2) 4.7.2 for radiographic
- (3) 4.7.3 for metallographic sizes

5.3.3.1 Production parts and lots are acceptable as welded with discontinuities of the sizes stipulated, provided the quantity does not exceed:

- (1) 4.7.1 for visible
- (2) 4.7.2 for radiographic
- (3) 4.7.3 for metallographic kinds

(4) The discontinuities shall be randomly distributed and not clustered in one area, in one part, or in one group of parts.

5.3.3.2 When discontinuities (of the size stipulated by 5.3.3) exceed the quantity limited by the paragraphs referenced in 5.3.3.1, but do not exceed twice that quan-

tity limit, the manufacturer may use standard repair procedures to make repairs without recourse to salvage or materials review action. All standard repair weld procedures shall be clearly identified as such. Standard repair procedures shall be approved by the Engineering Authority.

5.3.4 Deterioration of Welding. If investigation of imperfections in welding indicates that welding quality has deteriorated due to clear causes, (for example, swaged or improperly cleaned tips) and those causes are corrected so that acceptable welds (compared to certification requirements) are made, then certification of a new weld schedule will not be required. Under conditions where the machine weld schedule does not produce acceptable welds within the weld schedule latitude, then the machine qualification shall be voided and the machine shall be requalified. All Class A weld schedule certifications for that machine shall be discarded and new certifications shall be established.

5.3.5 Tack Welds. Tack welds shall not be used on Class A parts unless they are allowed on engineering drawings or applicable documents and are finally removed, or completely covered by subsequent production welding. Tack welds require no tests and need be only of sufficient strength to fulfill their temporary function. They are not subject to this specification except that residual discontinuities shall not exceed limits established for production parts.

Annex A (Informative)

Form for Resistance Welding Data Sheet for Spot and Projection Welding

This annex is not part of AWS D17.2/D17.2M:2007, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

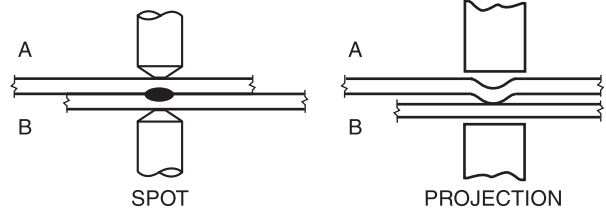
RESISTANCE WELDING DATA SHEET

EQUIPMENT IDENTIFICATION

TYPE _____ SERIAL _____

TRANSFORMER NO. _____ RATING _____

CONTROL _____



		SIDE A	SIDE B		
MATERIAL	Thickness			Weld Current	
	Approx. Analysis (type)			S. C. Current	
				Tap and/or Phase Setting	
				Throat Opening	
	Surface Cond.			Throat Spacing	
	Ultimate Strength			Synchronous or non-synchronous timing	
	Yield Strength				
	Elongation %			Heat Time	
	Red. in Area %			Squeeze Time	
Hardness			Cool Time		
Material			Hold Time		
ELECTRODE	Shape			No. of Pulsations	
				Electrode Force	
				Squeeze Force	
				Forging Force	
				Tension Shear Test	
				Tension Test	
SPOT	Diameter			TORSIONAL	Yield Point
	Overlap or Flange				Ultimate
	Spacing				Mod. of Rupt.
PROJECTION	Size Contour				Degree Twist at Ult.
		Indentation			
		Nugget Size			
		Other Tests:			
Remarks:				Photos	

Source: AWS C1.1M/C1.1:2000, Figure 34, p. 99.

Annex B (Informative)

Form for Resistance Welding Data Sheet for Seam Welding

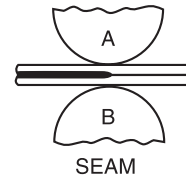
This annex is not part of AWS D17.2/D17.2M:2007, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

RESISTANCE WELDING DATA SHEET**EQUIPMENT IDENTIFICATION**

TYPE _____ SERIAL _____

TRANSFORMER NO. _____ RATING _____

CONTROL _____



		SIDE A	SIDE B			
MATERIAL	Thickness			Weld Current		
	Approx. Analysis (type)			S. C. Current		
				Tap and/or Phase Setting		
				Throat Opening		
	Surface Cond.			Throat Spacing		
	Ultimate Strength			Synchronous or		
	Yield Strength			Non-synchronous Timing		
	Elongation %			Heat Time		
	Red. in Area %			Cool Time		
Hardness			Electrode Force			
ELECTRODE	Material			Tension Shear Test		
	Shape			Tension Test		
				TORSIONAL	Yield Point	
					Ultimate	
					Mod. of Rupt.	
Degree Twist at Ult.						
SEAM	Roll Speed mm per min. (in. per min.)	Indentation				
	Spots per mm (in.)	Other Tests:				
	Width of Weld					
MASH	Overlap or Filler					
	Length of Weld					
Remarks:				Photos		

Source: AWS C1.1M/C1.1:2000, Figure 35, p. 100.

Annex C (Informative)

Informative References

This annex is not part of AWS D17.2/D17.2M:2007, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

(1) American Welding Society (AWS) A2 Committee on Definitions and Symbols, 1998, *Standard Symbols for Welding, Brazing and Nondestructive Examination*, AWS A2.4-98, Miami: American Welding Society.

(2) American Welding Society (AWS) C1 Committee on Resistance Welding, 2000, *Recommended Practices*

for Resistance Welding, AWS C1.1M/C1.1:2000, Miami: American Welding Society.

(3) Resistance Welding Manufacturing Alliance (RWMA), 1996, RWMA Bulletin 14, *Maintenance Manual for Resistance Welding Machines*, Miami: American Welding Society.

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Annex D (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS D17.2/D17.2M:2007, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

D1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

D2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

D2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry

along with the edition of the standard that contains the provision(s) the inquirer is addressing.

D2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

D2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

D2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

D3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official

interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

D4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

D5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be

obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

D6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

List of AWS Documents on Welding in the Aircraft and Aerospace Industries

Designation	Title
D17.1	<i>Specification for Fusion Welding for Aerospace Applications</i>

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