

AWS D17.2/D17.2M:2013
An American National Standard

Specification for Resistance Welding for Aerospace Applications



American Welding Society®



AWS D17.2/D17.2M:2013
An American National Standard

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Specification for Resistance Welding for Aerospace Applications

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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.



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Foreword

This foreword is not part of AWS D17.2/D17.2M:2013, *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 is the second edition of the D17.2/D17.2M specification. This specification 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.

Underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2007 edition. A vertical line in the margin also indicates a revision from 2007 edition.

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, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

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Specification for Resistance Welding for Aerospace Applications

1. General Requirements

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

1.1.1 Material Groups

Group 1—Aluminum and magnesium

Group 2—Steel, nickel, and cobalt

Group 3—Titanium

1.1.2 Classification.

Classification is based on the following:

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.

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.

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.

1.2 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.

1.3 Safety. 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 the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Material Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The standards listed below contain 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.

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

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.¹

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

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.

coring. Incipient melting adjacent to the **nugget**.

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.

fabricator. The organization responsible for producing weldments that satisfy the design and contract requirements.

foil. A material having thickness of 0.008 in [0.2 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 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** (fusion zone) into the thickness of a joined member.

production witness specimen. Test coupon welded using production setup and destructively tested to provide data on the quality of production welds.

¹ AWS standards are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

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 material having 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 A3.0M/A3.0, AWS A2.4, and as shown in Clause 3 herein.

4.1.2 The Engineering Authority shall be responsible for the development of the contract specification that governs products or structural assemblies produced under this specification. The Engineering Authority may add to, delete from, or otherwise modify, the requirements of this specification to meet the particular requirements of a specific structure. All requirements that modify this specification shall be incorporated into contract documents, engineering drawings, or item specifications. The Engineering Authority shall determine the suitability of all joint details to be used in a welded assembly.

4.1.3 When conditions are encountered which cause any of the requirements of this specification to be unattainable, the fabricator may submit alternate procedures and requirements for approval by the Engineering Authority.

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

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

4.1.5.1 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.

4.1.5.2 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 welds; 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.

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

Nominal Thickness of Thinner Sheet		Ultimate Strength ^a				Ultimate Strength ^a				Ultimate Strength ^a				Ultimate Strength ^a			
		56 000 psi and above lbf per spot weld		386 MPa and above N ^b per spot weld		35 000 psi to 55 999 psi lbf per spot weld		240 MPa to 385.9 MPa N ^b per spot weld		19 500 psi to 34 999 psi lbf per spot weld		135 MPa to 239.9 MPa N ^b per spot weld		Below 19 500 psi lbf per spot weld		Below 135 MPa N ^b per spot weld	
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	—	—	—	—	—	—	—	—

^a ultimate tensile strength of the weakest member joined by the spot weld.^b newtons.

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

Nominal Thickness of Thinner Sheet		Ultimate Strength ^a				Ultimate Strength ^a				Ultimate Strength ^a				Ultimate Strength ^a			
		Above 185 000 psi lb _f per spot weld		Above 1275 MPa N ^b per spot weld		150 000 psi to 185 000 psi lb _f per spot weld		1034 MPa to 1275 MPa N ^b per spot weld		90 000 psi to 149 999 psi lb _f per spot weld		620 MPa to 1033.9 MPa N ^b per spot weld		Below 90 000 psi lb _f per spot weld		Below 620 MPa N ^b per spot weld	
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
0.009	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

^a ultimate tensile strength of the weakest member joined by the spot weld.

^b newtons.

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

Nominal Thickness of Thinner Sheet		Ultimate Strength ^a				Ultimate Strength ^a			
		Above 100 000 psi: lbf per spot weld		689.5 MPa and above: N ^b per spot weld		100 000 psi and below: lbf per spot weld		Below 689.5 MPa: N ^b per spot weld	
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

^a ultimate tensile strength of the weakest member joined by the spot weld.

^b newtons.

Table 4
Shear Load Requirements for Spot Welds in Foil

Thickness of Outer Sheet		Standard Number of spot welds per inch [25 mm]	Acceptable range spot welds per inch [25 mm] ^b	Group 1 Alloys with an Ultimate Strength ^a of:				Group 2 and 3 Alloys with an Ultimate Strength ^a of:							
				Minimum Shear Load: Pounds per Linear Inch [Newtons (N) per Linear millimeter (mm)]: (S _o) ^{c,d}											
in	mm	(N _o)	R	Up to 56 ksi	Up to 386 MPa	Above 56 ksi	Above 386 MPa	Up to 90 ksi	Up to 620 MPa	90 ksi to 149 ksi	620 MPa to 1033.9 MPa	150 ksi to 185 ksi	1034 MPa to 1275 MPa	Above 185 ksi	Above 1275 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

^a ultimate tensile strength of the weakest member joined by the spot weld.

^b When the number of spot welds per linear inch [spot welds per 25 mm] 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).

N_o = 20 spot welds 0.85N_o = 17 spot welds 1.15N_o = 23 spot welds S_o = 130 lbf/in [22.8 N/mm]

If N_p < 0.15N_o, then S_x = N_p/20 × 1.15 × 130 lbf/in [N_p/20 × 1.15 × 22.8 N/mm]

If N_p > 0.15N_o, then S_x = N_p/20 × 0.90 × 130 lbf/in [N_p/20 × 0.90 × 22.8 N/mm]

N _p	S _x [lbf per inch (in)]	S _x [newtons (N) per millimeter (mm)]	N _p	S _x [lbf 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*

*N_p exceeds maximum R for the outer sheet thickness and material characteristics in Table 4.

^c When the actual number of spot welds per linear inch [number of spot welds per 25 millimeters] (N_p) is within 15% of the standard spot welds per inch [spot welds per 25 millimeters] (N_o), the tabulated Minimum shear loads as noted shall apply.

^d When the actual number of spot welds per linear inch [spot welds per 25 millimeters] (N_p) differs from the standard spot welds per inch [spot welds per 25 millimeters] (N_o) by 15% or greater, but do not exceed the above noted spot welds per inch range [spot welds per 25 millimeter range] (R), the applicable modified minimum shear load (S_x) shall be determined by using the formula below.

$$S_x = (S_o) \times (K) \times (N_p/N_o)$$

Where:

(N_o) is defined as the recommended (standard) number of spot welds per linear inch [spot welds per 25 millimeters].

(S_o) 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 spot welds per linear inch [spot welds 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 (N_o).

(K) is the constant shown below:

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

$$S_x = S_o \times (1.15) \times (N_p/N_o)$$

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

$$S_x = S_o \times (0.90) \times (N_p/N_o)$$

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:

- (1) Oxide coatings may be removed by mechanical treatment or by chemical treatment.
- (2) The cleaning procedure used to prepare Group 1 and Group 3 materials for certification shall be specified on the welding procedure for production welding. For Group 1 materials, 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. Refer to 5.1.4.
- (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 and 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 (micro-ohms) 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 may be applied prior to welding. Such finishes must be considered as final steps of the cleaning procedure and all necessary conditions shall be specified on the certified welding 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.

4.2.2.1 Preconditioning steps to compensate for fitup variations that involve the controlled application of heat and/or force may be employed, provided such actions are demonstrated to reduce weld variability from what would occur if such actions are not taken. Such preconditioning actions shall not be considered to represent an adjustment of the weld schedule parameters pursuant to 5.1.5.1 that are responsible for the actual formation of the weld nugget.

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 welding 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.

4.3.3 Jigs and Fixtures. Jigs and fixtures should be designed so no welding current can shunt through them instead of passing through the workpieces. Where shunting cannot be avoided due to part design, the effects of shunting shall be factored into the production weld schedule and necessary adjustments made to ensure acceptable welds are produced. 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 nonmagnetic materials insofar as possible.

4.3.4 Maintenance of Equipment. Unless otherwise specified, each item of equipment shall be inspected periodically. The periodic inspection may be in accordance with the manufacturer's maintenance schedule or per RWMA Bulletin 14, *Maintenance Manual for Resistance Welding Machines*. A preventative maintenance procedure shall be established and maintenance records kept. For machine characteristics wherein the behavior of the machine can be monitored, and criteria exists for those monitored parameters that would trigger maintenance when required, such monitoring techniques may be employed in place of periodical machine inspection.

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 verify the range of welding for which a machine may be considered capable to produce welds meeting requirements of this specification. 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 welding 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 welding machine qualified for spot welding is also qualified for overlap spot welding. Machines used for Class C foil welding are qualified by establishing a welding 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 unless a consistent set of adjustment rules are applied (i.e., first weld on part has specific heat adjustment that consistently occurs every time the 1st weld is produced).

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—the high end (thickest) machine qualification test and the low end (thinnest) machine qualification test. Usually both the high end and low end machine qualification tests are each made up of two equal members, however, two unequal members or a combination of three or more members may be used. The following requirements shall be met and used to determine the required machine qualification tests to cover production work:

(1) The total thickness of all members in a production weld combination shall not be more than the total thickness of all members in the high end machine qualification test and shall not be less than the total thickness of all members in the low end machine qualification test.

(2) The thinnest contact member (member in contact with the electrode) of any production weld combination shall not be thicker than the thinnest member in the high end machine qualification test.

(3) The thinnest contact member (member in contact with the electrode) of any production weld combination shall not be thinner than the thinnest member in the low end machine qualification test.

(4) For a single application, a single material thickness combination can be used for machine qualification by conducting the tests per the quantities and methods specified in Table 5.

Except that when a qualification is achieved on one combination of foil thicknesses, the equipment shall be considered qualified for all thicker foils welded to foils.

Table 5
Machine Qualification Specimens and Examination Requirements

Alloy Group	Class	Specimen	Amount Per Set	Examination			
				<u>Visual All</u>	<u>Radiographic All</u>	<u>Mechanical 100 Shear</u>	<u>Metallographic 5 Sections</u>
Spot Welds—Sheet							
1	A	Fig. 1(B)	105 welds	All	All	100 shear	5 microsections
1	B, C	Fig. 1(B)	105 welds	All	None	100 shear	5 <u>macrosections</u>
2, 3	A	Fig. 1(A) or 1(B)	105 welds	All	All	100 shear	5 microsections
2, 3	B, C	Fig. 1(A) or 1(B)	105 welds	All	None	100 shear	5 <u>macrosections</u>
Spot Welds—Foil							
1, 2, 3	A	Fig. 3	12 in [300 mm] continuous length of weld	All	All	10 shear	2 microsections
	C	Fig. 4			see 4.4.2		
Seam Welds—Sheet							
1, 2, 3	A	Fig. 5	24 in [600 mm] continuous length of weld	All	All	None	8 microsections (4 transverse, 4 longitudinal)
	B, C	Fig. 5	24 in [600 mm] continuous length of weld	All	None	None	8 <u>macrosections</u> (4 transverse, 4 longitudinal)
Seam Welds—Foil							
1, 2, 3	A	Fig. 6	12 in [300 mm] continuous length of weld	All	All	Pressure Test	2 microsections (1 transverse, 1 longitudinal)
	C	Fig. 4			see 4.4.2		

4.4.2.4 Welding 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 welding 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 Welding Procedure Certification

4.5.1 Procedure Certification. Tests shall be conducted to determine if a particular machine, in combination with a specific welding procedure and other specific conditions, will consistently produce resistance welds that conform to the requirements of this specification on a given set of materials. Documentation of these tests shall be contained in a completed Certified Welding Procedure Test Report that will be available to the Quality Assurance (QA) personnel. In addition, the welding procedure shall be posted near the machine and be available to machine operators and QA. The

following critical variables shall be included in the procedure certification. Any changes to these variables outside of 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 shall determine the effective welding machine settings for test and production parts. The conditions and parameters shall be formally entered on a welding 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 and Results. 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 must 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].

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

Type	Alloy Group	Class	Specimen	Number of Welds	Examination			
					Visual 4.7.1	Radiographic 4.7.2	Mechanical 4.7.4	Metallographic 4.7.3
Isolated, or Roll Spot Welds	1	A	Fig. 1(A) or 1(B)	25	All	All	20 Shear	5 Microsections
		B	Fig. 1(A) or 1(B)	15	All	None	10 Shear	5 Macrosections
		C	Fig. 1(A) or 1(B)	5	All	None	3 Shear	2 Macrosections
	2, 3	A	Fig. 1(A) or 1(B)	13	All	All	10 Shear	3 Microsections
		B	Fig. 1(A) or 1(B)	8	All	None	5 Shear	3 Macrosections
		C	Fig. 1(A) or 1(B)	5	All	None	3 Shear	2 Macrosections
Close- Spaced Spot Welds	1, 2, 3	A	Fig. 2	20	All	All	None	10 Microsections
		B	Fig. 2	10	All	None	None	5 Macrosections
		C	Fig. 2	3	All	None	None	3 Macrosections

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

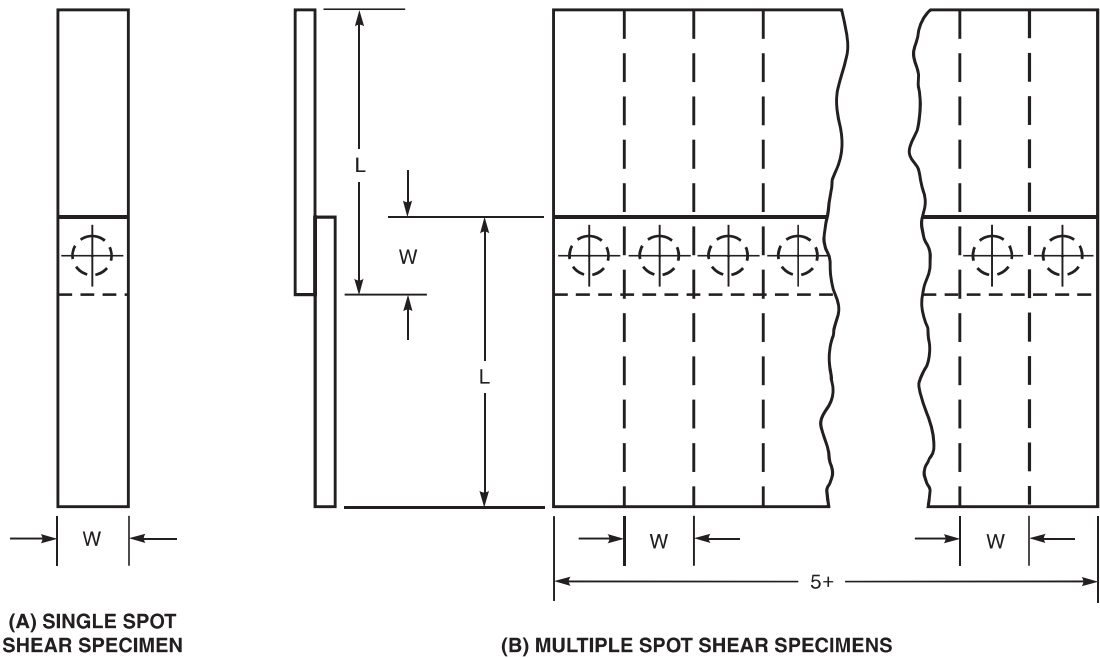
Alloy Group	Class	Specimen Configuration	Length of Weld	Examination			
				Visual	Radiographic	Mechanical	Metallographic
1, 2, 3	A	Fig. 3	12 in [300 mm] continuous length of weld	All	All	5 Shear and Peel 3 in [75 mm]	2 in [50 mm]
	C	Fig. 4	12 in [300 mm] continuous length of weld	All	None	Peel (10 in [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		
				Visual 4.7.1	Radiographic 4.7.2	Metallographic 4.7.3
1, 2, 3	A	Fig. 5	12 in [300 mm] continuous length of weld	All	All	4 transverse microsections (Tr) 4 longitudinal microsections (Lo)
	B	Fig. 5	12 in [300] mm continuous length of weld	All	None	4 transverse microsections (Tr) 4 longitudinal microsections (Lo)
	C	Fig. 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			
				Visual 4.7.1	Radiographic 4.7.2	Mechanical 4.7.4	Metallographic 4.7.3
1, 2, 3	A	Fig. 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	Fig. 4	12 in [300 mm] continuous length of weld	All	None	Peel 4.7.4.4 (10 in [250 mm] minimum length)	<u>None</u>

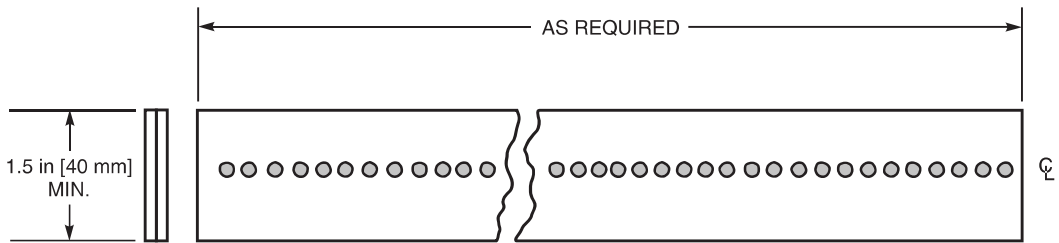


Notes:

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

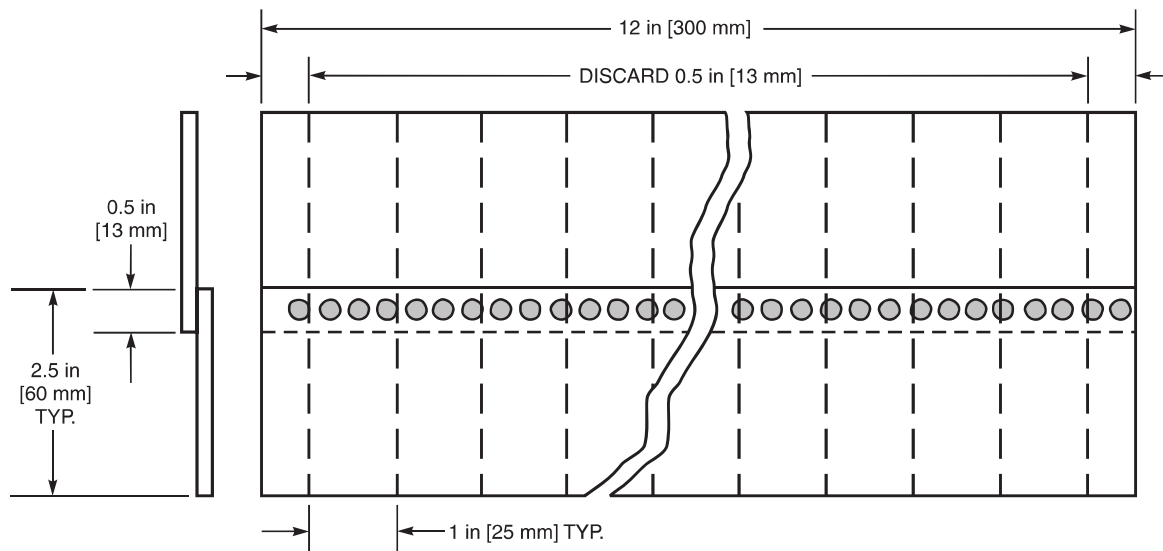
2. L shall not be less than 4W.
3. Figure 1(B) shall be made of 5 specimens or more.

Figure 1—Spot Welds in Sheet



- Notes:
1. Spot welds 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.

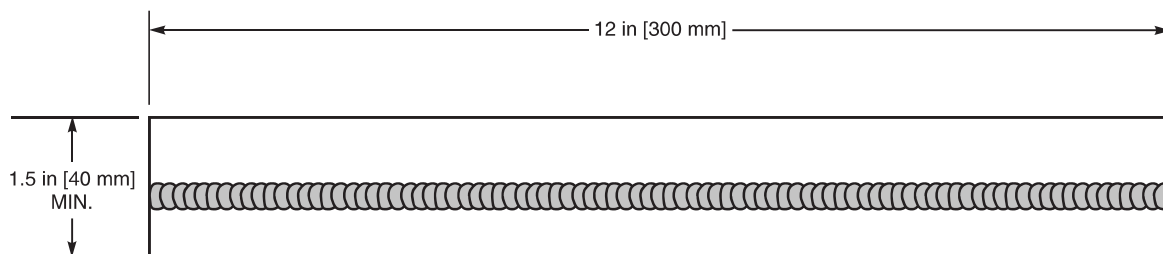
Figure 2—Close-Spaced Spot Welds in Sheet



Notes:

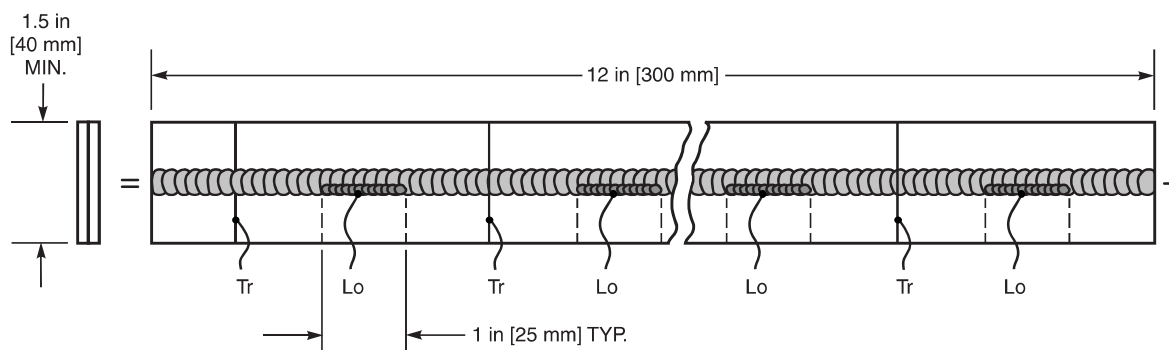
1. Spot welds spacing shall be in accordance with Table 4 (Standard Spots per in or mm) for qualification, and in accordance with the subject production part of certification.
2. For Class A, select at random five 1 in or 25 mm specimens for mechanical shear tests, three specimens for peel tests, and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

Figure 3—Spot Welds in Foil for Class A Welds



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

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

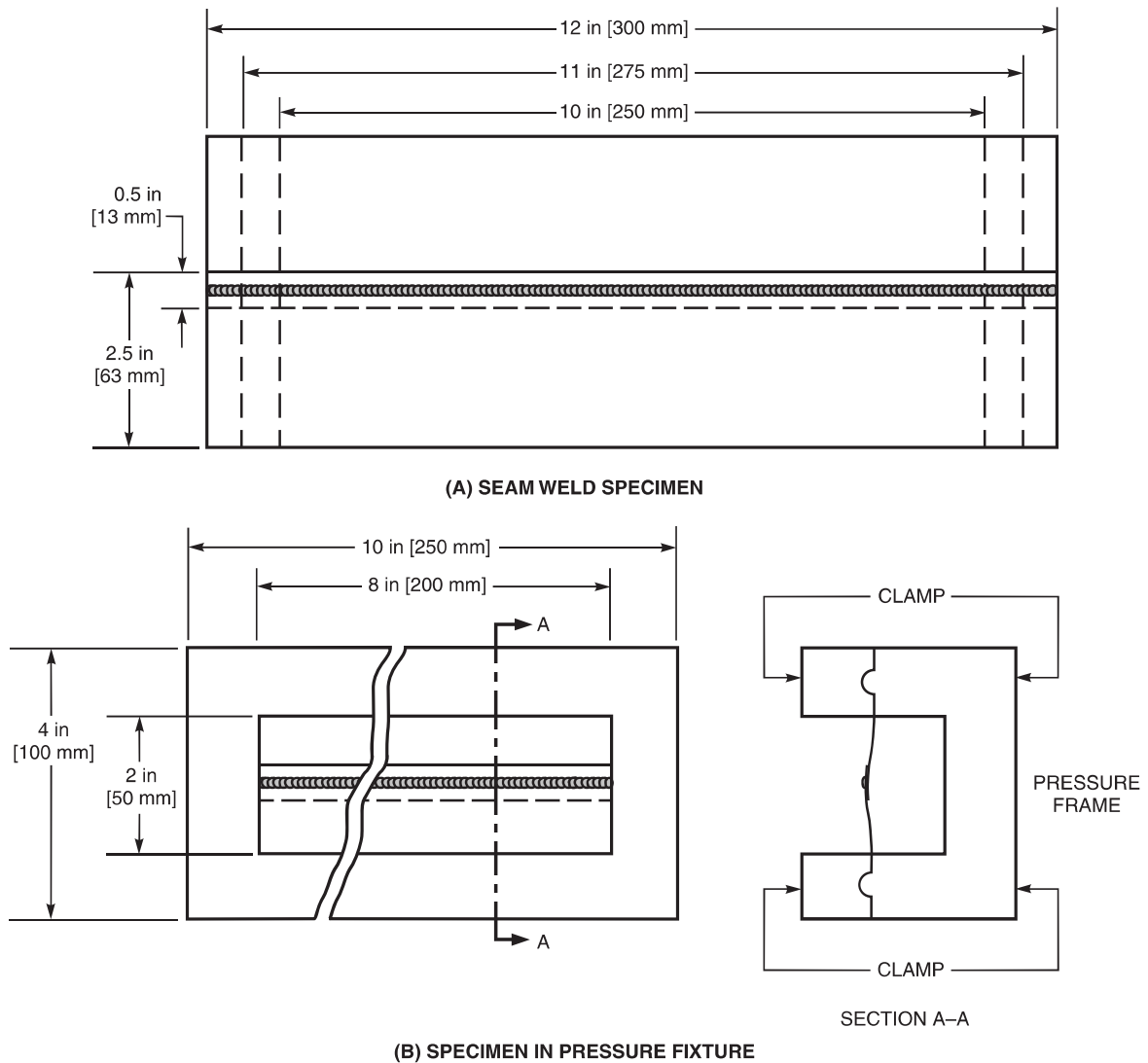


Note: Remove metallographic sections in the order above, but examine from random positions.

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

4.5.5 Thickness Latitudes. Thickness combinations falling within the following limits shall not require separate certified welding 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.

(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 inch [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 welding 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 welding 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 welding 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 welding 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, 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 welding 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 welding 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 Visual Acceptance Criteria

4.7.1.1 Visible 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 Visible Discontinuities in Parts or Lot. Visible 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.

Table 10
Limits for Visible Discontinuities in Production Parts or Lots

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.

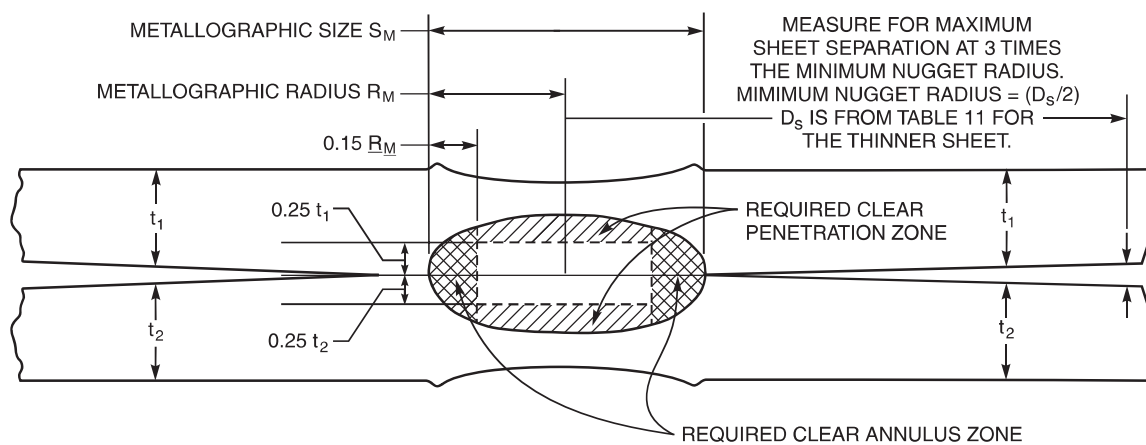


Figure 7—Nomenclature for Metallographic Spot Weld Sections and Seam Weld Transverse Sections

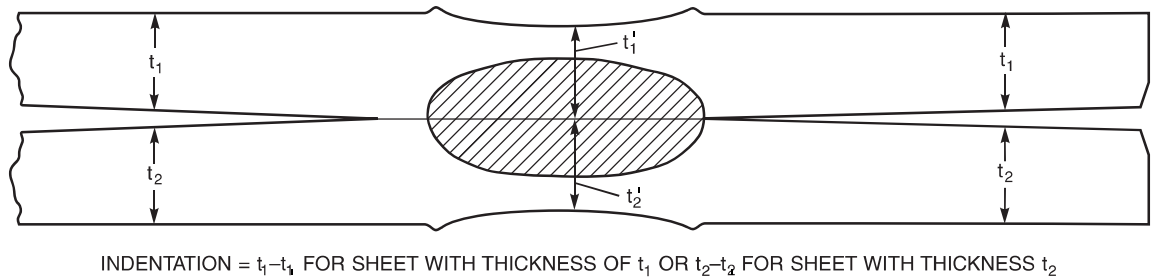


Figure 8—Surface Indentation

4.7.1.4 Surface Indentation. Indentations (see Figure 8) are not acceptable if their depth exceeds the 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. Locally displaced material, if present, resulting in a ridge around the periphery of weld shall not be included in determining indentation.

- (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 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 shall have a linear dimension greater than 15% of the minimum nugget size as specified in Table 11.

4.7.2.3 No pore shall extend into the outer 15% of the minimum nugget size, as specified in Table 11(D_s) or minimum nugget size as determined from metallography of production witness tests (S_M), which is the required clear annulus as shown in Figure 9.

4.7.2.4 Porosity 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 For multiple spot and seam welds, the nugget shall be of similar size and shape.

4.7.3 Metallographic Acceptance Criteria. The metallographic examination and acceptance criteria are applicable to machine qualification, standard procedure certification, and production witness specimens. Examination and acceptance criteria apply to production parts in the event of a test. Metallographic nomenclature is shown in Figures 7 (see 4.7.1.3) and 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. Cracks, 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.
- (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.

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

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]	—	—	—	—

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 (see Figure 10). Maximum penetration shall be measured at the maximum extent into each outer sheet using thickness at the indented area. See Annex E for proposed method of measuring seam welds.

(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 of the thinner member into each member.

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

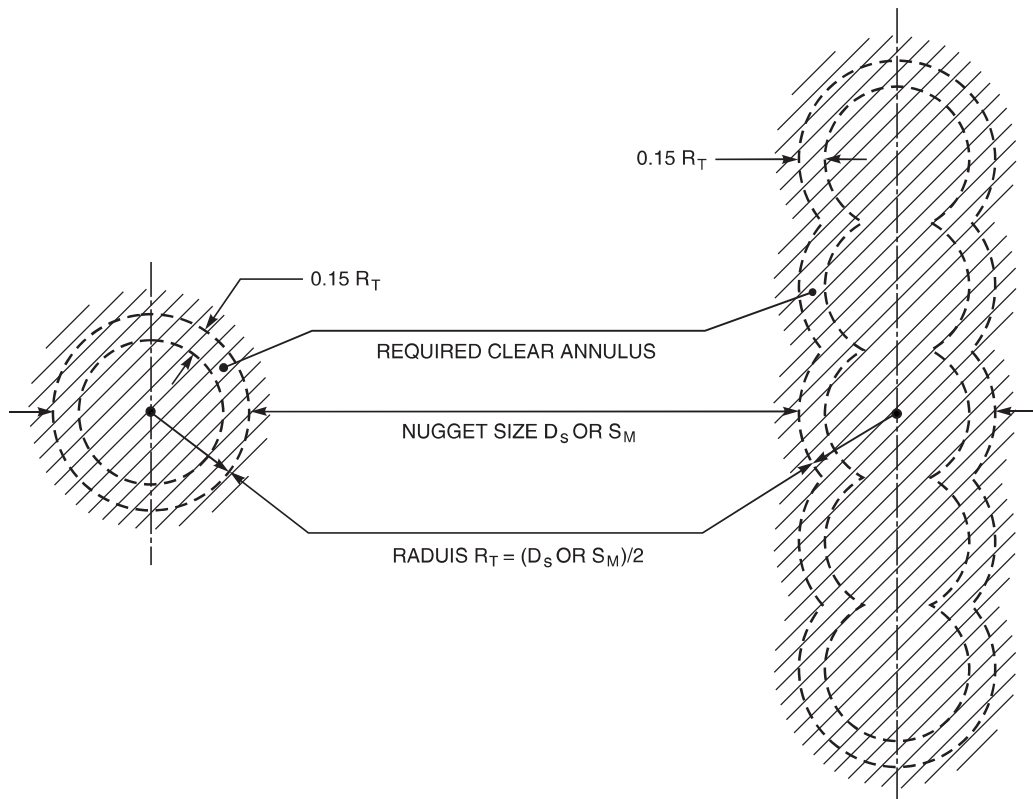
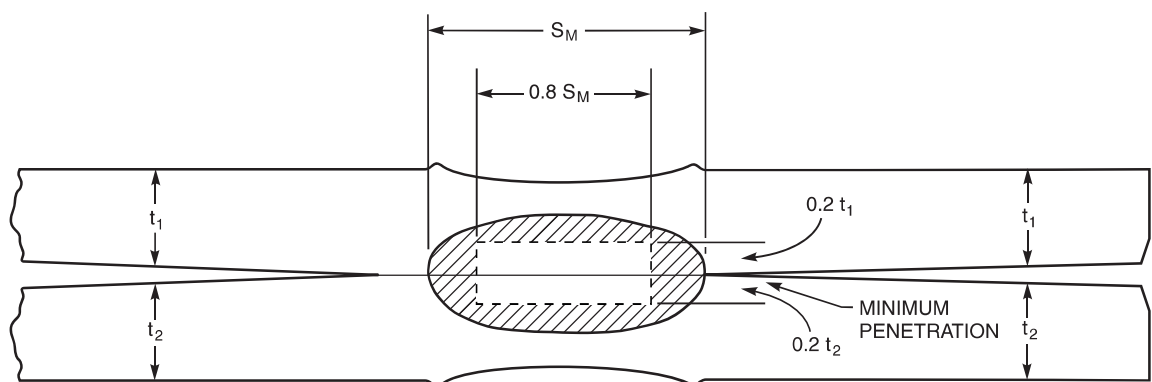


Figure 9—Nomenclature Diagram of Spot and Seam Weld Radiographs



Note: When $t_1 \leq t_2$.

Figure 10—Minimum Penetration

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

4.7.3.5 Nugget Size. The minimum nugget size for spot welds shall be that specified in Table 11 (see 4.7.2.2). 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 button pulled out from the 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 and shall have sufficient overlap to maintain acceptable width and penetration. See Annex E for proposed measurement.

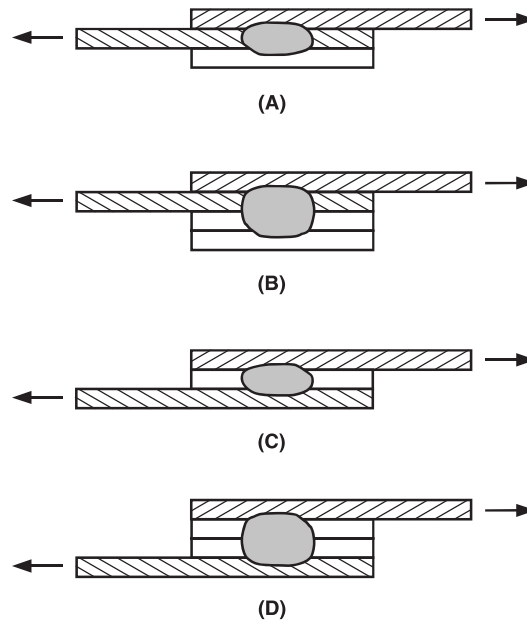
(2) *Machine Qualification and Procedure Certification.* The nugget size of all required metallographic sections will be measured for each interface plane and recorded. From the values of each plane the average size and the lowest size in the test group will be entered on the test record form. The peel 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 and for seam welds, per Table 13. It may also be an alternate method to spot weld shear tests of production witness specimens, see 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.



Note: Arrows indicate loaded members.

Figure 11—Shear Tests of Three or More Thicknesses

4.7.4 Mechanical Testing 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 (see 4.1.5).

(b) *Average.* The average shear strength shall equal or exceed the applicable minimum average strength specified in Tables 1 through 3 (see 4.1.5).

(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 not be less than 90% of the certification average and no weld shall be less than the applicable minimum value shown in Tables 1 through 3 (see 4.1.5).

(b) *Class B and Class C.* The test lot average shall not be less than the applicable value shown in Tables 1 through 3 (see 4.1.5).

4.7.4.2 Design Allowable Certification for Sheet

- (1) *Minimum*. The value of the lowest specimen in the test lot must exceed the specified design minimum.
- (2) *Average*. The test lot average (Ac) shall be recorded on the certification report form.
- (3) *Consistency*. 95% of the number of specimens tested must have values greater than 0.875 times the test lot averages (Ac).

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 not be 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 (see 4.1.5). 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 not be 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 not be 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 4 (see 4.1.5) 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 weld spacing, and part (overlap) width.

5.1.4 Surface Resistance. A daily check shall be made of the surface resistance in micro-ohms 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.

5.1.4.1 Use of existing material cleaning and etching process control/monitoring may be substituted for the surface resistance checks as deemed appropriate by the Engineering Authority.

5.1.4.2 Use of in-process weld control monitoring capable of detecting when a micro-ohms shift outside of the specification range occurs may be substituted for the surface resistance checks as deemed appropriate by the Engineering Authority.

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 must 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.

5.1.5.1 Control adjustments shall apply from start to finish of the weld nugget formation.

5.1.5.2 Any control adjustment made beyond the constraints set forth in 5.1.5 taken to minimize part damage during the occurrence of a welding fault shall be excluded as a condition that would require the establishment of a new certified welding procedure.

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 and 4.7.3.5(3). 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, whichever comes first, 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, whichever comes first. 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.

Table 13
Production Witness Welds, Test Lots

Class	Specimen	Amount of Welds In Test Lot ^c	Examination		
			Mechanical ^{a, c}		Metallographic Requirement ^b
			Test	Requirement	
Spot Welds—Sheet					
A	Fig. 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
B	Fig. 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
C	Fig. 1(A) or 1(B)	3 welds	Shear	4.7.4.1(2)	4.7.3
Spot Welds—Sheet—Close Space					
A	Fig. 2	3 Welds	None	None	4.7.3
B	Fig. 2	3 Welds	None	None	4.7.3
C	Fig. 2	3 Welds	None	None	4.7.3
Spot Weld—Foil					
A	Fig. 3	3 welds	Peel	4.7.4.4(2)(a)	4.7.3
C	Fig. 4	1 in [25 mm]	Peel	4.7.4.4(2)(b)	4.7.3
Seam Welds—Sheet					
A	Fig. 5	3 in [75 mm]	None	None	4.7.3
B	Fig. 5	3 in [75 mm]	None	None	4.7.3
C	Fig. 5	3 in [75 mm]	None	None	4.7.3
Seam Welds—Foil					
A	Fig. 4	3 in [75 mm]	Peel	4.7.4.5(2)(a)	4.7.3
C	Fig. 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.

5.2.2 Testing Requirements

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

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

5.2.2.4 Single Spot Weld—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 Spot Welds—Design Allowable Certification. Spot welds established by the design allowable certification are only required to meet the visual acceptance 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 Examination 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 real time nondestructive system may be used when approved by the Engineering Authority. As a minimum the 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 must still be used to establish and verify that the capability of this 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 visual acceptance criteria (4.7.1) 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 exceed the dimensions stated in:

- (1) 4.7.1 for visual examination
- (2) 4.7.2 for radiographic examination
- (3) 4.7.3 for metallographic examination

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 visual examination
- (2) 4.7.2 for radiographic examination
- (3) 4.7.3 for metallographic examination

5.3.3.2 The discontinuities in 5.3.3.1 shall be randomly distributed and not clustered in one area, in one part, or in one group of parts.

5.3.3.3 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 quantity limit, the manufacturer may use standard repair procedures to make repairs without recourse to salvage or materials review action. All standard repair welding 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 (5.1.5), 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.

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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:2013, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

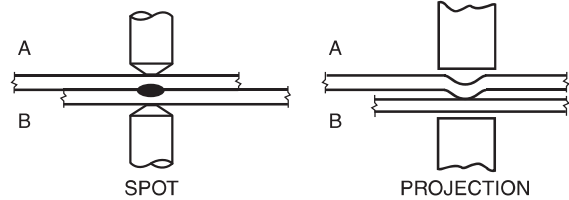
RESISTANCE WELDING DATA SHEET

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	
				Throat Spacing	
	Surface Cond.			Synchronous or non-synchronous timing	
	Ultimate Strength			Heat Time	
	Yield Strength			Squeeze Time	
	Elongation %			Cool Time	
Red. in Area %			Hold Time		
Hardness					
Material					
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	
	Number			Other Tests:	
	Location				
Remarks:				Photos	

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

Annex B (Informative)

Form for Resistance Welding Data Sheet for Seam and Roll Spot Welding

This annex is not part of AWS D17.2/D17.2M:2013, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

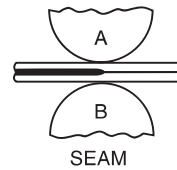
RESISTANCE WELDING DATA SHEET

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		
				Throat Spacing		
	Surface Cond.			Synchronous or Non-synchronous Timing		
	Ultimate Strength			Heat Time		
	Yield Strength			Cool Time		
	Elongation %			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:2013, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

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.

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:2013, *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
8669 Doral Blvd., Suite 130
Doral, FL 33166

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.

Annex E (Informative)

Recommendation for a Metallographic Method for the Evaluation of Weld Penetration in Resistance Seam Welds

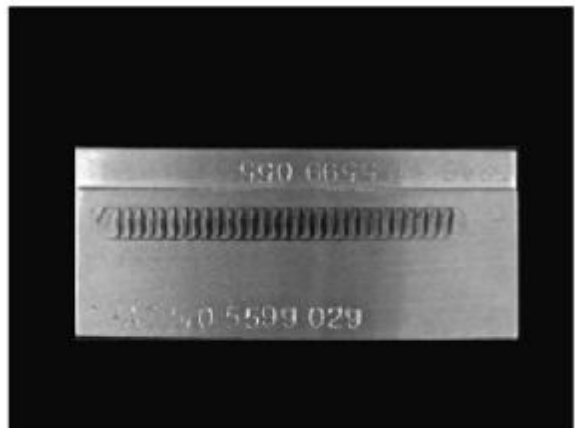
This annex is not part of AWS D17.2/D17.2M:2013, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

E1. Representative Test Assembly

(1 in [25 mm] × 3 in [76 mm] coupons, representative of base material alloys, thickness, and surface preparation.)

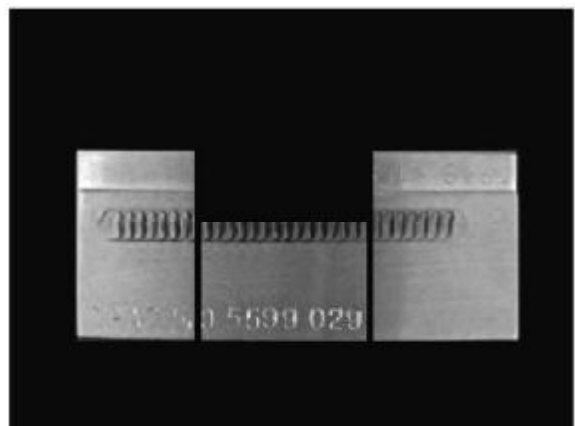
Material 1: AMS5599
nominal thickness 0.029 in [0.74 mm]

Material 2: AMS5599
nominal thickness 0.055 in [1.40 mm]



E2. Sectioning

2 transverse sections
1 longitudinal section, 1 in [25 mm] long



Courtesy of Pratt and Whitney Canada

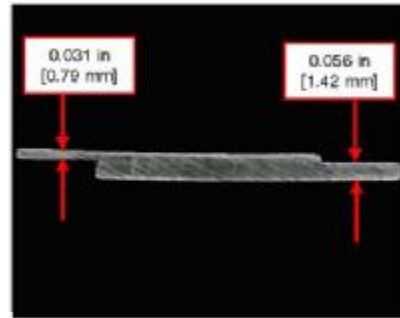
E3. Base Material Actual Thickness

Measured on the test assembly with a point micrometer

Material 1, T_1 : 0.031 in [0.79 mm]

Material 2, T_2 : 0.056 in [1.42 mm]

Total thickness (T_T) = $T_1 + T_2 = 0.087$ in [2.21 mm]



E4. Transverse Section:

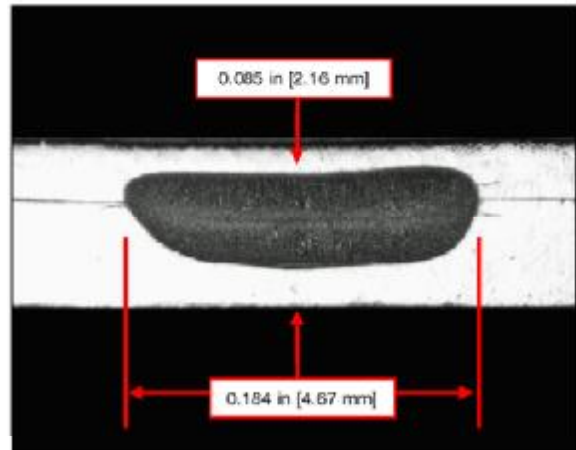
Nugget size (S_M) = 0.184 in [4.67 mm]

Total indented thickness (T_{IT}): 0.085 in [2.16 mm]

- Indentation: $T_T - T_{IT} = 0.002$ in [0.05 mm]

(Since indentation seems approximately similar into both components, it is assumed to be 0.001 in [0.025 mm] in each component)

- % indentation in Material 1:
 $0.001 \text{ in [0.025 mm]} / T_1 \times 100 = 3.2\%$
- $T_1' = T_1 - 0.001 \text{ in [0.025 mm]} = 0.030 \text{ in [0.765 mm]}$
- % indentation in Material 2:
 $0.001 \text{ in [0.025 mm]} / T_2 \times 100 = 1.8\%$
- $T_2' = T_2 - 0.001 \text{ in [0.025 mm]} = 0.055 \text{ in [1.395 mm]}$



Courtesy of Pratt and Whitney Canada

E5. Penetration Evaluation on the Longitudinal Section

Under the microscope, scan for minimum and maximum penetration points along the seam. At these points, measure the non fused based material thickness.

Minimum penetration in Material 1: $(T_1' - 0.019 \text{ in } [0.48 \text{ mm}]) / T_1' \times 100 = 37\%$

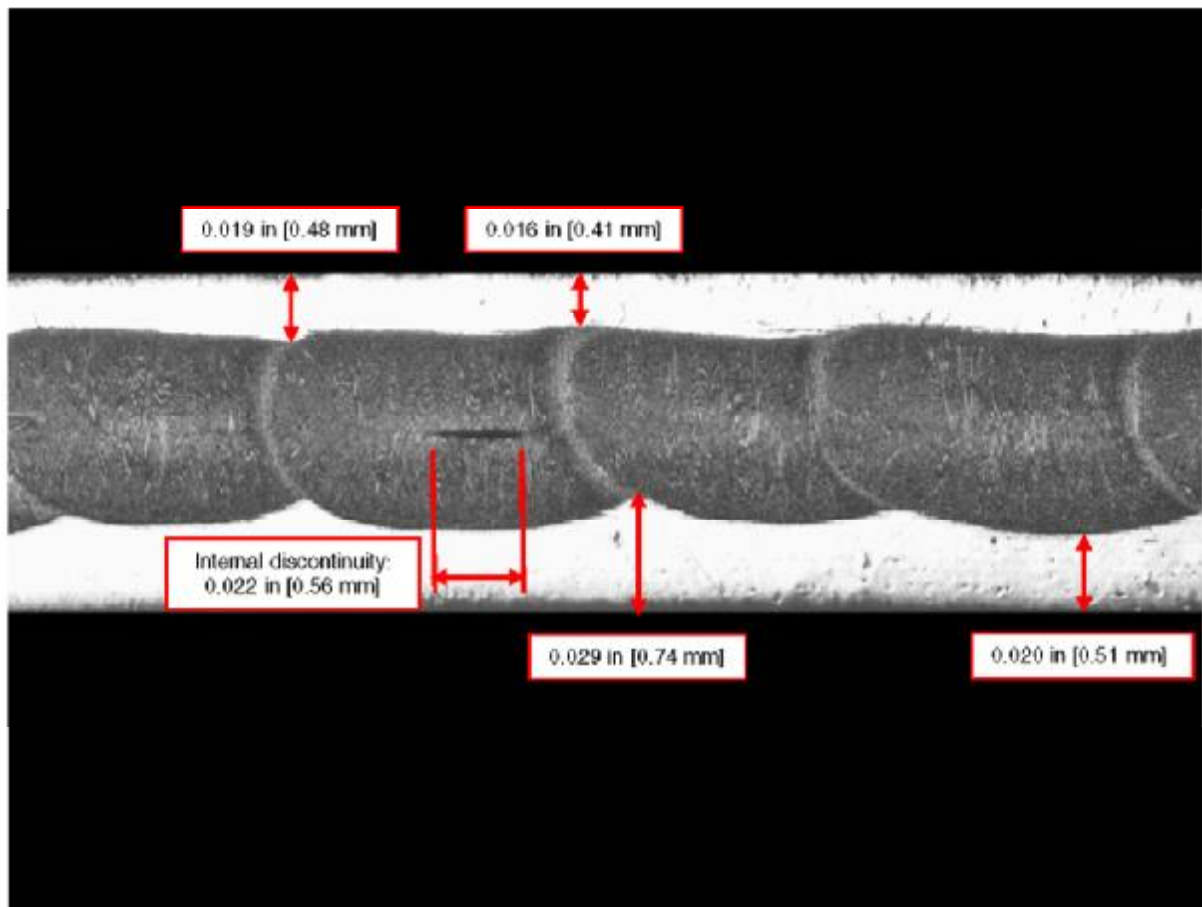
Maximum penetration in Material 1: $(T_1' - 0.016 \text{ in } [0.41 \text{ mm}]) / T_1' \times 100 = 47\%$

Minimum penetration in Material 2: $(T_2' - 0.029 \text{ in } [0.74 \text{ mm}]) / T_2' \times 100 = 47\%$

Maximum penetration in Material 2: $(T_2' - 0.020 \text{ in } [0.51 \text{ mm}]) / T_2' \times 100 = 64\%$

E6. Internal Discontinuity

$(0.022 \text{ in } [0.56 \text{ mm}] / S_M) \times 100 = 12\%$ (Acceptable for Class B, not acceptable for Class A)



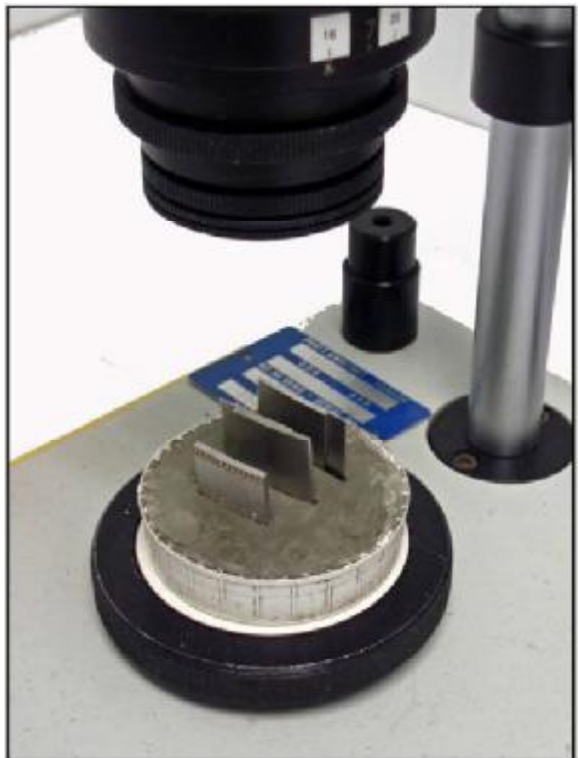
Courtesy of Pratt and Whitney Canada

E7. Typical Metallographic Equipment for Metallurgical Evaluation

The microscope shown is a LEICA, model M-420, providing magnification from 16X to 80X. A linear graticule measurement scale is installed into the eyepiece and it is calibrated to perform direct measurement. The weld zone diameter, the weld penetration and any other metallurgical defects can be directly evaluated with this equipment.



A convenient support for the polished and etched samples is made with a plastic cap filled with modeling clay. Most applications do not require plastic encapsulation.



Courtesy of Pratt and Whitney Canada

Annex F (Informative)

Commentary of Machine Qualification

This annex is not part of AWS D17.2/D17.2M:2013, *Specification for Resistance Welding for Aerospace Applications*, but is included for informational purposes only.

F1. Introduction

This annex is intended to clarify the machine qualification requirements set forth in 4.4.2.3 of this document. The basis for the qualification limits defined by 4.4.2.3 is determined by two factors:

- (1) Total weld combination thickness.
- (2) Thinnest contact member (member in contact with the electrode).

The production weld combination limits of each material group for a resistance welding machine are defined by these two factors.

F2. Background

The intent of the machine qualification test is to demonstrate that a particular welding machine has the ability to consistently produce welds meeting the requirements for the desired class of welds over a range of assembly thicknesses. The qualification test serves as a means of establishing the application range of each welding machine. Generally, it is best to select two members of equal thickness to establish the upper (thickest) and lower (thinnest) qualification limits that cover the thickness range of welded assemblies expected in production. However, when more than two members are to be welded, it may be necessary to qualify using multiple member assemblies. Typically, this situation would represent the upper machine qualification limit.

F3. Table of Examples

Table of Examples in Inches			
Example Number	Machine Qualifications— Low & High	Production Weld Combination in Question— Stack up from top to bottom	Is Production Weld Combination Covered by Machine Qualifications?
1	0.016–0.016 (0.032 Combined Thickness) & 0.080–0.080 (0.160 Combined Thickness)	0.016–0.010 (0.026 Combined Thickness)	NO
2		0.016–0.040 (0.056 Combined Thickness)	YES
3		0.040–0.040 (0.080 Combined Thickness)	YES
4		0.040–0.080 (0.120 Combined Thickness)	YES
5		0.082–0.082 (0.164 Combined Thickness)	NO
6		0.120–0.040 (0.160 Combined Thickness)	YES
7		0.012–0.010–0.010–0.016 (0.048 Combined Thickness)	NO
8		0.040–0.010–0.010–0.010–0.080 (0.150 Combined Thickness)	YES
9	0.010–0.014 (0.024 Combined Thickness) & 0.063–0.125 (0.188 Combined Thickness)	0.010–0.010 (0.020 Combined Thickness)	NO
10		0.012–0.012 (0.024 Combined Thickness)	YES
11		0.065–0.065 (0.130 Combined Thickness)	NO
12		0.050–0.130 (0.180 Combined Thickness)	YES
13		0.040–0.010–0.010–0.040 (0.100 Combined Thickness)	YES
14		0.078–0.050–0.050 (0.178 Combined Thickness)	YES
15		0.063–0.125 (0.188 Combined Thickness)	YES
16		0.078–0.056–0.056 (0.190 Combined Thickness)	NO
17	0.020–0.020 (0.040 Combined Thickness) & 0.063–0.063–0.063 (0.189 Combined Thickness)	0.020–0.010 (0.030 Combined Thickness)	NO
18		0.020–0.010–0.010 (0.040 Combined Thickness)	NO
19		0.020–0.020 (0.040 Combined Thickness)	YES
20		0.020–0.040 (0.060 Combined Thickness)	YES
21		0.050–0.100 (0.150 Combined Thickness)	YES
22		0.080–0.025–0.080 (0.185 Combined Thickness)	NO
23		0.063–0.125 (0.188 Combined Thickness)	YES
24		0.065–0.100 (0.165 Combined Thickness)	NO

Table of Examples in Millimeters

Example Number	Machine Qualifications— Low & High	Production Weld Combination in Question— Stack up from top to bottom	Is Production Weld Combination Covered by Machine Qualifications?
1	0.41–0.41 (0.81 Combined Thickness) & 2.03–2.03 (4.06 Combined Thickness)	0.41–0.25 (0.66 Combined Thickness)	NO
2		0.41–1.02 (1.42 Combined Thickness)	YES
3		1.02–1.02 (2.03 Combined Thickness)	YES
4		1.02–2.03 (3.05 Combined Thickness)	YES
5		2.08–2.08 (4.17 Combined Thickness)	NO
6		3.05–1.02 (4.06 Combined Thickness)	YES
7		0.30–0.25–0.25–0.41 (1.22 Combined Thickness)	NO
8		1.02–0.25–0.25–0.25–2.03 (3.81 Combined Thickness)	YES
9	0.25–0.36 (0.61 Combined Thickness) & 1.60–3.18 (4.78 Combined Thickness)	0.25–0.25 (0.51 Combined Thickness)	NO
10		0.30–0.30 (0.61 Combined Thickness)	YES
11		1.65–1.65 (3.30 Combined Thickness)	NO
12		1.27–3.30 (4.57 Combined Thickness)	YES
13		1.02–0.25–0.25–1.02 (2.54 Combined Thickness)	YES
14		1.98–1.27–1.27 (4.52 Combined Thickness)	YES
15		1.60–3.18 (4.78 Combined Thickness)	YES
16		1.98–1.42–1.42 (4.83 Combined Thickness)	NO
17	0.51–0.51 (1.02 Combined Thickness) & 1.60–1.60–1.60 (4.80 Combined Thickness)	0.51–0.25 (0.76 Combined Thickness)	NO
18		0.51–0.25–0.25 (1.02 Combined Thickness)	NO
19		0.51–0.51 (1.02 Combined Thickness)	YES
20		0.51–1.02 (1.52 Combined Thickness)	YES
21		1.27–2.54 (3.81 Combined Thickness)	YES
22		2.03–0.64–2.03 (4.70 Combined Thickness)	NO
23		1.60–3.18 (4.78 Combined Thickness)	YES
24		1.65–2.54 (4.19 Combined Thickness)	NO

F4. Explanation of Examples

Example 1: Thinnest production weld contact member (*0.010 in [0.25 mm]*) is thinner than thinnest contact member from the low end machine qualification test (*0.016 in [0.41 mm]*). Also, total combined thickness of production weld combination (*0.026 in [0.66 mm]*) is less than that of the low end machine qualification test (*0.032 in [0.81 mm]*).

Example 2: All requirements of 4.4.2.3 are met.

Example 3: All requirements of 4.4.2.3 are met.

Example 4: All requirements of 4.4.2.3 are met.

Example 5: Thinnest production weld contact member (*0.082 in [2.08 mm]*) is thicker than thinnest contact member from the high end machine qualification test (*0.080 in [2.03 mm]*). Also, total combined thickness of production weld combination (*0.164 in [4.17 mm]*) is greater than that of the high end machine qualification test (*0.160 in [4.06 mm]*).

Example 6: All requirements of 4.4.2.3 are met.

Example 7: Thinnest production weld contact member (*0.012 in [0.30 mm]*) is thinner than thinnest contact member from the low end machine qualification test (*0.016 in [0.41 mm]*).

Example 8: All requirements of 4.4.2.3 are met.

Example 9: Total combined thickness of production weld combination (*0.020 in [0.51 mm]*) is less than that of the low end machine qualification test (*0.024 in [0.61 mm]*).

Example 10: All requirements of 4.4.2.3 are met.

Example 11: Thinnest production weld contact member (*0.065 in [1.65 mm]*) is thicker than thinnest contact member from the high end machine qualification test (*0.063 in [1.60 mm]*).

Example 12: All requirements of 4.4.2.3 are met.

Example 13: All requirements of 4.4.2.3 are met.

Example 14: All requirements of 4.4.2.3 are met.

Example 15: All requirements of 4.4.2.3 are met.

Example 16: Total combined thickness of production weld combination (*0.190 in [4.83 mm]*) is greater than that of the high end machine qualification test (*0.188 in [4.78 mm]*).

Example 17: Thinnest production weld contact member (*0.010 in [0.25 mm]*) is thinner than thinnest contact member from the low end machine qualification test (*0.020 in [0.51 mm]*). Also, total combined thickness of production weld combination (*0.030 in [0.76 mm]*) is less than that of the low end machine qualification test (*0.040 in [1.02 mm]*).

Example 18: Thinnest production weld contact member (*0.010 in [0.25 mm]*) is thinner than thinnest contact member from the low end machine qualification test (*0.020 in [0.51 mm]*).

Example 19: All requirements of 4.4.2.3 are met.

Example 20: All requirements of 4.4.2.3 are met.

Example 21: All requirements of 4.4.2.3 are met.

Example 22: Thinnest production weld contact member (*0.080 in [2.03 mm]*) is thicker than thinnest contact member from the high end machine qualification test (*0.063 in [1.60 mm]*).

Example 23: All requirements of 4.4.2.3 are met.

Example 24: Thinnest production weld contact member (*0.065 in [1.65 mm]*) is thicker than thinnest contact member from the high end machine qualification test (*0.063 in [1.60 mm]*).

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

Designation	Title
D17.1/D17.1M	<i>Specification for Fusion Welding for Aerospace Applications</i>
D17.2/D17.2M	<i>Specification for Resistance Welding for Aerospace Applications</i>
D17.3/D17.3M	<i>Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications</i>

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