

Specification for Resistance Welding for Aerospace Applications



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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 welding schedule qualification, production witness samples, and inspection and acceptance criteria for aerospace hardware.



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Foreword

This foreword is not part of this standard, 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 third 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.

A vertical line in the margin and underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2013 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 NW 36th Street, Suite 130, Miami, 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 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) 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 documents listed below are referenced within this publication and are mandatory to the extent specified herein. 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*.

[AWS A2.4](#), *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.

[NAS 410](#), *NAS Certification & Qualification of Nondestructive Test Personnel*.

3. Terms and Definitions

[AWS A3.0M/A3.0](#), *Standard Welding Terms and Definitions*, 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 spot welds. Spot welds on sheet placed less than two diameters apart (D_s , as defined in Table 11), 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.

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.

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.

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].

welding 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.

welding 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 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.

4.1.2 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.

4.1.3 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.

4.1.4 Spot Weld Certification. There shall be two methods of certification for spot welding schedules:

- 1) Standard Certification and
- 2) Design Allowable Certification

4.1.4.1 Standard Certification. The standard method for certification of a spot welding schedule is based on the material type, sheet thickness, and a corresponding shear load value as specified by this specification. The welding schedule shall be certified to the requirements of Tables 1 through 3 (sheet) or Table 4 (foil) and the requirements of Clause 4.6.

4.1.4.2 Design Allowable Certification. The design allowable certification method is based on a welding schedule that meets a minimum shear strength value or weld nugget size as specified on the engineering drawing by the Engineering Authority.

When design allowable certification is used, the minimum strength value or nugget size, and weld class shall be specified on the engineering drawing. This certification method is limited to spot welds in sheet, except that it shall not be used for close-spaced spot welds.

The Design Allowable Certification method is intended to routinely permit the design and use of smaller welds where the design stress permits and space or equipment or material conditions compel; or to permit the design and use of stronger welds where the weld conditions are able to provide them. The provisions of the Design Allowable Certification method may be used to certify a welding schedule when unusual conditions apply: for example, when welds are made through adhesives or through protective finishes.

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 lbf per Spot Weld		Above 1275 MPa N ^b per Spot Weld		150 000 psi to 185 000 psi lbf per Spot Weld		1034 MPa to 1275 MPa N ^b per Spot Weld		90 000 psi to 149 999 psi lbf per Spot Weld		620 MPa to 1033.9 MPa N ^b per Spot Weld		Below 90 000 psi lbf 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 Alloys—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	
		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] ^d	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) ^{b,c}											
				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
in	mm	(N _o)	R												
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 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.

^c 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 specimen 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.

(S_x) is the modified minimum shear load in pounds per linear inch [newtons (N) per millimeter (mm)] of test specimen 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 d). 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 inch [spot welds per 25 mm] required in the table above. (i.e., see Notes a and d). If N_p is greater than $1.15N_o$, then the modified minimum shear load (S_x) is obtained by using the following formula:

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

(continued)