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28 March 1978
SUPERSEDING
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MILITARY SPECIFICATION

WELDING, RESISTANCE: SPOT AND SEAM

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

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

Group 1 - Aluminum and magnesium
Group 2 - Iron, nickel, and cobalt
Group 3 - Titanium

1.2 Classification. Classification is based on function and use of the welded joint, rather than certain average levels of strength. Therefore, reliability is the key underlying quality distinguishing the work for each class. The criteria described herein are intended to prevent larger variations in weld strength and quality than are compatible with the intended use.

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, loss of control, unintentional release or inability to release any armament store, failure of gun installation components; or which may cause significant injury to occupants of manned systems.

Class B - A welded joint whose failure would reduce the overall strength of the equipment or system or preclude the intended functioning or use of equipment.

Class C - A welded joint which is considered non-critical and for which no stress analysis is considered.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to the Aeronautical Systems Division, ENESS, WPAFB, Ohio 45433 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1.2.1 The classification of welds in foil thicknesses is limited to Class A and Class C.

2. APPLICABLE DOCUMENTS

2.1 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN WELDING SOCIETY (AWS)

AWS A3.0 - Terms and Definitions
AWS C1.1 - Recommended Practices for Resistance Welding

(Application for copies should be addressed to American Welding Society Inc., 2501 N.W. 7th Street, Miami, Florida 33125.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal Agencies.)

3. REQUIREMENTS

3.1 Design requirements.

3.1.1 Definition of terms used in this specification shall be in accordance with AWS A3.0, and as shown in 6.2 herein.

3.1.2 The class of welding shall be designated on the item specification or drawing. The design of Class A resistance welded joints shall require the specific approval of the procuring activity who may approve if satisfactory resistance welded prototypes exist, or upon evidence of the adequacy of the design and pattern of spot welding or upon the satisfactory performance of suitable static and repeated loading testing of the design or applicable prototype.

3.1.3 There shall be two methods of certification for spot welds. The Standard Certification method shall be for a weld schedule that certifies that the requirements of Tables I through III or IV, and all other applicable weld property requirements have been met. The Design Allowable Certification method shall be a weld schedule that certifies a guaranteed strength value has been met.

TABLE I. Shear strength requirements for spot weld sheet specimens.

GROUP 1 ALLOYS								
Nominal Thickness of Thinner Sheet, inch	Ultimate Strength 56,000 psi and above		Ultimate Strength 35,000 to 55,999 psi		Ultimate Strength 19,500 to 34,999 psi		Ultimate Strength below 19,500 psi	
	lb per spot		lb per spot		lb per spot		lb per spot	
	min	min avg	min	min avg	min	min avg	min	min avg
0.010	60	75	50	65	--	--	--	--
0.012	75	95	65	85	30	40	20	25
0.016	110	140	100	125	70	90	50	65
0.018	125	160	115	145	85	110	65	85
0.020	140	175	135	170	100	125	80	100
0.022	160	200	155	195	120	150	95	120
0.025	185	235	175	200	145	185	110	140
0.028	215	270	205	260	175	220	135	170
0.032	260	325	235	295	210	265	165	210
0.036	305	285	275	345	255	320	195	245
0.040	345	435	310	390	300	375	225	285
0.045	405	510	370	465	350	440	260	325
0.050	465	585	430	540	400	500	295	370
0.050	555	670	515	645	475	595	340	425
0.063	670	840	610	765	570	715	395	495
0.071	825	1,035	720	900	645	810	450	565
0.080	1,025	1,285	855	1,070	765	960	525	660
0.090	1,255	1,570	1,000	1,250	870	1,090	595	745
0.100	1,490	1,865	1,170	1,465	940	1,175	675	845
0.112	1,780	2,225	1,340	1,675	1,000	1,255	735	920
0.125	2,120	2,650	1,625	2,035	1,050	1,315	785	985
0.140	2,525	3,160	1,920	2,400	--	--	--	--
0.160	3,120	3,900	2,440	3,050	--	--	--	--
0.180	3,725	4,660	3,000	3,750	--	--	--	--
0.190	4,035	5,045	3,240	4,050	--	--	--	--
0.250	7,350	9,200	6,400	8,000	--	--	--	--

TABLE I(SI)*. Shear strength requirements for spot weld sheet specimens.

GROUP 1 ALLOYS								
Nominal Thickness of Thinner Sheet	Ultimate Strength 386 MPa and above		Ultimate Strength 240 to 385.9 MPa		Ultimate Strength 135 to 239.9 MPa		Ultimate Strength below 135 MPa	
	N per spot		N per spot		N per spot		N per spot	
millimeters	min	min avg	min	min avg	min	min avg	min	min avg
0.25	265	335	225	290	--	--	--	--
0.30	335	425	290	380	135	175	90	110
0.40	490	625	445	555	310	400	225	290
0.45	555	710	510	645	380	490	290	380
0.50	625	780	600	755	445	555	355	445
0.55	710	890	690	865	535	665	425	535
0.65	825	1,045	780	890	645	825	490	625
0.70	955	1,200	910	1,155	780	980	600	755
0.80	1,155	1,445	1,045	1,310	935	1,180	735	935
0.90	1,355	1,710	1,225	1,535	1,135	1,425	865	1,090
1.00	1,535	1,935	1,380	1,735	1,335	1,670	1,000	1,270
1.10	1,800	2,270	1,645	2,070	2,555	2,955	1,155	1,445
1.30	2,070	2,600	1,910	2,400	1,780	2,225	1,310	1,645
1.40	2,470	2,980	2,290	2,870	2,110	2,645	1,510	1,890
1.60	2,980	3,635	2,715	3,400	2,535	3,180	1,755	2,200
1.80	3,670	4,605	3,200	4,005	2,780	3,600	2,000	2.515
2.00	4,560	5,715	3,805	4,760	3,400	4,270	2,335	2,935
2.30	5,580	6,985	4,450	5,560	3,870	4,850	2,645	3,315
2.50	6,630	8,295	5,205	6,515	4,180	5,225	3,000	3,660
2.80	7,915	9,895	5,960	7,450	4,450	5,580	3,270	4,090
3.20	9,430	11,785	7,228	9,050	4,670	5,850	3,490	4,380
3.60	11,230	14,055	8,540	10,675	---	---	---	---
4.10	13,880	17,345	10,585	13,565	---	---	---	---
4.60	16,570	20,730	13,345	16,680	---	---	---	---
4.80	17,950	22,440	14,410	18,015	---	---	---	---
6.40	32,695	40,920	28,465	35,585	---	---	---	---

*(SI) - International System of Unit.

TABLE II. Shear strength requirements for spot weld sheet specimens.

GROUP 2 ALLOYS								
Nominal Thickness of Thinner Sheet	Ultimate Strength above 185,000 psi		Ultimate Strength 150,000 to 185,000 psi		Ultimate Strength 90,000 to 149,000 psi		Ultimate Strength below 90,000 psi	
	lb per spot		lb per spot		lb per spot		lb per spot	
inch	min	min avg	min	min avg	min	min avg	min	min avg
0.009	200	245	175	210	130	160	100	125
0.010	245	305	205	255	160	195	115	140
0.012	350	410	275	340	200	245	150	185
0.016	480	595	400	495	295	365	215	260
0.018	590	725	490	600	340	415	250	305
0.020	635	785	530	655	390	480	280	345
0.022	730	905	610	755	450	550	330	405
0.025	870	1,075	725	895	530	655	400	495
0.028	1,025	1,260	855	1,055	635	785	465	575
0.032	1,250	1,545	1,045	1,280	775	955	565	695
0.036	1,500	1,850	1,255	1,545	920	1,140	690	860
0.040	1,750	2,150	1,460	1,065	1,065	1,310	815	1,000
0.045	2,100	2,600	1,795	2,210	1,285	1,585	1,005	1,240
0.050	2,450	3,000	2,125	2,620	1,505	1,855	1,195	1,475
0.056	2,880	3,550	2,550	3,145	1,770	2,185	1,460	1,800
0.063	3,550	4,375	3,090	3,815	2,110	2,595	1,760	2,170
0.071	4,200	5,150	3,730	4,595	2,535	3,125	2,080	2,560
0.080	4,850	6,000	4,410	5,440	3,005	3,705	2,455	3,025
0.090	5,600	6,900	5,090	6,275	3,515	4,335	2,885	3,560
0.100	6,300	7,750	5,720	7,050	4,000	4,935	3,300	4,070
0.112	7,000	8,600	6,365	7,855	4,545	5,610	3,795	4,675
0.125	7,785	9,600	7,080	8,730	5,065	6,250	4,300	5,310

TABLE II(SI)*. Shear strength requirements for spot weld sheet specimens.

GROUP 2 ALLOYS								
Nominal Thickness of Thinner Sheet	Ultimate Strength above 1275 MPa		Ultimate Strength 1034 to 1275 MPa		Ultimate Strength 620 to 1033.9 MPa		Ultimate Strength below 620 MPa	
	N per spot		N per spot		N per spot		N per spot	
millimeters	min	min avg	min	min avg	min	min avg	min	min avg
0.22	890	1,090	780	935	580	710	440	555
0.25	1,090	1,355	910	1,135	710	865	510	625
0.30	1,555	1,825	1,225	1,510	890	1,090	665	825
0.40	2,135	2,645	1,780	2,200	1,310	1,625	955	1,155
0.45	2,625	3,225	2,200	2,670	1,510	1,845	1,110	1,355
0.50	2,825	3,490	2,355	2,915	1,735	2,135	1,245	1,535
0.55	3,245	4,025	2,715	3,360	2,000	2,445	1,470	1,800
0.65	3,870	4,780	3,225	3,980	2,355	2,915	1,780	2,200
0.70	4,560	4,605	3,805	4,690	2,825	3,400	2,070	2,555
0.80	5,560	6,870	4,650	5,695	3,445	4,250	2,515	3,090
0.90	6,670	8,230	5,582	6,870	4,090	5,070	3,070	3,825
1.00	7,785	9,565	6,495	8,005	4,735	5,825	3,625	4,450
1.10	9,340	8,895	7,985	9,830	5,715	7,050	4,470	5,515
1.30	10,900	13,345	9,450	11,655	6,695	8,250	5,315	6,560
1,40	12,810	15,790	11,340	13,990	7,875	9,720	6,495	8,005
1.60	15,790	19,460	13,745	16,970	9,385	11,545	7,830	9,650
1.80	18,680	22,905	16,590	20,440	11,275	13,900	9,250	11,385
2.00	21,575	26,690	19,615	24,195	13,365	16,480	10,920	13,455
2.30	24,910	30,690	22,640	27,910	15,635	19,280	12,830	15,835
2.50	28,020	34,470	25,445	31,360	17,790	21,950	14,680	18,105
2.80	31,135	38,255	28,310	34,940	20,215	24,955	16,880	20,795
3.20	34,630	42,700	31,490	38,830	22,530	27,800	19,125	23,620

*(SI) - International System of Unit.

TABLE III. Shear strength requirements for spot weld sheet specimens.

GROUP 3 ALLOYS				
Nominal Thickness of Thinner Sheet	Ultimate Strength above 100,000 psi		Ultimate Strength 100,000 psi and below	
	lb per spot		lb per spot	
inch	min	min avg	min	min avg
0.010	205	265	160	210
0.012	275	360	200	260
0.016	400	520	295	385
0.018	490	635	340	445
0.020	530	690	390	510
0.022	610	795	450	585
0.025	725	945	530	690
0.028	855	1,110	635	825
0.032	1,045	1,360	775	1,000
0.036	1,255	1,630	920	1,200
0.040	1,460	1,900	1,065	1,385
0.045	1,795	2,340	1,285	1,670
0.050	2,125	1,760	1,505	1,910
0.056	2,550	3,320	1,770	2,300
0.063	3,000	3,900	2,110	2,730
0.071	3,380	4,400	2,395	3,115
0.080	3,810	4,960	2,700	3,510
0.090	4,290	5,570	3,040	3,955
0.100	4,760	6,170	3,380	4,395
0.112	5,320	6,800	3,785	4,925
0.125	5,950	7,700	4,220	5,490

TABLE III(SI)*. Shear strength requirement for spot weld sheet specimens.

GROUP 3 ALLOYS				
Nominal Thickness of Thinner Sheet	Ultimate Strength above 689.5 MPa		Ultimate Strength 689.5 MPa and below	
	N per spot		N per spot	
millimeters	min	min avg	min	min avg
0.25	910	1,180	710	935
0.30	1,225	1,600	890	1,155
0.40	1,780	2,310	1,310	1,710
0.45	2,180	2,825	1,510	1,980
0.50	2,355	3,070	1,735	2,270
0.55	2,715	3,535	2,000	2,600
0.65	3,225	4,205	2,355	3,070
0.70	3,805	4,940	3,380	3,670
0.80	4,515	6,050	3,445	4,450
0.90	5,580	7,250	4,090	5,340
1.00	6,495	8,450	4,735	6,160
1.10	7,985	10,410	5,715	7,430
1.30	9,450	12,275	6,695	8,495
1.40	11,340	14,765	7,875	10,230
1.60	13,345	17,345	9,385	12,145
1.80	15,035	19,570	10,625	13,855
2.00	16,945	22,060	12,010	15,610
2.30	19,080	24,775	13,520	17,590
2.50	21,170	27,445	15,035	19,550
2.80	23,665	30,245	16,835	21,905
3.20	26,465	34,250	18,770	24,420

*(SI) - International System of Unit

TABLE IV. Shear strength requirements for spot welds in foil.

Thickness of Outer Sheet	Defined Standard (Spots per Inch)	Group 1 Alloys		Group 2 & 3 Alloys			
		Ultimate Strength		Ultimate Strength			
		Above 56 ksi	Up to 56 ksi	Above 185 ksi	150 to 185 ksi	90 to 149 ksi	Up to 90 ksi
inch	No	Minimum Shear Strength, Pounds Per Inch, So					
0.001	40	30	20	90	80	65	45
0 002	20	60	40	180	160	130	90
0.003	12	100	65	300	260	205	150
0.004	10	135	90	405	350	285	190
0.005	9	165	115	490	425	340	235
0.006	7	185	125	540	475	380	275
0.007	6	210	140	630	550	440	320
0.008	5	235	160	690	610	490	355

TABLE IV(SI). Shear strength requirements for spot welds in foil.

Thickness of Outer Sheet	Defined Standard (Spots per 25mm)	Group 1 Alloys		Group 2 & 3 Alloys			
		Ultimate Strength		Ultimate Strength			
		386 MPa and over	Up to 386 MPa	Above 1275 MPa	1034 to 1275 MPa	620 to 1033.9 MPa	Below 620
milli-meters	No	Minimum Shear Strength, N/mm, So					
0.03	40	5.25	3.50	15.8	14.0	11.3	7.88
0.05	20	10.5	7.00	31.5	28.0	22.8	15.8
0.08	12	17.5	11.3	52.5	45.5	35.9	26.3
0.10	10	23.6	15.8	70.9	61.3	49.9	33.3
0.12	9	28.9	20.1	85.8	74.4	59.5	41.1
0.16	7	32.4	21.9	94.6	83.2	66.5	48.2
0.18	6	36.8	24.5	110.3	96.3	77.0	56.0
0.20	5	41.1	28.0	120.8	106.8	85.8	62.2

NOTES: 1. When the number of spots in a production part (Np) or representative specimen is less than 0.85No, the minimum shear strength shall be equal to:

$$\frac{Np}{No} \times (1.15)\ So$$

2. When the number of spots in a production part (Np) or representative specimen is more than $1.15N_o$, the minimum shear strength shall be equal to:

$$\frac{Np}{No} \times (0.90)\ So$$

3.1.3.1 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 they are wanted and the weld conditions are able to provide them. For a given joint a guaranteed strength value and weld class must be specified on the drawing.

3.1.3.2 The provisions of the Design Allowable Certification method may be used to certify a weld schedule when unusual conditions apply. For example, when welds are made through adhesives or through protective finishes or when it is desirable to use diffusion welds as integral reinforcements to nuggets or in lieu of nuggets.

3.1.4 When conditions are encountered which cause any of the requirements of this specification to be inapplicable, the contractor shall submit alternate procedures and requirements for approval by the procuring activity. The request for approval shall include a description of the conditions which render the requirements inapplicable, such as reduced flange widths and space limitations; and shall include data to indicate that the alternate procedures and requirements are adequate for the given application.

3.1.4.1 Granted approvals of alternate procedures shall remain in effect as complying with this specification until the contractor is notified otherwise by the procuring activity.

3.2 Materials and methods of preparation.

3.2.1 Material combinations.

3.2.1.1 Combinations not requiring specific approval. The metals listed below may be welded in any combination within each lettered grouping.

a. Aluminum and its alloys
b. Magnesium and its alloys
c. Titanium and its alloys
d. Plain carbon steels of less than 0.15 percent carbon
e. Austenitic steels; precipitation hardening steels; nickel and cobalt base alloys.

3.2.1.2 Combinations requiring approval. Use of the following metals requires specific approval of the procuring activity: Clad 7075 aluminum alloy in thicknesses less than 0.020 inch or 0.51 millimeter (mm); any aluminum alloy in the 2000 or 7000 series which is unclad; or any magnesium alloy which will be exposed to accelerating corrosion conditions like a marine environment.

3.2.1.3 Special requirements. Metal combinations not included in 3.2.1.1 shall require the following establishment of weld ductility. The average tensile (normal to spot plane) strength of twenty spot welded specimens shall be greater than 0.25 times the minimum average shear strength in Tables I through IV applicable to the subject alloy or as established for the Design Allowable Certification. This test may be conducted on specimens, as welded, or after subsequent heat treatment. Heat treatment is a later manufacturing operation and not the post weld current provided through welder electrodes. The production process shall specify the certified weld schedule plus the subsequent heat treatment used to demonstrate the weld ductility required herein.

3.2.2 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.

3.2.2.1 Group 1 materials.

3.2.2.1.1 Oxide coatings may be removed by mechanical treatment (such as sanding or wire brushing) or by chemical treatment.

3.2.2.1.2 The ability of a cleaning procedure to effectively prepare Group 1 materials for welding shall be demonstrated by ability of materials cleaned by the process to be welded in compliance with the Certification requirements of this specification. The cleaning procedure is a necessary component of the Certification weld schedule.

3.2.2.1.3 Conformity of test and production materials surfaces to those produced by the normal cleaning procedure shall be checked by surface resistance readings. Maximum values for test and production materials shall be established as indications of the conformity required for welding in compliance with this specification.

3.2.2.1.4 The minimum and maximum time span that is permitted between parts cleaning and parts welding shall be established by the contractor. The contractor shall demonstrate that no deterioration of surface conditions take place during typical holding or storage conditions during that span. Deterioration shall be excessive when high values lead to inability to meet Certification requirements. Conditions and limitations may be applied generally as to a standard process, or specifically as to an exceptional assembly or material combination where warranted.

3.2.2.1.5 When a cleaning procedure is changed, if the contractor can demonstrate that the new procedure produces the same results as the old procedure, recertification of weld schedules shall not be required. This conformity will be shown by (1) producing the same weld results as made during Qualification tests (with Certification quantities) with a weld heat change within ±10 percent of the established value and (2) showing a surface resistance average that is no more than 1.05 times that achieved by the replaced procedure.

3.2.2.1.6 Coatings which improve the corrosion resistance or sealing characteristics without affecting the weld properties may be applied prior to welding. Such finishes must be considered as final steps of the cleaning procedure and necessary conditions specified on the Certified weld schedule.

3.2.3 Joint thickness. Joint thicknesses are only limited to those thicknesses or combination of thicknesses on which Certification weld schedule can be established and production parts can be made to meet the production requirements of this specification.

3.2.4 Fitup. Mating parts assembled for welding shall be designed and 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 with manual pressure.

3.3 Equipment requirements.

3.3.1 Welding machines. The welding machine shall consist of a suitable source of electrical energy, means of adequately cooling the electrodes, and a means of reliably controlling and indicating the relative magnitude of the current, the welding force, and the time of current flow; to fulfill the requirements specified herein. The force and current controls shall operate so that no current can flow until the welding force is applied by the welding electrodes. It shall not be possible to reduce electrode force before current is terminated.

3.3.2 Electrodes. Suitable electrode material and shapes shall be used to perform welding in conformance with this specification.

3.3.3 Shear testing machines. The contractor shall provide spot weld shear testing machines as required. All shear testing machines shall be accurate within ±2 percent of the indicated reading. Portable spot weld shear test machines shall be checked for accuracy at intervals not to exceed 2 months.

3.3.4 Surface resistance indicators. The contractor shall provide one or more surface resistance indicators for checking the effectiveness of cleaning solutions and procedures engaged in preparing Group 1 metals for spot welding. Surface resistance indicators shall be checked for accuracy and recalibrated as necessary.

3.3.5 Jigs and fixtures. 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, shall be made of nonmagnetic materials insofar as possible. Jigs and fixtures must be so designed that no welding current can shunt through them instead of passing through the work pieces.

3.3.6 Maintenance of equipment. Unless otherwise specified, each item of equipment shall be inspected periodically as recommended by the manufacturer. Adequate preventative maintenance shall be furnished. Defective equipment parts affecting machine operation shall be replaced before production welding is resumed.

3.4 Qualification of welding machines.

3.4.1 Qualification approval. Qualification is performed on a distinctive resistance spot or seam welding machine to determine the ability and consistency of operation of a machine type at a facility. Qualification has as a purpose to identify and verify the range of welding that a facility may, for contractual purposes, be considered capable. To have his equipment qualified and approved for use the contractor shall perform the tests specified herein under the surveillance of the procuring activity. Weld conditions shall be documented on a Machine Qualification Test Report. Typical examples of report forms are given in AWS C1.1. Such forms may be modified or expanded as required. Weld conditions and test results shall be submitted with an application for approval to the procuring activity. After approval is indicated, these reports shall be posted near the machine so as to be available to contractor operators and inspectors, and agents of the procuring activity.

3.4.1.1 Qualification by one procuring activity of the Department of Defense shall be Qualification for all DOD procuring activities and for those other governmental agencies who elect to subscribe to this specification.

3.4.2 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. When one machine of a distinctive type in a plant

site passes the Qualification tests all other machines of the same type shall be considered qualified. Machines used for Class C foil welding are qualified just by establishing a weld schedule Certification. Machines qualified to a class for seam welding shall be considered qualified for roll spot welding to the same class.

3.4.2.1 Types of equipment. Distinctive types of equipment must include those differing in any of the following respects:

a. Manufacturer of machine
b. Manufacturer of control panel
c. Type of machine, or model number
d. Electrical rating or capacity
e. Type of electrical energy
f. Type of pressure application.

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

3.4.2.3 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 commonly used in resistance welded products.

3.4.2.4 Combination selection. For each group of alloys, two test sets shall be required. One at the highest, one at the lowest end of the range for which the Qualification is desired. This normally means that the thickest to thickest metal combination on one end and the thinnest to thinnest on the other end.

3.4.2.4.1 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.

3.4.2.5 Test specimen requirements. Weld test and examination requirements are shown in Table V.

3.4.2.6 Weld machine requalification. When the equipment has once been qualified, it need not be requalified for other contracts or production lots. A change of location within a plant, not involving a change in power source, or maintenance, or parts replacement does not necessitate requalification. Requalification shall be required if the machine is rebuilt or if significant operational changes are made in it. Existing machine Qualifications made under superseded revision of this specification shall be honored.

3.5 Weld schedule certification.

3.5.1 Certification. Tests shall be conducted to determine if a particular machine, in combination with a specific weld schedule and other specific conditions, will produce on a given set of materials

TABLE V. Machine qualification test specimen requirements.

Alloy Group	Class	Specimen	Amount Per Set	Visible 3.6.1	Radio-graphic 3.6.2	Mechanical 3.6.4	Metallographic 3.6.3
SPOT WELDS - SHEET							
1	A	Fig. 1b	105 welds	All	All	100 shear	5 microsections
	B,C	Fig. 1b	105 welds	All	None	100 shear	5 macrosections
2,3	A	Fig. 1a or b	105 welds	All	All	100 shear	5 microsections
	B,C	Fig. 1a or b	105 welds	All	None	100 shear	5 macrosections
SPOT WELDS - FOIL							
1,2,3	A	Fig. 3	12 in. or 300 mm	All	All	10 shear	2 microsections
	C	Fig. 4	See 3.4.2				
SEAM WELDS - SHEET							
1,2,3	A	Fig. 5	24 in. or 600 mm	All	All	None	8 microsections
	B,C	Fig. 5	24 in. or 600 mm	All	None	None	8 macrosections
SEAM WELDS - FOIL							
1,2,3	A	Fig. 6	12 in. or 300 mm	All	All	Pressure Test (3.6.4.3.1.1)	2 microsections
	C	Fig. 4	See 3.4.2				

resistance welds that conform to the requirements of specification. Documentation of these tests will be contained in a completed Certification Test Report that will be available to agents of the procuring activity. In addition, the weld schedule shall be posted near the machine and be available to machine operators, inspectors, and agents of the procuring activity.

3.5.2 Certification test reports. For each machine and each combination of relevant material conditions (such as alloy, temper, surface conditions, and thickness combinations), the contractor will determine the effective weld machine settings for test and production parts. The schedule of conditions and parameters shall be formally entered on a report form before the test welding. Typical examples of report forms are given in AWS C1.1. These shall be modified or expanded as required. After acceptance, production setups shall be made to the schedule therein given, with the scheduled latitude of 4.2.6 allowed.

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

3.5.3 Test vs. production conditions. It is the purpose of Certification to show the results that can be expected on production parts. It is necessary then to produce a correspondence between test conditions and production conditions. The material conditions (3.5.2) must be replicated in parts and material for weld tests. Any other production condition known to be relevant must be part of the test. These include, for example, curvature of the parts, mandrels in lieu of electrodes, large magnetic tools lying in the weld machine throat, narrow edge distances, offset or shaped electrodes tips, time spans (minimum and maximum) between final preparation and welding, initial and final surface preparations, and close spot spacing. A test of relevancy may be that the average nugget diameters in the part will equal the average Certification nugget diameters when produced by any machine weld heat seetings not further than 10 percent from the Certification heat settings.

3.5.4 Certification test specimen configuration and examination requirements. Tests shall be as specified in Tables VI through IX and as shown in Figures 1 through 6.

TABLE VI. Certification specimen and examination requirements.

SPOT WELDS - SHEET								
					EXAMINATION			
Type	Alloy Group	Class	Specimen	Number of Welds	Visible 3.6.1	Radiographic 3.6.2	Mechanical 3.6.4.1	Metallographic 3.6.3
Isolated, or Roll Spot	1	A	Fig. 1a or b	25	All	All	20 Shear	5 Microsections
		B	Fig. 1a or b	15	All	None	10 Shear	5 Macrosections
		C	Fig. 1a or b	5	All	None	3 Shear	2 Macrosections
	2,3	A	Fig. 1a or b	13	All	All	10 Shear	3 Microsections
		B	Fig. 1a or b	8	All	None	5 Shear	3 Macrosections
		C	Fig. 1a or b	5	All	None	3 Shear	2 Macrosections
Close Space	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 VII. Certification specimen and examination requirements.

SPOT WELDS - FOIL							
				EXAMINATION			
Alloy Group	Class	Specimen Configuration	Length of Weld	Visible 3.6.1	Radiographic 3.6.2	Mechanical 3.6.4.2.1	Metallographic 3.6.3
1,2,3	A	Fig. 3	12 in. or 300mm	All	All	5 Shear Peel 3 in. (75mm)	2 in. or 50mm
	C	Fig. 4	12 in. or 300mm	All	None	Peel	None

TABLE VIII. Certification specimen and examination requirements.

SEAM WELDS - SHEET							
				EXAMINATION			
Alloy Group	Class	Specimen Configuration	Length of Weld	Visible 3.6.1	Radiographic 3.6.2	Mechanical	Metallographic 3.6.3.3
1,2,3	A	Fig. 5	12 in. or 300 mm	All	All	None	4 transverse micro-sections (Tr) 4 longitudinal micro-sections (Lo)
	B	Fig. 5	12 in. or 300 mm	None	None	None	4 transverse micro-sections (Tr) 4 longitudinal micro-sections (Lo)
	C	Fig. 5	12 in. or 300 mm	All	None	None	1 transverse macro-sections 2 longitudinal macro-sections

TABLE IX. Certification specimen and examination requirements.

SEAM WELDS - FOIL							
				EXAMINATION			
Alloy Group	Class	Specimen Configuration	Length of Weld	Visible 3.6.1	Radiographic 3.6.2	Mechanical	Metallographic
1,2,3	A	Fig. 6a	12 in. or 300mm	All	All	Pressure Test 3.6.4.3.1	1 in. or 25mm 3.6.4.5.1b
	C	Fig. 4	12 in. or 300mm	All	None	Peel 3.6.4	None

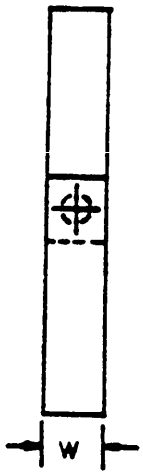


Figure 1a. Single spot shear specimen.

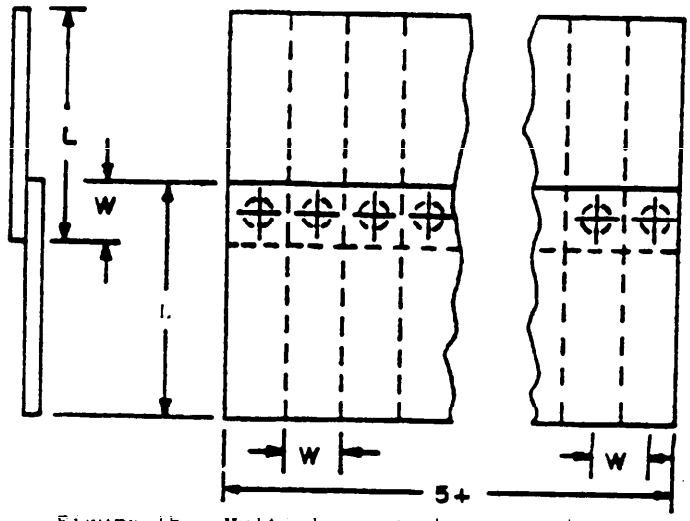


Figure 1b. Multiple spot shear specimen.

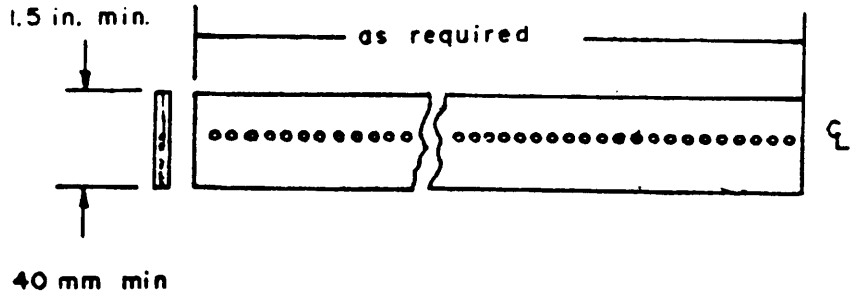
NOTE 1.

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 0.50 to 3.20,	32.0
Over 0.130	1.50	Over 3.20	38.0

NOTE 2. L shall be not less than 4W.

NOTE 3. Figure 1b shall be made of 5 specimens or more.

FIGURE 1. Spot welds in sheet.

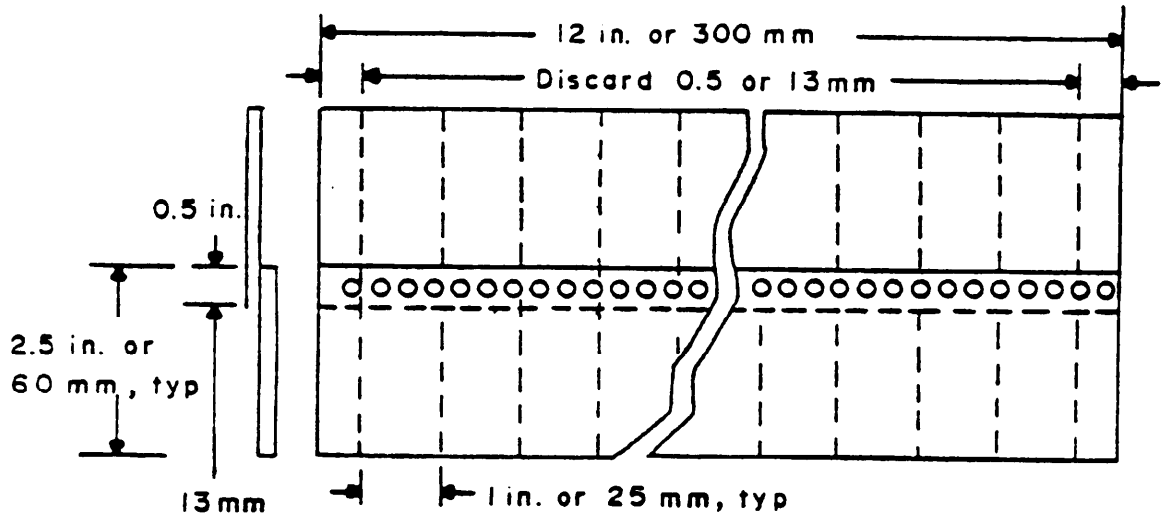


NOTE 1. Spot spacing shall be in accordance with the subject production part.

NOTE 2. Specimen lengths shall be as required.

NOTE 3. See 6.2.3 for definition of close space welds.

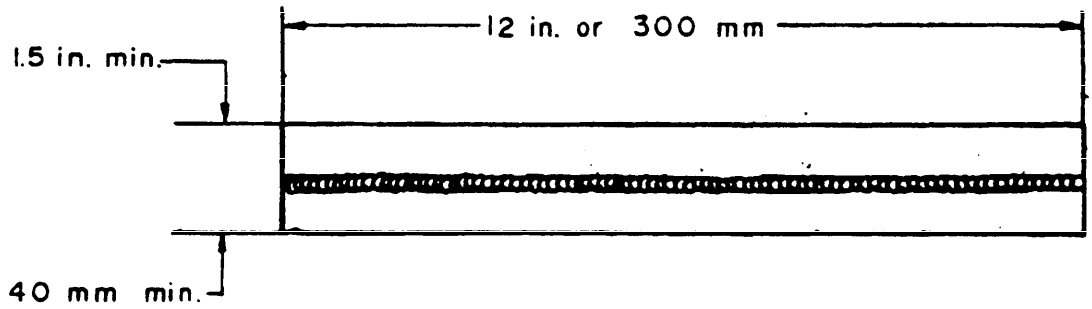
FIGURE 2. Close space spot welds in sheet.



NOTE 1. Spot spacing shall be in accordance with Table IV (Standard Spots per inch or mm) for Qualification, and in accordance with the subject production part for Certification.

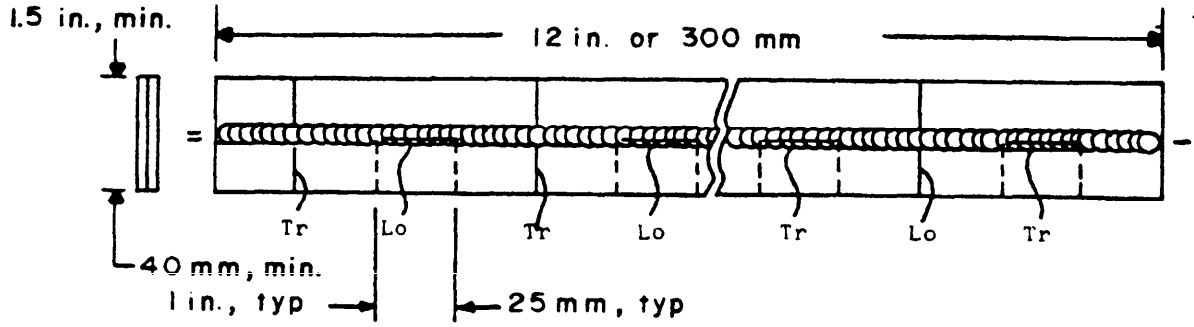
NOTE 2. For Class A, select at random 5 one-inch or 25-mm specimens for mechanical shear tests, 3 specimens for peel tests, and 2 specimens for metallographic examination.

FIGURE 3. Spot welds in foil.



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

FIGURE 4. Spot and seam welds in foil, peel specimen.



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

FIGURE 5. Seam welds in sheet.

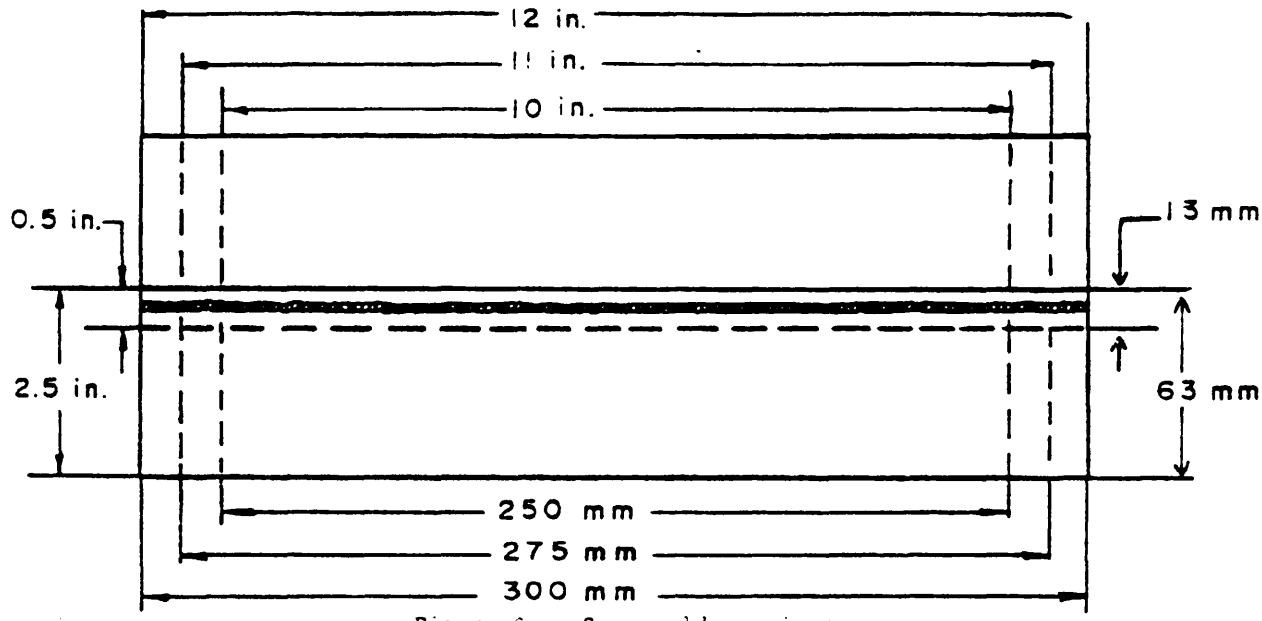


Figure 6a. Seam weld specimen.

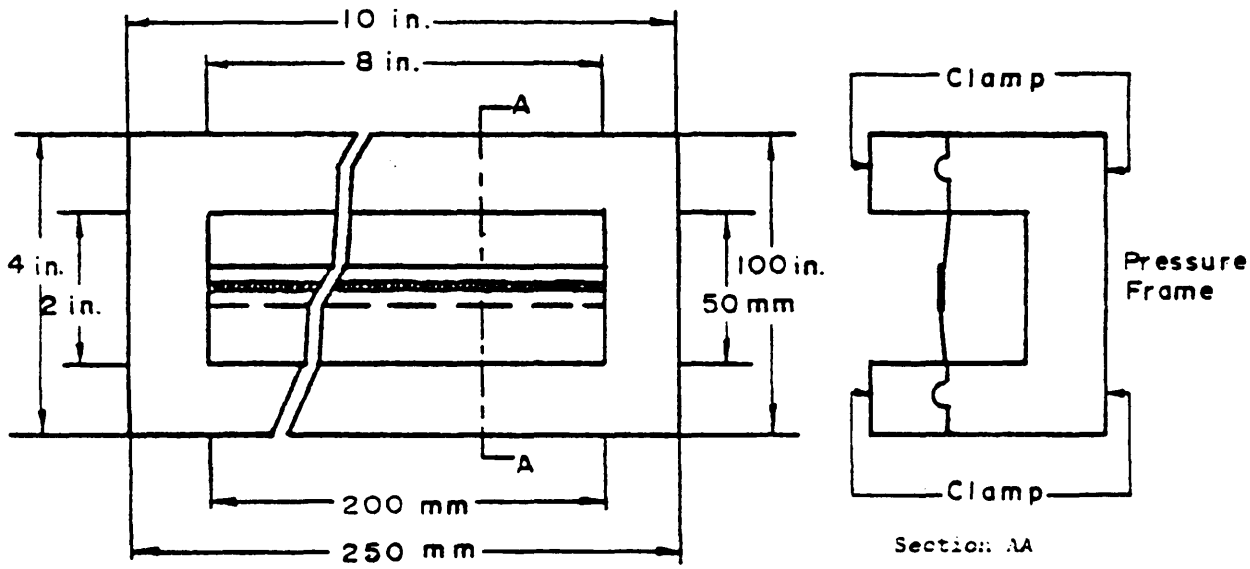


Figure 6b. Specimen in pressure fixture.

NOTE: After welding, discard the outside 0.5 in. or 13 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. or 250 mm remainder in the pressure fixture and test.

FIGURE 6. Seam welds in foil, class A.

3.5.4.1 Locate all welds in all figures within ±0.060 inch or ±1.5 mm of specimen centers. Specimen dimensions are given with a tolerance of ±0.060 inch or ±1.5 mm.

3.5.4.2 All multiple weld specimens shall be cut and dressed for testing after radiography is completed.

3.5.5 Thickness latitudes. Thickness combinations falling within the following limits shall not require separate certified weld schedules provided that the certified nugget size average can be reproduced with a weld heat (current) setting that lies within ±10 percent of the value established by the original Certification schedule; all other conditions being the same.

(a) Foil -

The variation in thickness (with regard to the original schedule) of outer sheet is within ±0.001 inch (±0.03 mm) and

The variation in the summed thickness of the combination is within ±0.003 inch (±0.08 mm).

(b) Sheet (outer) up to 0.040 inch (±1.02 mm), inclusive -

The variation in thickness of either outer sheet is within ±0.004 inch (±0.10 mm) and

The variation in the summed thickness of the combination is within ±0.006 inch (±0.16 mm).

(c) Sheet (outer) over 0.040 inch (1.02 mm) -

The variation in thickness of either outer sheet is within ±10 percent for Group 1 alloys, or ±20 percent for Groups 2 and 3 alloys and

The variation in the summed thickness of the combination is within ±10 percent.

3.5.6 Design allowable certification. A process weld schedule and conditions may be certified to produce any strength requirement specified on a drawing by conforming to the Design Allowable Certification requirements of this specification. This Certification method is limited to spot welds in sheet that are not close space spot welds. Examination results shall be entered on the test report. After acceptance, production setups shall be made to the schedule therein given, with the schedule latitude of 4.2.6 allowed.

3.5.6.1 Design allowable Certification requires the identification of the required strength, (G), on the applicable drawing. (See 3.1.3.) The Certification report shall state "These conditions certify a 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 denominator quantities (e.g., 300) may be changed by the part or systems designer through drawing notes or design specifications with the approval of the procuring activity.

3.5.6.1.1 Specimen requirements are given in Figure 1a or 1b. Examination requirements are given in 3.6.1 for visible and 3.6.4.1.3 and 3.6.4.1.4 for mechanical criteria.

3.5.7 Recertification. An existing weld schedule need not be recertified for other contracts or designs provided all material conditions are equal. A change of location within a plant not involving a change in power source or maintenance or parts replacement do not necessitate recertification. Recertification shall be required if the machine is rebuilt or if significant operational changes are made in it. Existing Certifications made under superseded revisions of this specification shall be honored. However, recertification of a welding schedule 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.

3.6 Weld property requirements. The weld acceptance criteria for Qualification and for Certification and production conducted under the standard certification method are given under 3.6.1 for visible; 3.6.2 for radiographic; 3.6.3 for metallographic; and 3.6.4 for mechanical. For Certification and production conducted under the Design Allowable Certification weld acceptance criteria fall under 3.6.1 for visible, and 3.6.4.1.3 and 3.6.4.1.4 for mechanical criteria.

3.6.1 Visible criteria - spot welds and seam welds.

3.6.1.1 Sheet separation. Separation between an inner and outer member is excessive when it exceeds a. or b., below, measured at a distance (radius) from the nugget center equal to 3 times the radius of the minimum nugget size given in Table X for the thinner member.

a. Greater than 0.15 times the summed thickness of the outer sheet and the one adjacent to it, or 0.006 inch (0.15 mm), whichever is greater, or

b. Greater than 0.003 inch (0.08 mm) between foil and the number adjacent to it.

TABLE X. Nugget size (all groups).

Nominal Thickness of Thinner Sheet inch	(mm)	Nugget Size inch	(mm)	Nominal Thickness of Thinner Sheet, inch	(mm)	Nugget Size inch	(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)				

3.6.1.1.1 Excessive separation is not acceptable on specimens.

3.6.1.1.2 Excessive separation is not acceptable on production work if it exceeds 0.03 times the Class A or 0.10 times the Class B or C production welds sampled for examination, when the product is raised to the next whole number.

3.6.1.2 Surface indentation. Indentations (see Figure 7) are not acceptable if their depth exceeds the following limitations (where, t is the thickness of the indented outer member).

3.6.1.2.1 Excessive indentation is not acceptable on specimens.

3.6.1.2.2 Excessive indentation is not acceptable on production work if it exceeds 0.03 times the samples of production welds measured in Class A welds; or in more than 0.10 times the samples measured in Class B and C welds, when the product is raised to the next whole number.

a. Sheet; Class A and B: 0.10 t or 0.005 inch (0.13 mm); whichever is greater.

b. Sheet; Class C: 0.20 t or 0.005 inch (0.13 mm); whichever is greater.

c. Foil; Class A and B: 0.30 t.

d. Foil; Class C: 0.40 t.

e. But when aerodynamic smoothness is a requirement, the outside indentation shall not exceed 0.004 inch (0.10 mm) on sheet and 0.20 t_o on foil.

3.6.1.3 Production parts. Certain other imperfections are limited in quantity by Table XI. The number of visible imperfections shall be calculated by multiplying the factor shown in Table XI times the number of welds inspected and raising the product to the next highest whole number. Parts or lots with imperfections exceeding the quantity as determined from Table XI shall be rejectable. Cracks open to the surface on seam welds shall be rejected and subject to a Material Review.

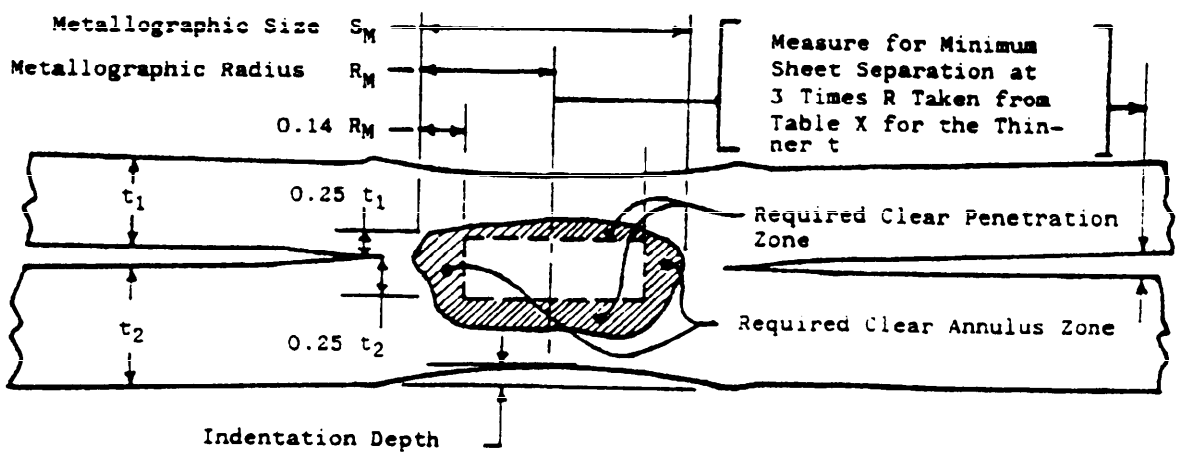


FIGURE 7. Nomenclature for metallographic spot weld sections and seam weld transverse sections.

TABLE XI. Visible external imperfections for production parts.

Nature of Weld Imperfections	Acceptance Factor (see 4.4.3)		
	Class A	Class B	Class C
Cracks open to surface	.00	.00	.05
Edge bulge cracks	.00	.00	.10
Surface pits over 0.063 inch (1.60 mm) dia.	.00	.00	.10
Surface pits under 0.063 inch (1.60 mm) dia.	.03	.05	.10
Flash and surface fusion	.03	.05	.10

3.6.1.4 Test specimens. Qualification, Certification, 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 penetration.

3.6.2 Radiographic criteria - spot welds and seam welds.

3.6.2.1 Qualification. All Class A test welds shall be examined for compliance with the following:

a. Welds shall be free of cracks and flash.

b. No pore or instance of incomplete fusion shall have a linear dimension greater than 0.15 S_T, where S_T is the nugget size as given in Table X.

c. No pore or instance of incomplete fusion shall extend into the outer 0.15 R_T required clear annulus as shown in Figure 8.

d. Porosity or incomplete fusion shall not have an aggregate area of greater than 5 percent in Group 1 alloy, or 10 percent in Group 2 and Group 3 alloys, when seen in the nugget area of the plane of the radiograph.

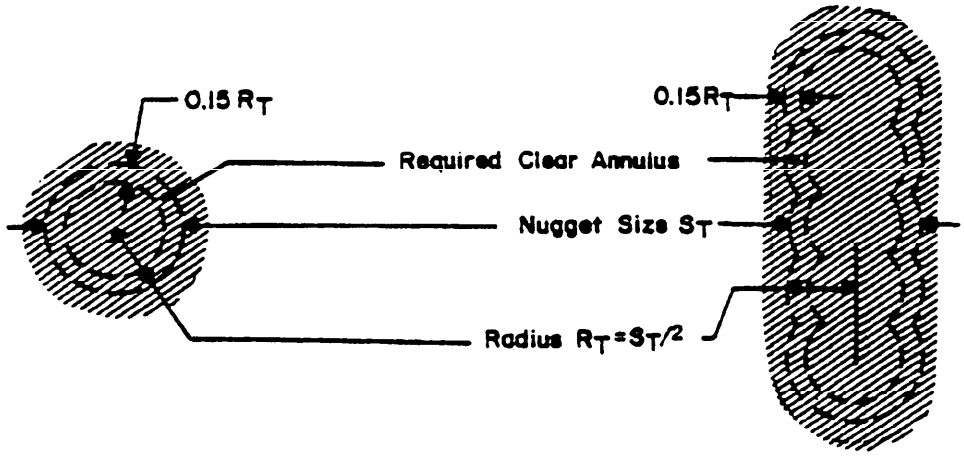


FIGURE 8. Nomenclature diagram of spot and seam weld radiographs.

3.6.2.2 Standard Certification. All Class A tests welds shall be examined for compliance with the following:

a. No crack, pore, or instance of incomplete fusion shall have a linear dimension greater than 0.15 S_T.

b. No pore or instance of incomplete fusion shall extend into the outer 0.15 R_T required clear annulus as shown in Figure 8.

c. Porosity or incomplete fusion shall not have an aggregate area of greater than 5 percent in Group 1 alloys, or 10 percent in Groups 2 and 3 alloys, when seen in the nugget area of the plane of the radiograph.

3.6.2.3 Production parts.

3.6.2.3.1 Class A or Class B parts. When radiography is required for Class A or Class B parts, the following standards shall apply.

a. No Class A or Class B part is acceptable as it is with a no-nugget (dud) where a weld was called for.

b. No Class A part is acceptable when any weld has a crack, pore, or instance of incomplete fusion that either has a linear dimension greater than 0.15 S_T or extends into the 0.15 R_T required clear annulus (also see 4.4.3).

c. No Class B part is acceptable when the number of welds in it that have cracks, pores, or instances of incomplete fusion with a linear dimension greater than 0.15 S_T or that extend into the 0.15 R_T required clear annulus is greater than 0.06 times the number of welds in the part. A lot of parts may be rejected if the number of welds radiographed indicates that 0.06 of welds in the lot have imperfections above requirements (also see 4.4.3).

3.6.2.3.2 Class C parts. Radiography is not applicable to Class C parts.

3.6.3 Metallographic criteria. The metallographic examination and acceptance criteria are applicable to Qualification, Standard Certification, and production witness specimens, and to production parts when tested. Metallographic and visible nomenclature are shown in Figures 7 and 9.

3.6.3.1 Internal imperfections. Cracks, porosity, and instances of lack of fusion are completely acceptable within the nugget of metallographic sections of test specimens, witness specimens, and production parts, unless they contain:

a. An imperfection extending into the 0.15 R_M required clear annulus zone.

b. An imperfection extending more than 0.25 times the thickness into that sheet (required clear penetration zone) for Class A and Class B welds or 0.50t for Class C welds.

c. An imperfection with its largest dimension exceeding the following fraction of nugget size: 0.10 for Class A welds, 0.15 for Class B welds, and 0.25 for Class C welds.

3.6.3.1.1 For Certification and Qualification, Class A and Class B weld specimens shall not have flashes or the imperfections of 3.6.3.1 a, b, and c, above.

3.6.3.1.2 For production witness specimens or parts sectioned for routine or postproduction tests the work preceding the test lot shall be rejected and subjected to material review procedures, if the imperfections of 3.6.3.1 a, b, and c, above, no-nuggets, or insufficient or excessive penetration exceed the fraction of the test lot permitted by Table XII. The maximum number permitted in each case shall be calculated by multiplying the factor shown in Table XII times the number of welds in the test group and raising the product to the next highest whole number. For this purpose, a test group shall be the instant accumulation of all metallographic sections run on a production lot through its completion or through the end of the shift, whichever occurs first. The provisions of 4.2.6, 4.4.3, and 4.4.4 shall continuously be applied.

3.6.3.1.3 Whenever a metallographic section of a production witness specimen or part reveals no-nugget, welding shall be stopped and prior-made parts shall be rejected and subjected to materials review procedures.

TABLE XII. Internal metallographic imperfections for production parts.

Nature of Weld Imperfection	Acceptance Factor		
	Class A	Class B	Class C
Porosity, Cracks and Incomplete Fusion (3.6.3.1)	.00	.06	N/A
Insufficient Penetration (3.6.3.2.4)	.00	.03	N/A
Excessive Penetration (3.6.3.2.5)	.00	.03	N/A
Insufficient Size (3.6.3.3)	.00	.03	N/A

3.6.3.2 Penetration. The extent of the nugget or fusion zone into the thickness of a joined member is called penetration. Penetration shall be measured at lines located at 0.8 of the nugget size, as shown in Figure 9.

3.6.3.2.1 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. (See Figure 9a.)

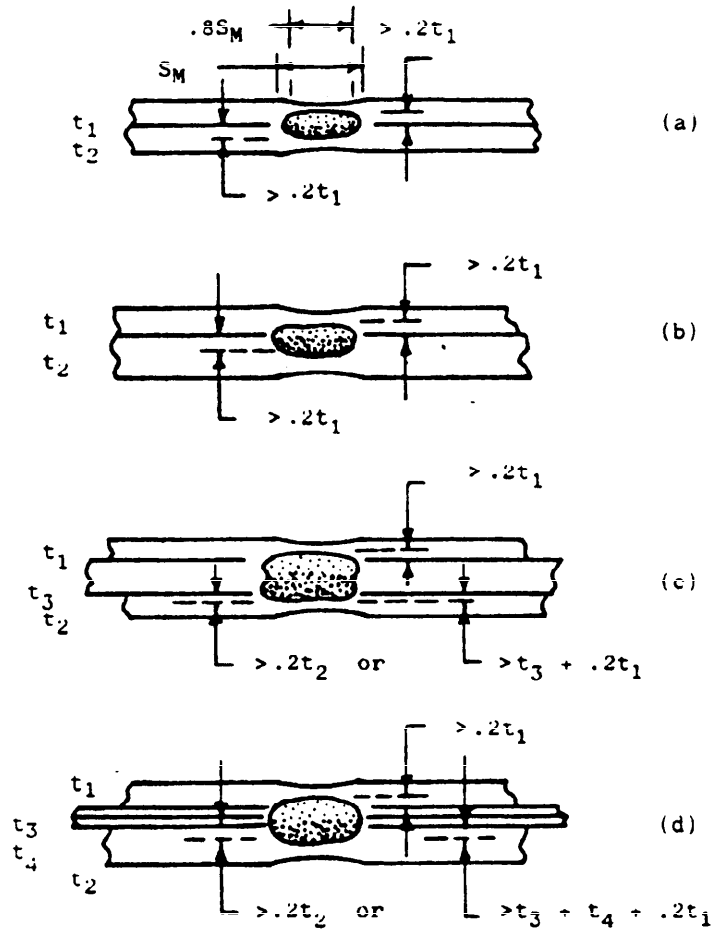


FIGURE 9. Penetration minima.

b. In two unequal-thickness members, penetration shall exceed 0.2 times the thickness of the thinner member, into each member. (See Figure 9b.)

c. In three or more thicknesses, penetration into the outer members shall exceed 0.2 times the thickness of the thinner member into the thinner member and either; (1) 0.2 times the thickness of the thicker outer member into the thicker outer member, or (2) the sum of the center members plus 0.2 times the thickness of the thinner member into the thicker outer member. (See Figure 9c or 9d.)

d. In three or more thicknesses, penetration into either side of an inner member shall exceed either; (1) 0.2 times its own thickness, or (2) the measured value of penetration into its adjacent partner; whose own minimum value is derived from c, above, it it is an outer member.

3.6.3.2.2 Maximum penetration. The upper limit of penetration for all resistance welds is the greatest depth of the fusion zone into the thickness (t) of either outer sheet. Penetration shall not exceed:

a. Group 1 materials. 0.8t for Class A and Class B welds, 0.9t for Class C welds.

b. Group 2 and 3 materials. 0.9t for all classes.

3.6.3.3 Nugget size. The minimum nugget size of Qualification, Standard Certification, and production witness specimens shall be those specified in Table X. In welds of two members of unequal thickness, the thinner member shall determine the required minimum nugget size at the interface. In multiple thickness welds, the thinner of two members at any interface shall determine the minimum nugget size from Table X, unless load carrying members are identified for the Certification combinations, such as in Figure 10c and 10d. In this case, the lesser thickness of the two load carrying members shall identify and be the determinant of minimum nugget size for each interface lying between them. Each nugget shall be measured at the subject interface plane on the metallographic section through the center of the nugget. Class A foil weld size may be measured by the size of the fractured peel specimen instead of a metallographic section, when the foil is an outer member.

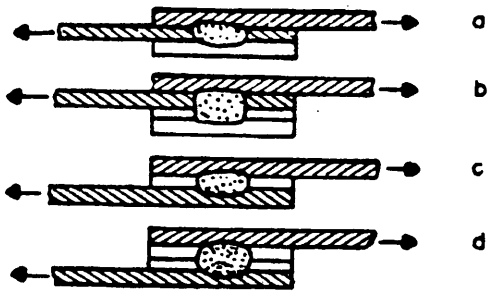


FIGURE 10. Shear tests of three or more thicknesses.

3.6.3.3.1 Qualification and 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 X, also requires that the largest weld not be more than 1.20 the size of the smallest.

3.6.3.3.2 Production specimens.

3.6.3.3.2.1 Nugget size measurement shall be the process control for close space spot welds and for seam welds, and may be an alternate method to spot shear tests of sheet (shear tests of production witnes specimens, 3.6.4.1.2). Size shall be measured on metallographic sections or peel specimens (3.6.3.3).

3.6.3.3.2.2 For Class A welds, the average size of welds in the test lot shall be not less than 0.9 times the average nugget size recorded for Certification or not more than 0.020 inch (0.51 mm) smaller than the Certification average, when the average is larger than 0.200 inch (5.08 mm). In multi-ply welds, this applies only to the interfaces beneath outside members, while the other interfaces must only meet the minimum requirements of Table X, determined in accordance with 3.6.3.3.

3.6.3.3.2.3 Class B and Class C welds shall meet the requirements of Table X determined in accordance with 3.6.3.3.

3.6.3.3.2.4 Welds which are examined for nugget size shall, at the same time, be visually examined for fusion and for evidence of obvious internal defects, such as cracks, porosity, lack of fusion, spits, and cladding inclusions. The incidence of these imperfections shall be limited by Table XII.

3.6.4 Mechanical criteria.

3.6.4.1 Spot welds - sheet.

3.6.4.1.1 Minimum. Each and every shear test specimen (such as Figure 1a or Figure 1b) shall equal or exceed the minimum strength required by Tables I through III. Improvement of method or equipment shall be made after a test failure before a retest is made on a material combination.

3.6.4.1.1.2 Average. The average shear strength shall equal or exceed the applicable minimum average strength specified in Tables I through III.

3.6.4.1.1.3 Consistency - Group 1 materials. For Class A and Class B welds, each of 90 percent of the number of welds tested, shall have shear strength values between 0.875 and 1.125 times the lot average. Each of the remaining 10 percent of the welds shall have shear strength values between 0.75 and 1.25 times the lot average. For Class C welds, the spread between the lowest and highest specimen shall be less than 0.35 times the lot average.

3.6.4.1.1.4 Consistency - Group 2 and 3 materials. For Class A and Class B welds, each of 90 percent of the number of welds tested, shall have shear strength values between 0.9 and 1.1 times the lot average. Each of the remaining 10 percent of the welds shall have shear strength values between 0.8 and 1.2 times the lot average. For Class C welds, the spread between the lowest and highest specimen shall be less than 0.33 times the lot average.

3.6.4.1.2 Production witness specimens. The spread between the lowest and highest specimen shall be less than 0.35 times the applicable production test lot average.

3.6.4.1.2.1 Class A. The test lot average shall be not less than 0.9 times the Certification average and no weld shall be less than the applicable minimum value shown in Tables I through III.

3.6.4.1.2.2 Class B and Class C. The test lot average shall be not less than the applicable value shown in Tables I through III.

3.6.4.1.3 Design allowable certification.

3.6.4.1.3.1 Minimum. The value of the lowest specimen in the test lot must exceed the specified design minimum.

3.6.4.1.3.2 Average. The test lot average (Ac) shall be recorded on the Certification report form.

3.6.4.1.3.3 Consistency. 95 percent of the number of specimens tested must have values greater than 0.875 times the test lot average (Ac).

3.6.4.1.4 Production witness specimens - design allowable certification.

3.6.4.1.4.1 The average strength of the production test lot shall be not less than 0.94 times Ac for Class A welds, and not less than 0.90 for Class B and Class C welds, without consideration of the provisions of 4.4.4.

3.6.4.1.4.2 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 Ac for Class A welds, 0.83 Ac for Class B welds, and 0.80 Ac for Class C welds.

3.6.4.2 Spot welds - foil.

3.6.4.2.1 Certification and Qualification.

3.6.4.2.1.1 Class A. Each shear specimen shall equal or exceed the applicable values in Table IV. In addition, the peel test run shall cause a button (plug) pull-out failure in 95 percent of the welds tested. The remaining 5 percent may fail at the interface plane, but the cleavage in each case shall be of a fused zone that is at least 0.80 times the average button size.

3.6.4.2.1.2 Class C. Peel tests shall cause a button pull-out failure in 85 percent of the welds tested. The remaining 15 percent may fail at the interface plane, but there shall be evidence of fusion at the interface in each case.

3.6.4.2.2 Production witness specimens. The required test lot shall be tested for compliance with the peel requirements only of 3.6.4.2.1.1 or 3.6.4.2.1.2.

3.6.4.3 Seam welds - foil.

3.6.4.3.1 Qualification and Certification requirements.

3.6.4.3.1.1 Class A. A pressure test specimen as shown in Figure 6 shall show no evidence of leakage through the joint while under a pressure greater than (1) 25 percent 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.

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

3.6.4.3.2 Production witness specimens.

3.6.4.3.2.1 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 percent of the weld length. The remaining portion of the weld length may fail by fracture across the faying plane, but the smallest nugget size (fusion) shall be not less than 0.80 times the average nugget size.

3.6.4.3.2.2 Class C. The weld specimen shall be tested in peel and shall meet the requirements of 3.6.4.3.1.2.

3.6.4.4 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 10. The strength requirements of such combinations shall be determined from Tables I through IV 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 bent 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.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Production quality control.

4.2.1 Production welding and inspection. Production welding shall be so accomplished as to obtain welds of consistent strength above the prescribed minimum and of acceptable metallographic structure, rather than welds of maximum strength without due regard to metallographic structures. The requirement for acceptable metallographic structure is not required by this specification when Design Allowable Certification is used. Welds shall be tested by the contractor under the surveillance of his authorized inspector.

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

4.2.3 Weld location. Welds shall be located as specified on the engineering drawing or applicable document. The edge distance of each weld shall be such that no deformation or bulging will occur at the edge of the sheet. Jigs shall be used whenever necessary to locate welds as specified above.

4.2.4 Test specimens. All test specimens, except Qualification specimens, shall conform to the production parts they represent with respect to material, thickness combination, and surface condition or preparation.

4.2.4.1 Witness specimens. Production witness specimens shall be run with production weld conditions and 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 (4.2.6), the Certification shall be run again with the subject critical production conditions included. Examples of such production conditions are, but are not limited to, magnetic material in the machine throat, curvature of the part, spot spacing, and part width.

4.2.5 Surface resistance. A daily check of the surface resistance in michohoms shall be made for Class A, Group 1 welds. 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 schedules or cleaning procedures, and the values of the surface resistance shall not exceed the limits of consistency and maximum values established at that time.

4.2.6 Control adjustments. When adjustment of the control settings is desirable, the settings may be varied by ±5 percent from the established certification values, or by ±10 percent when only one setting is adjusted. Rounded to the nearest unit this shall be called the permitted schedule latitude adjustment. Production welds must be made within ±5 percent 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. It it can be shown that conditions other than certified welding schedule conditions were the cause of faulty welding and with the correction of these conditions the original certified welding schedule is capable of producing acceptable welds, the establishment of a new certified welding schedule will not be required. For Class A welds, also see 4.4.4.

4.3 Production witness welds. The following welding shall accompany the welding of production parts to represent properties, such as material, thickness combinations, and surface conditions, of production parts not themselves tested. Results of these tests shall be maintained in a register by the welding machine. The witnessing of welding test lots by contractor quality control personnel may or may not be required by the contractor at his discretion.

4.3.1 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 XIII. Any of the quantities specified may be made on a simulation of the production joint or a production part.

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

b. Routine lot. At specified points or intervals in production welding and after an electrode change, or other minor welding equipment change.

TABLE XIII. Production witness welds, test lots.

Class	Specimen	Amount of Weld in Test Lot	Examination		
			Mechanical		Metallographic Requirement
			Test	Requirement	
SPOT WELDS - SHEET					
A	Fig 1a or 1b	3 welds	Shear	3.6.4.1.2 or 3.6.4.1.4	3.6.3.3
B	Fig 1a or 1b	3 welds	Shear	3.6.4.1.2 or 3.6.4.1.4	3.6.3.3
C	Fig 1a or 1b	3 welds	Shear	3.6.4.1.2 or 3.6.4.1.4	3.6.3.3
SPOT WELDS - SHEET - CLOSE SPACE					
A	Fig 2	3 weld	None		3.6.3.3
B	Fig 2	3 weld	None		3.6.3.3
C	Fig 2	3 weld	None		3.6.3.3
SPOT WELD - FOIL					
A	Fig 3	3 weld	Peel	3.6.4.2.1.1	3.6.3.3
C	Fig 4	1 in. or 75 mm	Peel	3.6.4.2.1.2	3.6.3.3
SEAM WELDS - SHEET					
A	Fig 5	3 in. or 75 mm	None		3.6.3.3
B	Fig 5	3 in. or 75 mm	None		3.6.3.3
C	Fig 5	3 in. or 75 mm	None		3.6.3.3
SEAM WELDS - FOIL					
A	Fig 4	3 in. or 75 mm	Peel	3.6.4.3.2.1	3.6.3.3
C	Fig 4	3 in. or 75 mm	Peel	3.6.4.3.1.2	3.6.3.3

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

4.3.2 Testing requirements.

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

a. Preproduction lot
b. Routine lot at each 1 hour interval or minor equipment change
c. Postproduction lot.

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

a. Preproduction lot
b. Routine lot at each 2 hour interval or minor equipment change
c. Postproduction lot.

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

a. Preproduction lot
b. Postproduction lot.

4.3.3 Table XIII identifies the kind and quantity of specimens required for each lot whose frequency is specified in 4.3.2. Each line of Table XIII identifies the kind and amount of welding in the test lot for each material group and kind of weld. The lengths of seam welds or specimens that the referenced figures give may be reduced to the values given in this table for these production tests.

4.3.3.1 Single spot welds established by the Standard Certification procedure may be controlled either by mechanical strength (3.6.4.1.2) or by nugget size with soundness examination (3.6.3.3). Spot welds established by the Design Allowable Certification are only required by this specification to meet the requirements for visible criteria of 3.6.1 and strength criteria of 3.6.4.1.4.

4.3.3.1.1 When mechanical tests are used to witness production weld compliance of spot welds established by the Standard Cerfification procedure, three welds will be added for metallographic examination (3.6.3.3) to the preproduction lot for Class A and Class B welding, and three welds for metallographic examination will be added to every fourth routine lot for Class A welds.

4.3.3.2 All specimens shall be visually examined in accordance with 3.6.1. Radiographic examinations of specimens shall not be required, unless otherwise specified in the applicable drawing or part specification.

4.3.3.3 The contractor may substitute nondestructive evaluation for routine lot tests upon approval of the procuring activity, provided he can demonstrate that the evaluation system will identify welds complying with strength or size requirements with a 99.5 percent reliability.

4.4 Inspection of production parts.

4.4.1 External imperfections. Welds shall be examined for compliance with the visible criteria (3.6.1) by determining the presence and number of imperfections on the following basis.

a. Class A parts - All welds.

b. Class B and Class C parts - On sampling plans established by the contractor and approved by the procuring activity.

4.4.2 Internal imperfections. Inspection for internal imperfections in production parts is not normally required. When specified on the applicable drawing or part specification, the inspections shall be made on randomly selected production parts. At the option of the contractor, inspection may be accomplished by:

a. Nondestructive radiographic examination (3.6.2.3.1)

b. Destructive metallographic examination (3.6.3).

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

a. 3.6.1.1.2, 3.6.1.2.2, and 3.6.1.3 for visible

b. 3.6.2.3.1 for radiographic

c. 3.6.3.1.2 for metallographic sizes.

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

a. 3.6.1.1.2, 3.6.1.2.2, and 3.6.1.3 for visible

b. 3.6.2.3.1 for radiographic

c. 3.6.3.1.2 for metallographic kinds.

4.4.3.1.1 The sum of all these imperfections shall not exceed 0.10 of the sample in Class A parts, 0.15 in Class B parts, and 0.20 in Class C parts. Spot welding work is acceptable without repair, when the quantities of imperfections are less than those permitted by a, b, and c, above, and the imperfections are randomly distributed and not clustered in one area, in one part, or in a group of parts.

4.4.3.2 When imperfections (of the size stipulated by 4.4.3) exceed the quantity limited by the paragraphs referenced in 4.4.3.1, 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. Such procedures shall be approved by the procuring activity prior to their use.

4.4.4 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 a new Certification weld schedule will not be required. Under conditions where the Certification weld schedule does not produce acceptable welds within the weld schedule latitude (4.2.6), then the Certification 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.

4.4.5 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 insofar as residual imperfections may be detrimental to the production part. The imperfections shall not exceed limits established for production parts.

5. PACKAGING

This section is not applicable to this specification.

6. NOTES

6.1 Intended use. This specification is intended to establish the basic controlling factors in the resistance welding process through Qualification of equipment and Certification of weld schedules, designation of material combinations, methods of preparing materials, and for methods of process control in the resistance welding.

6.2 Definitions.

6.2.1 Resistance spot welding. 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 limited primarily by the size and contour of the electrodes.

6.2.2 Resistance seam welding. 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.

6.2.3 Close space welds. Close space welds are spot welds on sheet placed less than two weld diameters apart, center to center. Such proximity requires more power than other spot welds.

6.2.4 Weld parameters. Weld parameters are machine settings or adjustments, such as, but not limited to, weld current, weld time, and electrode force.

6.2.5 Weld conditions. Weld conditions are all circumstances surrounding the making of a given weld, including material configuration and kind, material preparation, electrode shape, machine number and all weld parameters. Weld conditions that are relevant require documentation on the suggested forms.

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

6.2.7 Sheet. A thickness, for the purpose of this specification, of more than 0.008 through 0.250 inch (0.02 through 6.35 mm).

6.2.8 Foil. A thickness of 0.008 inch (0.02 mm) or less.

6.2.9 Nugget. The weld metal (cast) joining the parts in spot, seam, or projection welds.

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

6.2.11 Metallographic section. A metallographic section is 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 the near center of the weld and often etched to accentuate the metallographic structure. Microsections are prepared for examination at magnifications between 25 and 40X. Macrosections are prepared for examination at magnifications up to 10X.

6.2.12 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.

6.3 Solid state corona or diffusion weld effects.

6.3.1 The relation between weld strength and nugget size should be kept clear. Weld strength, normally a regular consequence of weld area, varies often from strict proportion because of the possible existence of a variable solid state weld around the cast nugget. Because this solid state weld varies widely with subtle surface conditions, the melted nugget diameter size itself is a superior index of the welding process consistency. The solid state corona, or diffusion weld confuses results by adding strength to the nugget strength. When it is occasional and strong, it causes a wide spread of specimen strengths. When it occurs regularly, Certification weld strengths may be considerably higher than the nugget strengths alone.

6.3.2 Certifications must be run in such a manner as to be free of the corona strength additions that may not occur in production parts (Group 1 in particular). On the other hand, when a diffusion weld can be produced so reliably as to be an integral and counted quality of Certification, then the production parts should be handled so that they will have the same diffusion weld in them.

6.4 Design consideration. The designer's ultimate interest lies in the strength of his assembly; this may be dependent either on average strength of the welds in a group or on a guaranteed minimum strength of each weld. The difference may be illustrated by the examples in 6.4.1 and 6.4.2.

6.4.1 A given weld schedule produces 300 welds that have an average strength of 1100 pounds and the lowest spot is 600 pounds. The guaranteed strength (G) in this case is 600 pounds. The guaranteed strength is usually the basis for design calculations, not the average strength of the welds. Thus, two members that must withstand a 33,000 pound load will be designed for 55 welds, (for example, 33,000 divided by 600). If the average spot strength was used, then only 30 welds, (for example, 33,000 divided by 1100), would be required.

6.4.2 Consider then, the affect of a weld schedule that raises the average, while lowering the guarantee. For example, an average of 1200 pounds with a guarantee of 500 pounds. Then, in spite of the average strength rise, the number of welds required would rise in this case to 66 welds, (for example, 33,000 divided by 500).

6.4.3 For economy's sake, the designer should establish when an entire joint depends on each weld meeting the guarantee (G) and when the weld array operates as a gang. In the latter, the strength of the joint can indeed be calculated to be the number of the welds times the weld average strength. With gang shear strength, the numerical example in 6.4.2 has the joint strength well satisfied by 28 welds, (for example, 33,000 divided by 1200 equals 27.5).

6.5 Certification and Production comparisons. A graphical method of showing the comparison of Certification and Production requirements is shown in two versions in Figures 11a and 11b.

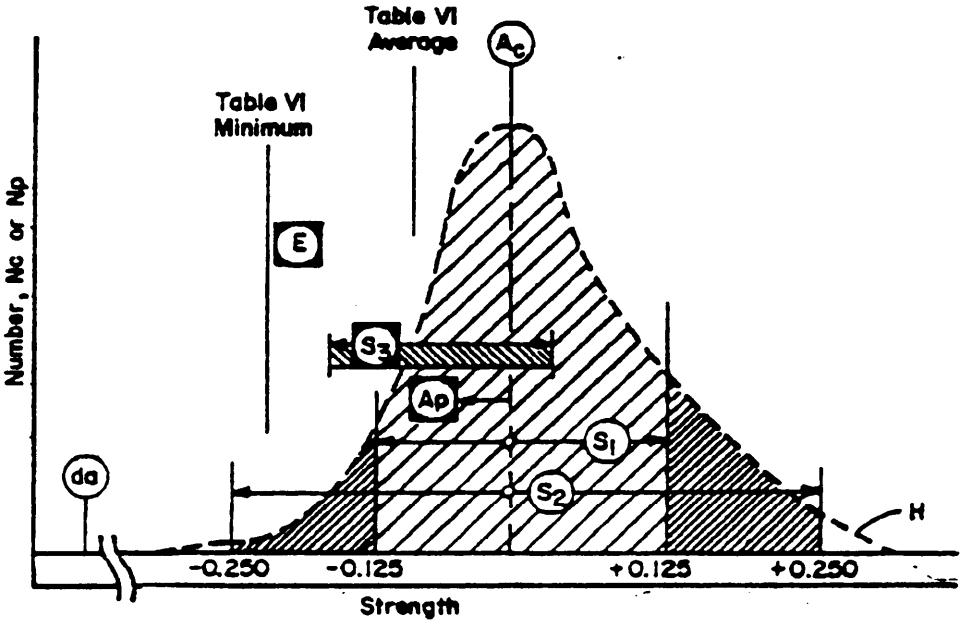
6.6 Marginal indicia. The margins of this specification revision have not been marked to indicate additions, changes, or deletions from the previous issue due to the extensive nature of all changes. Reviewers are cautioned to evaluate the specification as a whole in relation to the previous issue.

Custodians:
Air Force - 11
Navy - AS
Army - MR

User activities:
Air Force - 99
Navy - YD, SH

Preparing activity:
Air Force - 11

(Project THJM-0077)



CERTIFICATION (Ref. 3.6.4.1.1)

Nc Test lot size: 25 welds.

Ac Average strength given by the chosen weld conditions (must be greater than Tables I through III averages).

S_1 80% of the Nc specimens must lie within ±0.125Ac of Ac.

S_2 100% of the Nc specimens must lie within ±0.250Ac of Ac.

E Every specimen must be equal to or greater than the Tables I through III minimums.

H The actual distribution that would be seen if plotted.

da Handbook strength design values.

PRODUCTION (Ref. 3.6.4.1.2)

Np Production test lot size.

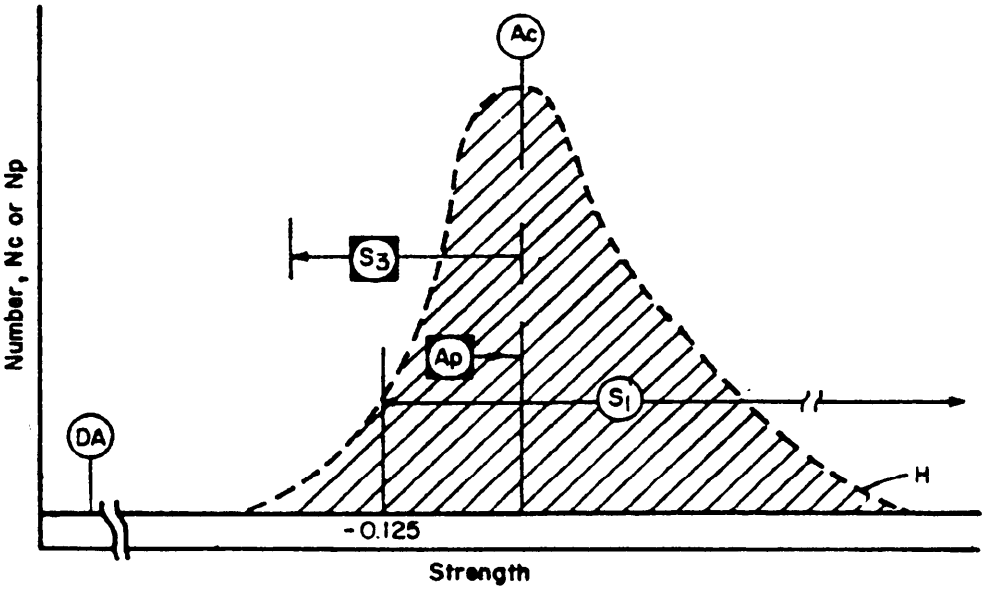
Ap The average of each test lot must be equal to or greater than 0.90Ac.

E Every specimen must be equal to or greater than the minimums of Tables I through III.

S_3 Variation (highest less lowest tested) must be equal to or less than 0.35Ap.

FIGURE 11a. Graphical summary of standard certification and production strength requirements.

(Example given for Class A, Group 1)



CERTIFICATION (Ref. 3.6.4.1.3)

Nc Test lot size: 300 welds.

Ac The mode value or the average of the distribution given by the chosen weld conditions.

S_1 95% of the Nc specimens must be greater than 0.875Ac.

DA The design value must be less than the value equal to the lowest specimen in 300 welds.

PRODUCTION (Ref. 3.6.4.1.4)

Np Production test lot size.

Ap The average of each test lot must be equal to or greater than 0.94Ac.

S_3 No specimens in nine welds less than 0.88Ac.

FIGURE 11b. Graphical summary of design allowable certification and production strength requirements.

(Example given for Class A, all groups)

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NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document*(s)* or to amend contractual requirements.

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER

2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION *(Mark one)*

- ☐ VENDOR
- ☐ USER
- ☐ MANUFACTURER
- ☐ OTHER *(Specify)*: _____

b. ADDRESS *(Street, City, State, ZIP Code)*

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional

c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional

8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426

PREVIOUS EDITION IS OBSOLETE.