Downloaded from http://www.everyspec.com

NASA

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

MSFC-SPEC-504B
REVISION B
EFFECTIVE DATE: 15 AUGUST 1984

SPECIFICATION: WELDING, ALUMINUM ALLOYS

PREPARED BY:

MATERIALS AND PROCESSES LABORATORY
SCIENCE AND ENGINEERING

Downloaded from http://www.everyspec.com

1/7/85

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

WELDING ALUMINUM ALLOYS

EB William R. Wilson	EH-42	9/21/84
Prepared by	Organization	Date
Approved by	Organization	Date
Carmelo J. Bianca, Jr.	EP42	10/11/84
Stress Approval	Organization	Date
Houston W. Oakley	EH02	10/16/84
Materials Approval	Organization	Date

Downloaded from http://www.everyspec.com

GEORGE C. MARSHALL SPACE FLIGHT CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HUNTSVILLE, ALABAMA

SPECIFICATION

WELDING, ALUMINUM ALLOYS

This specification has been approved by the George C. Marshall Space Flight Center (MSFC) and is available for use by MSFC and associated contractors.

1. SCOPE

1.1 Scope - This specification covers the guidelines for welding and the quality acceptance criteria for aluminum and aluminum alloy weldments, manual or automatic, which are made by gas tungsten arc, gas metal arc, or variable polarity plasma arc processes.

1.2 Classification - Welding performed under this specification shall be classified in accordance with the service requirements of the weldment as follows: (Also, See Table 1)

1.2.1 Class I - (Flight or non-flight) welds shall meet the highest strength and quality requirements specified.

1.2.2 Class II - (Flight or non-flight) welds shall meet the strength and quality requirements specified and be construed as capable of sustaining a tensile load of 80% of a Class I weld.

1.2.3 Class III - (Non-flight only) structural welds shall meet the highest strength and quality requirements specified with the exception of internal quality requirements (Section 3.11.).

1.2.4 Class IV - (Non-flight only) structural welds shall meet the strength and quality requirements specified with the exception of internal quality requirements (Section 3.11.) and be construed as capable of sustaining a tensile load of 80% of a Class I weld.

Downloaded from http://www.everyspec.com

1.2.5 Class V - Non-flight only welds which are non-critical, and non-structural shall have no strength specified but shall meet the quality requirements specified in 3.8.2.

CLASS / REQUIREMENTS	FLIGHT STRUCTURAL		NON-FLIGHT STRUCTURAL		NON-FLIGHT NON-STRUCTURAL
	1	2	3	4	5
100% STRENGTH	*		*		
80% STRENGTH		*		*	
INTERNAL QUALITY REQUIREMENTS	*	*			
EXTERNAL QUALITY REQUIREMENTS	*	*	*	*	*

TABLE I

WELD CLASS DEFINITION AND REQUIREMENTS

Downloaded from http://www.everyspec.com

2. APPLICABLE DOCUMENTS

2.1 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 proposals shall apply. When requirements in this specification and the requirements of any applicable document conflict, the requirements identified in this specification shall take precedence.

SPECIFICATIONS

Federal

BB-0925	Oxygen, Technical, Gas and Liquid
QQ-R-566	Rods, Welding, Aluminum and Aluminum Alloys

Military

MIL-T-1595	Tests, Aircraft and Missile Welding Operations' Qualification
MIL-E-16053	Electrodes, Welding, Bare, Aluminum Alloys
MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-A-18455	Argon, Technical
MIL-P-27407	Helium

STANDARDS

Military

MIL-I-6866	Dye Penetrant Inspection
MIL-STD-453	Inspection, Radiographic

George C. Marshall Space Flight Center

MSFC-STD-366	Penetrant Inspection Method
MSFC-STD-655	Standard, Weld Filler Material, Control of

(Copies of specifications, standards, procedures, drawings, and publications required by contractors in connection with specific procurement functions shall be obtained from the procuring agency or as directed by the contracting officer).

Downloaded from http://www.everyspec.com

2.2 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 proposals shall apply. When requirements of this specification and the requirements of any other publication conflict, the requirements of this specification shall take precedence.

American Society for Testing and Materials

ASTM-E-8	Methods of Tension Testing of Metallic Materials

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Penn. 19103).

American Welding Society

AWS A.2.0	Standard Welding Symbols
AWS A.2.2	Nondestructive Testing Symbols
AWS A.3.0	AWS Definitions - Welding and Cutting
AWS B.4.0	Standard Methods for Mechanical Testing of Welds

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

3. REQUIREMENTS

Unless otherwise specified on the engineering drawing or other controlling document weldments shall meet the requirements of Class I.

3.1 Welding Schedule - All production welding shall be performed in accordance with qualified welding schedules.

3.1.1 Schedule Qualification - Prior to welding of the first production part of each different configuration, a qualification weld shall be made to establish a satisfactory welding schedule (see 6.3.3).

The qualification weld shall simulate the production part with respect to section thickness, alloy, heat treat condition, joint preparation, pre-weld cleaning, and fitup and shall be made in either the actual production weld fixture or in a test fixture simulating the production fixture using the actual production welding equipment. The qualification weld shall be of sufficient length and width to provide the test specimens required by 3.1.1.4, 3.1.1.5 and 3.1.1.6.

Downloaded from http://www.everyspec.com

3.1.1.1 All machine welding parameters such as arc voltage, arc current, rate of travel and filler-wire feed rate shall be recorded during qualification welding. Manual weld parameters and operating parameter ranges shall be established during the schedule qualification.

3.1.1.2 The qualification weld shall be visually and nondestructively inspected as specified in 3.8.1.

3.1.1.3 Following visual and nondestructive inspection, the qualification weld shall be subjected to the processes affecting mechanical properties to which the production part will be subjected, such as reinforcement removal, mechanical deformation and thermal treatments associated with artifical aging, and stress relief.

3.1.1.4 Tensile Tests - A minimum of five specimens shall be tested for each qualification weld. Tensile specimens and test procedure shall conform to ASTM-E-8. Tensile specimens shall be tested to destruction at room temperature with a loading rate of 1.27 mm (0.05 in.) per minute head travel. Percent elongation in 2.5 cm (1 in.) and 5 cm (2 in.) and ultimate tensile load shall be recorded. Tensile strength shall meet or exceed 3.9.1.

3.1.1.5 Shear Tests - Fillet Welds - A minimum of five specimens shall be tested for each qualification weld. Shear specimens may be prepared and shear tested in accordance with AWS B.4.0 Standard Method for Testing of Welds in lieu of simulated production parts. The shear strength shall meet or exceed the requirements of 3.9.2.1.

3.1.1.6 Metallographic Sections - The welded joint for each weld type specified (butt and fillet) shall be sectioned transverse to the direction of welding and the surface of the section shall be ground and polished to suitable fineness. The polished section shall be examined visually (at a magnification of from 3 to 10 diameters) for fusion characteristics and weld defects. The section shall then be lightly etched to reveal macro-structure and reexamined at low magnification. The section shall be examined for properties in accordance with paragraphs 3.10 and 3.11.

(a) Overall fusion of the weld, root penetration, burn-through, and blowholes.
(b) Convexity, concavity, and size of bead or fillet.
(c) Undercutting and overlapping
(d) Inclusions or voids
(e) Cracks

Downloaded from http://www.everyspec.com

3.1.1.7 Welding Schedule - The qualification welding schedule including weld evaluation results, shall be prepared and retained as a permanent record. One copy shall be located at the welding station.

3.1.1.8 Welding Schedule Approval - Welding schedules and qualification results must be presented to MSFC for approval prior to use on flight hardware. The schedules must contain the welding parameters, identify the welding equipment and any pertinent information about the welding system used.

3.1.2 Schedule Departure - Departure from the qualified welding schedule during production welding shall require withholding or rejecting the part. The cause for departure shall be determined and corrective action taken prior to further production welding. (Reference 4.2.6).

3.1.3 Operator Qualification - Operators of automatic, semi-automatic or manual welding equipment shall be qualified in accordance with MIL-T-1595.

3.2 Material

3.2.1 Base Metal - Unless otherwise specified or approved by the procuring activity, the base metal shall be those alloys specified in Table I.

3.2.1.1 Base metals for qualification welding tests shall be identified by specification, type and condition, lot or heat number, and shall maintain lasting identification through all evaluation processes.

3.2.2 Filler Metal - Unless otherwise specified or approved by the procuring agency, filler metal alloy shall be selected in accordance with Table I. Filler metal shall conform to QQ-R-566 or MIL-E-16053 and shall be controlled by MSFC-STD-655.

3.2.3 Shielding Gas - Welding grade argon conforming to MIL-A-18455, helium conforming to MIL-P-27407, oxygen conforming to BB-0925, or a mixture of these gases shall be used for gas shielding.

3.2.4 Non-consumable Tungsten Electrodes - The size, shape and alloy shall be recorded as a part of the welding schedule (3.1).

3.3 Welding Equipment - Unless otherwise specified, the welding equipment shall be capable of producing acceptable welds when operated by a qualified operator in accordance with a qualified welding schedule.

Downloaded from http://www.everyspec.com

3.3.1 General - Welding equipment shall be capable of making satisfactory welds when operated by a qualified operator in accordance with a qualified welding schedule.

3.3.2 Acceptance Testing - New, repaired, relocated or modified welding machines shall be acceptance tested under the cognizance of the Quality Control Organization prior to release to manufacturing departments for production welding. Machines shall meet the requirements of the applicable purchase specification, design specification or modification order. Power supplies and supporting components (electrical or mechanical or both) shall be capable of operating reliably within the range of parameters and duty cycle to be used for welding of production parts.

3.3.3 Calibration - Measuring instruments, meters, gages, or direct reading electrical control circuits to be utilized for machine welding operations shall be initially calibrated, and periodically recalibrated at intervals not to exceed six (6) months or when any maintenance is performed which may have changed the calibration.

3.3.4 Maintenance - Welding machines shall be provided with adequate periodic preventive maintenance service.

3.3.5 Records - A current record of each maintenance repair, or functional check shall be maintained for each welding machine. Records shall be located on welding machines.

3.4 Tooling - Tooling and fixtures used in the welding operation shall be constructed of non-magnetic materials that do not affect the welding arc, and are not detrimental to the weld quality.

Downloaded from http://www.everyspec.com

TABLE II

FILLER ALLOYS APPLICABLE FOR WELDING

ALUMINUM ALLOYS AND COMBINATIONS

Base Aluminum Alloy	2014	2219	5052	6061*	5456
2014	4043 2319				
2219	2319 4043	2319			
5052			5356		
6061*	4043	4043	4043	4043	
5456	4043 5356	4043 5356	5356 5556	4043 5356	5356 5556

* Filler metal shall always be used when welding 6061.

3.5 Joint Design

3.5.1 Classes I, II, III & IV - Welded Joints - The technique of welding the initial passes from both sides where the weld roots overlap beneath the exposed surfaces (Figure IA) shall not be allowed. Prepared joints and/or multi-pass welds shall have a weld land (Figures 1B or 1D) which is completely penetrated on the initial pass. Partial penetration welds from one side are permissible provided the opposite side is machined into the penetration root prior to completing the weld. NDT procedures shall be employed to assure that the weld root has been exposed by machining. All penetration weld passes shall have no visual evidence of improper fusion or presence of dross. (These discrepancies can be readily detected by visual examination of the fracture plane after tensile tests of schedule qualification per paragraph 3.1.1.3.) Square Butt Joints (Figure 1C) shall be completely penetrated from one side.

3.5.2 Class V - Welded Joints - The technique of welding and joint geometry shall be as stated on the engineering drawing and/or determined by the contractor.

Downloaded from http://www.everyspec.com

3.6 Pre-weld Operations

3.6.1 Cleaning - Pre-weld cleaning of surfaces to be welded shall be accomplished in an environment which will not degrade the quality of the weld. The cleaned surfaces shall be maintained in an environment which is sufficiently controlled as to assure required quality welds.

3.6.2 Inspection - Prior to welding of each production part, a pre-weld inspection shall be performed in accordance with 4.2.

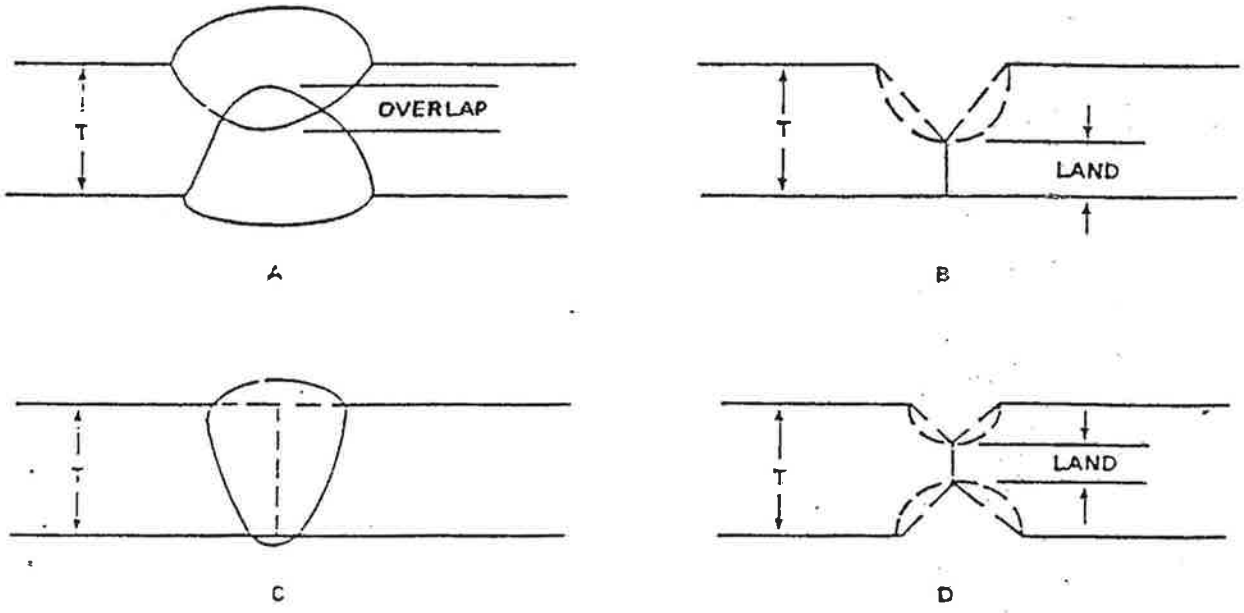


FIGURE 1

Downloaded from http://www.everyspec.com

3.7 Production Welding

3.7.1 A welding equipment operational readiness check weld shall be made immediately prior to a production weld to verify the equipment is operating in accordance with the qualified welding schedule.

3.7.2 Interpass Temperature - Interpass temperature shall be controlled so as to not degrade the mechanical properties of the material.

3.7.3 Repair Welding

3.7.3.1 Two additional welding operations may be permitted to correct any condition listed below provided that the repair welding parameters and procedures are specified in a qualified repair welding schedule, and the repair is contained within the original weld zone. Complete records of the repair welding operation including indentification of the repaired weldment, type of defect, and location of the repair weld shall be retained in permanent records.

(a) Underout
(b) Lack-of-fill
(c) Suck-back
(d) Incomplete penetration
(e) Off center weld nugget
(f) Oxides and porosity exposed to the surface

3.7.3.2 Any further weld repair attempts must be authorized by the Material Review Board.

3.7.3.3 Any weldment repair area shall be reinspected in accordance with 3.8.1.

3.8 Post-weld Operations

3.8.1 Inspection - Each completed weldment, and the base metal for 12.5 mm (1/2 in.) on either side of the weld edge, shall be inspected to assure compliance with the requirements of 3.8.2, and of 3.10, 3.11, 3.12, and/or 3.12.3 as dictated by the class of weld.

3.8.1.1 Nondestructive testing procedures to be employed in inspection for weldment internal and surface quality requirements shall be qualified/validated as being capable of detecting the weldment quality criteria prescribed, prior to inspection of the first production weld. The documentation proof of capability shall be retained as a permanent record. See 4.3.3.

Downloaded from http://www.everyspec.com

3.8.2 General Workmanship Requirements - When employing visual inspection, weld deposits, buildup, and root penetration shall display a smooth appearance or an even repetitive ripple. The edge of the weld deposit shall blend into the base metal without unfused overlaps or undercut. The face and root sides shall be free of surface cracks, crater cracks, and other defects open to the surface. Except in the case of fillet welds, both the crown and the penetration of the weldment shall be convex. The deposit shall be free of open voids or unfused overlapping folds.

3.8.3 Reinforcement Removal

3.8.3.1 Unless otherwise specified on the engineering drawing, the weld bead reinforcement may be removed to eliminate defects occurring in the outer zones of the reinforcement provided the section thickness of the base metal is not reduced below drawing requirements.

3.8.3.2 Following reinforcement removal, the affected weld area shall be inspected to assure compliance with 3.11 and 3.12.

3.8.4 Weldment Straightening - Welds and adjacent base metal which have been deformed by the welding operation may be straightened; however, prior to implementation the contractor shall verify by destructive testing and metallurgical evaluation that the process used for straightening shall not degrade the weld and surrounding material below specified design requirements.

3.8.4.1 Following weldment straightening, the weld and adjacent base metal shall be inspected in accordance with 3.8.1. Weldments in which discontinuities have been altered by such operations shall not be acceptable.

3.8.5 Weldment Heat Treatment - Weldments subjected to heat treatment operations shall subsequently be inspected for surface quality requirements of 3.12.

3.9 Weld Joint Strength Requirements

3.9.1 Butt Welds

3.9.1.1 Classes I and III butt welded joints shall meet the ultimate tensile strength requirements specified in Table III or on the Engineering Drawings when tested in accordance with 3.1.1.3. When dissimilar alloys are welded, the weld strength which pertains to the alloy having the lower tensile strength shall determine the minimum joint strength.

Downloaded from http://www.everyspec.com

3.9.1.2 Classes II and IV butt welded joints shall meet 80 percent of the Class I requirements.

TABLE III

BUTT WELD ULTIMATE TENSILE STRENGTH REQUIREMENTS

Alloy	Temper of Base Mat'l During Weld Operation	Post Weld Age Cycle	Thickness of Thinner Member of Weld Joint		Ultimate Tensile Strength			
					Average		Min Single Value	
			mm	Inch	Nx103/ cm^2	KSI	Nx103/ cm^2	KSI
2014	T6	As welded	< 3	< 1/8	31.4	45.5	29.7	43
			3-6	1/8-1/4	29.3	42.5	27.6	40
			> 6	> 1/4	27.9	40.5	26.2	38
2219	T81	As welded	All	All	27.6	40	26.2	38
	T87	As welded	All	All	27.6	40	26.2	38
	T3X*	350°F (177±C) for 18 hrs.	to 6	to 1/4	30.3	44	29.9	42
			> 6-13	>1/4-1/2	29.0	42	27.6	40
			>13-19	>1/2-3/4	30.3	44	29.0	42
			>19-25	>3/4-1	31.0	45	29.7	43
			>25-32	>1-1 1/4	31.7	46	30.3	44
			>32-38	>1 1/4 - 1 1/2	32.4	47	31.0	45
5052	All	As welded	All	All	19.3	28	17.2	25
5456	All	As welded	All	All	30.3	44	29.0	42
6061	T4	As welded	All	All	18.6	27	16.6	24
	T6	As welded	All	All	18.6	27	16.6	24

Average shall be the arithmetic average of all values measured and no single value shall be less than the minimum single value specified.

* Applicable to tempers which require an aging cycle of 177°C ± 5°C (350°F ± 10°F) for 18 hours per MIL-H-6088. Butt weld ultimate tensile strength requirements for tempers which require other post weld aging cycles must be approved by the procuring agency.

TABLE IV

DIMENSIONAL REQUIREMENTS FOR BUTT WELDS

Thickness		d-Minimum		As Welded Reinforcement Minimum				Weld Width W & W' Maximum	
				R		R'		Multi-Pass Beveled Joint and Torch Oscillated	Single Pass Square Butt
mm	in	mm	in	mm	in	mm	in		
3	<1/8	0.508	0.020	0.127	0.005	0.381	0.015	5T	9.5 mm (3/8 in.) or 5T whichever is smaller
3-6	1/8-1/4	1.270	0.050	0.127	0.005	0.381	0.015	1T + 10.2 mm (0.4 in.)	1T + 6 mm (1/4 in.)
6	>1/4	1.524	0.060	0.127	0.005	0.381	0.015	As required by design	As required by joint design

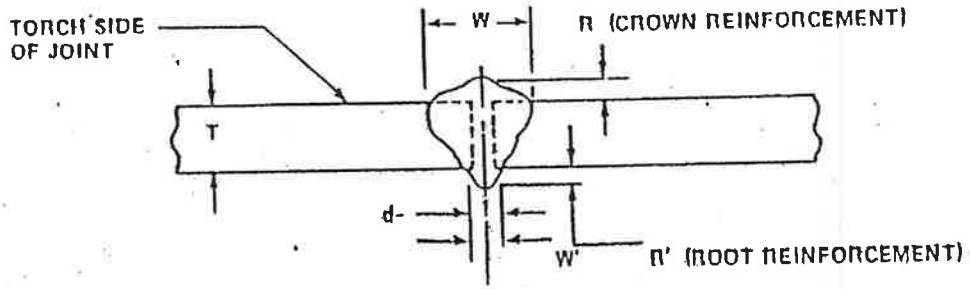


FIGURE 2

NOTE

d = distance from original joint centerline to edge of root reinforcement. Examine in the as-welded condition to ensure that the original joint centerline can be detected on the root side of the joint.

Downloaded from http://www.everyspec.com

Downloaded from http://www.everyspec.com

3.9.2 Fillet Welds

3.9.2.1 Unless otherwise directed by the procuring agency, fillet weld shear ultimate strength shall meet 60 % of the ultimate tensile strength (Class I or Class II, whichever is applicable) requirements from Table II. Where values are shown in Table II for different thickness of the same temper, 60 per cent of the least value shall apply.

3.10 Post Weld Dimensional Requirements

3.10.1 Butt Welds

3.10.1.1 Butt welds shall have 100 per cent penetration and shall meet the geometry requirements of Figure 2 and Table IV. The underbead width, including any runout, shall not exceed the maximum weld width specified in Table III.

3.10.1.2 Undercut, lack of fill or suckback - Undercutting, smooth concavity or lack of fill, or suckback (Figure 3) shall be unacceptable in any weld where it occurs as a sharp notch or where the depth reduces the material thickness below the minimum thickness specified on the applicable drawing.

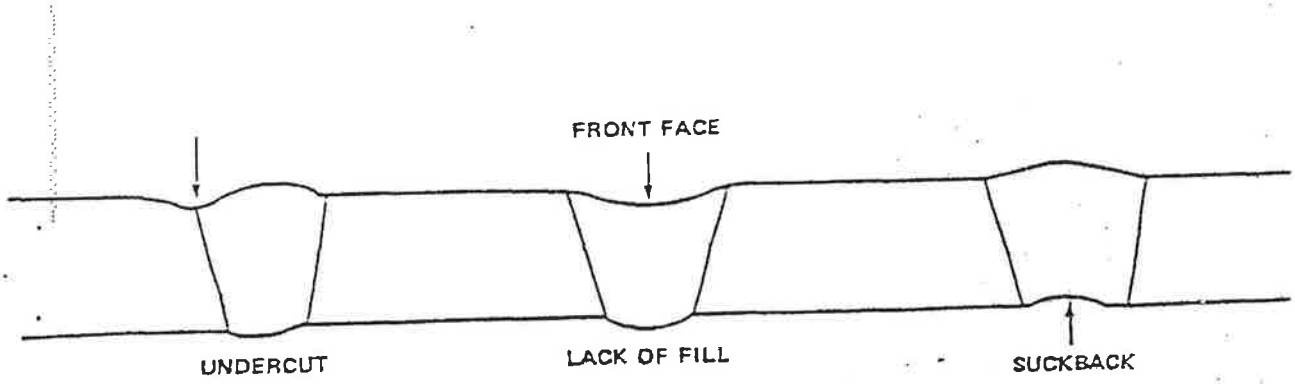


Figure 3

Downloaded from http://www.everyspec.com

3.10.1.3 Joint Offset - Unless otherwise specified by the drawing, the post-weld offset between two sheets or plates of a butt welded joint shall not exceed 0.508 mm (0.020 in.) for material thicknesses of 5.08 mm (0.200 in.) or less. For material thicknesses greater than 5.08 mm (0.200 in.), offset shall not exceed 10.16 mm (0.040 in.) or 10 per cent of the material thickness (T), whichever is smaller.

3.10.1.4 Peaking - Unless otherwise specified by the drawing, the Peaking of the weld bead and adjacent base metal shall not exceed a total angle of 5 degrees as shown in Figure 4. When a weld will be subsequently intersected by another weld, peaking shall not exceed a total included angle of 2 degrees for the 15.2 cm (6 in.) of the weld adjacent to the intersection. A standard template or other device having specified reference points shall be used for determination of peaking.

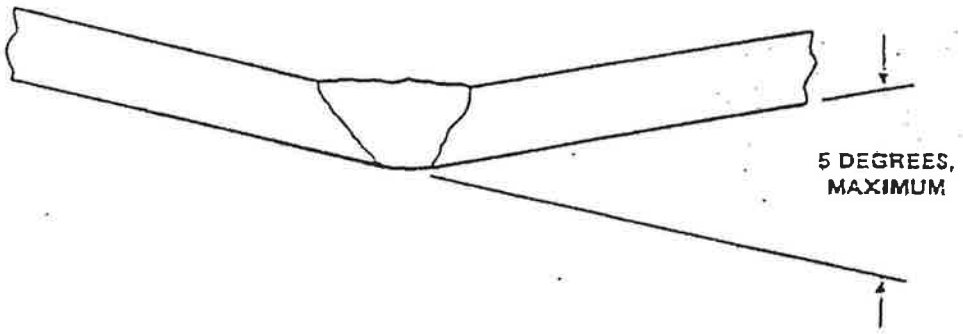


FIGURE 4

3.10.2 Fillet Welds

3.10.2.1 Continuous fillet welds including outside corner joints, lap joints and tee joints shall have 100 percent penetration into the root of the joint (Figure 6).

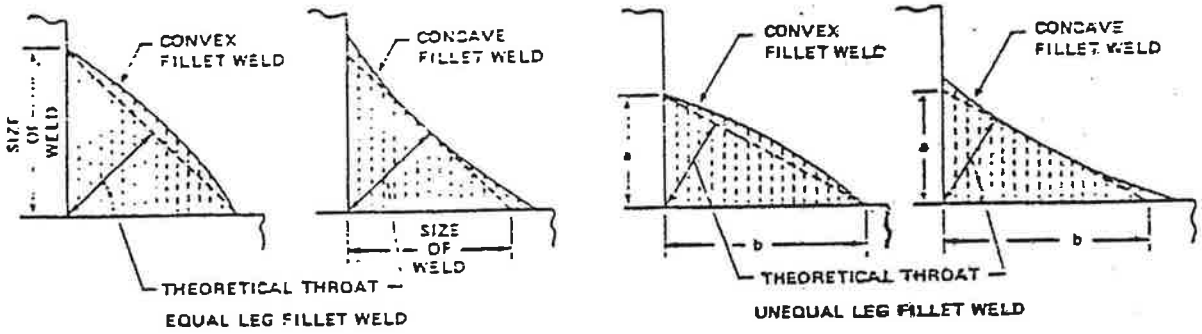
3.10.2.2 Intermittent fillet welds shall have root of joint fusion throughout the entire length of the fillet designated on the engineering drawing. Unless otherwise specified on the engineering drawing, the fillet may be extended by 6 mm (1/4 in.) at each end without root penetration in the extension.

Downloaded from http://www.everyspec.com

3.10.2.3 The minimum acceptable fillet size shall be that specified on the engineering drawing. The maximum acceptable fillet size shall be the size specified on the drawing plus 50 percent or 4.8 mm (3/16 in.), whichever is the lesser (see Figure 5). (Except as allowed in 3.11).

3.10.2.4 The minimum acceptable actual throat shall equal or exceed the theoretical throat (see Figure 5).

3.10.2.5 Fillet weld root joint fusion, Figure 6, shall be determined by evaluation of transverse sections taken from the qualification welds.



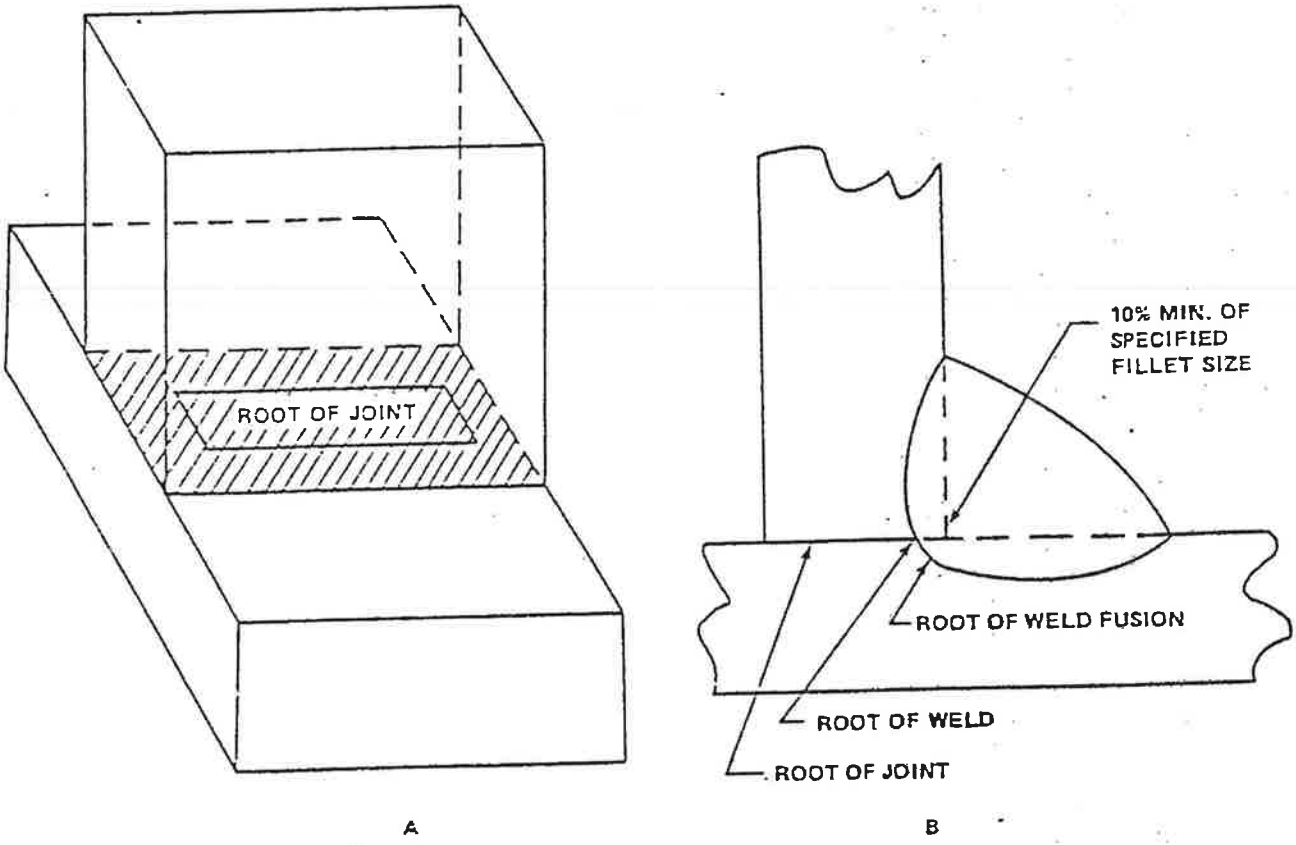
For equal-let fillet welds, the fillet size is equal to the leg length of the largest inscribed right isosceles triangle.

For unequal-leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section. Size of weld is a and b.

SIZE OF FILLET WELD

FIGURE 5

Downloaded from http://www.everyspec.com



FILLET WELD DEFINITIONS

FIGURE 6

NOTES: Root of Joint - That portion of a joint where members are closest to each other.

Root of Weld - The point, as shown in cross section, at which the weld intersects the base metal surfaces.

The root of the weld shall penetrate to the extent that the actual throat dimension exceeds the theoretical throat dimension. In addition, the web member shall be penetrated a minimum of 10 % of the specified fillet size at the root of the weld. Each leg length shall show fusion along the surface of each common member.

Downloaded from http://www.everyspec.com

3.11 Weldment Internal Quality - Internal quality requirements of butt and fillet welds shall be consistent with the strength requirements of 3.9. Weld quality requirements may be varied provided it can be shown by engineering analysis (e.g. stress and fracture mechanics analysis) and mechanical testing that the resulting structural capability is adequate for intended application. Variations from the requirements of this specification, plus the supporting data and rationale, must be approved by the procuring agency prior to use.

Note: Nondestructive inspection per 4.3.3 may be waived for fillet welds when the specified fillet size is increased 25% for Class I welds or 20% for Class II welds by either Engineering Design approval or by Material Review Board Action.

3.11.1 Class I - Class I fusion welds shall meet the following internal quality requirements. Failure to meet any one of the following requirements shall be cause for rejection.

3.11.1.1 Cracks - The weld metal and adjacent base metal shall not contain any discernable cracks. The line at the root of the weld (Figure 6) for fillet welds shall not be considered to be a crack.

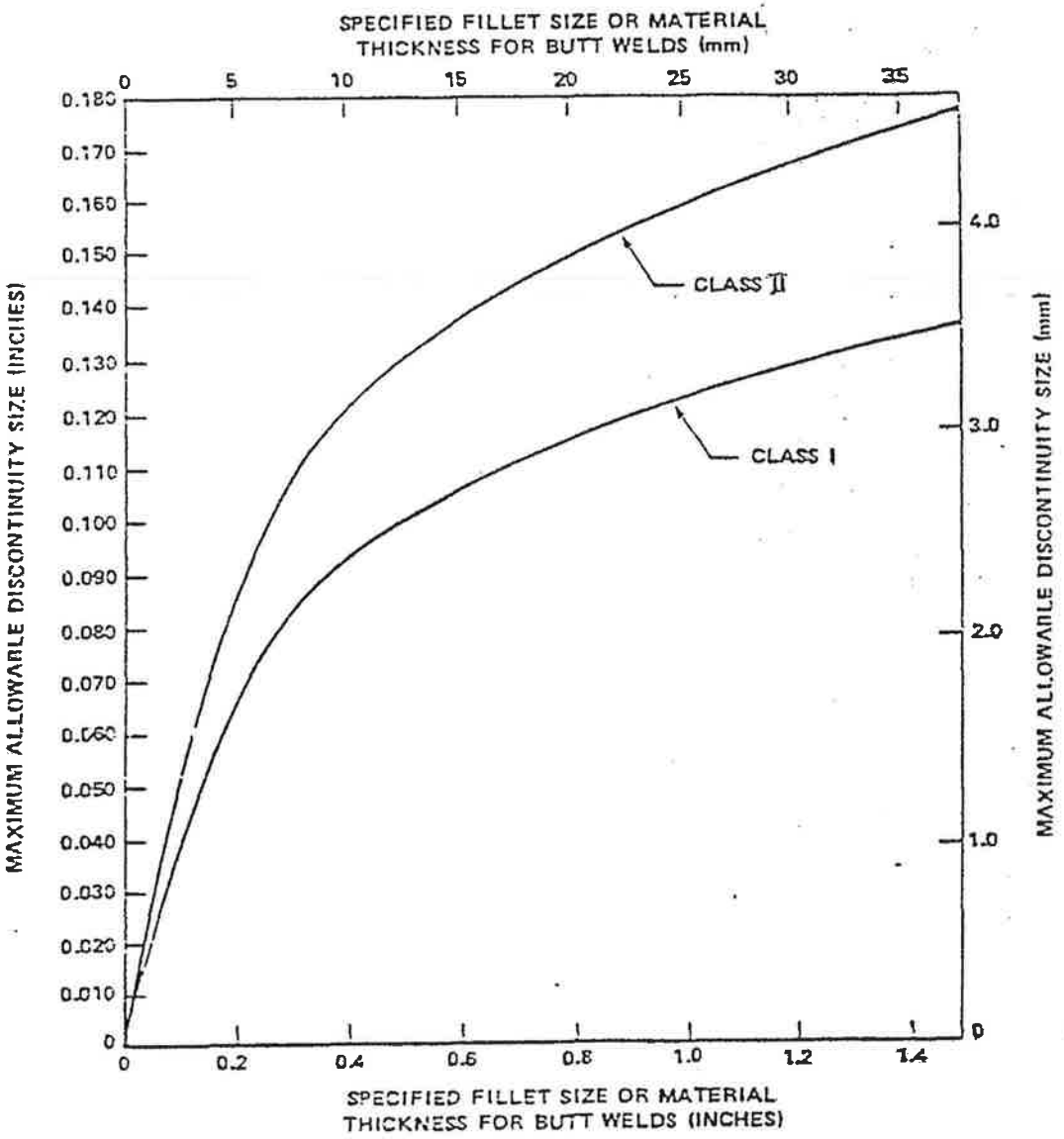
3.11.1.2 Improper Fusion/Incomplete Penetration - Improper fusion, incomplete penetration, laps and/or folds between the base metal and weld, or between weld beads or multiple pass welds shall be unacceptable.

3.11.1.3 Close Spacing - Discontinuities that appear overlapping, touching or connected viewed normal to the weld surface for butt welds, and at an optimum angle for fillet welds shall be treated as a single discontinuity. The spacing requirement is not applicable to discontinuities connected to the root of weld (Figure 6) for fillet welds. (Optimum angle is defined as the angle nearest to the normal view, considering geometry constraints which prevent access of x-ray equipment).

3.11.1.4 Maximum Discontinuity Size - The maximum dimension of an individual internal discontinuity (voids and inclusions) as viewed normal to the weld surface for butt welds, and at an optimum angle for fillet welds shall not exceed the values obtained from Figure 7.

3.11.1.5 Scattered Discontinuities - Scattered internal discontinuities not exceeding individual discontinuity limitations shall be evaluated for accumulative area per 2.5 cm (1 in.) of weld. Area calculations shall be based on the best fit circle or rectangle. Butt and fillet welds, including discontinuities connected to the root of fillet welds (Figure 6), shall conform to the requirements of Figure 8 and butt welds shall also conform to the following:

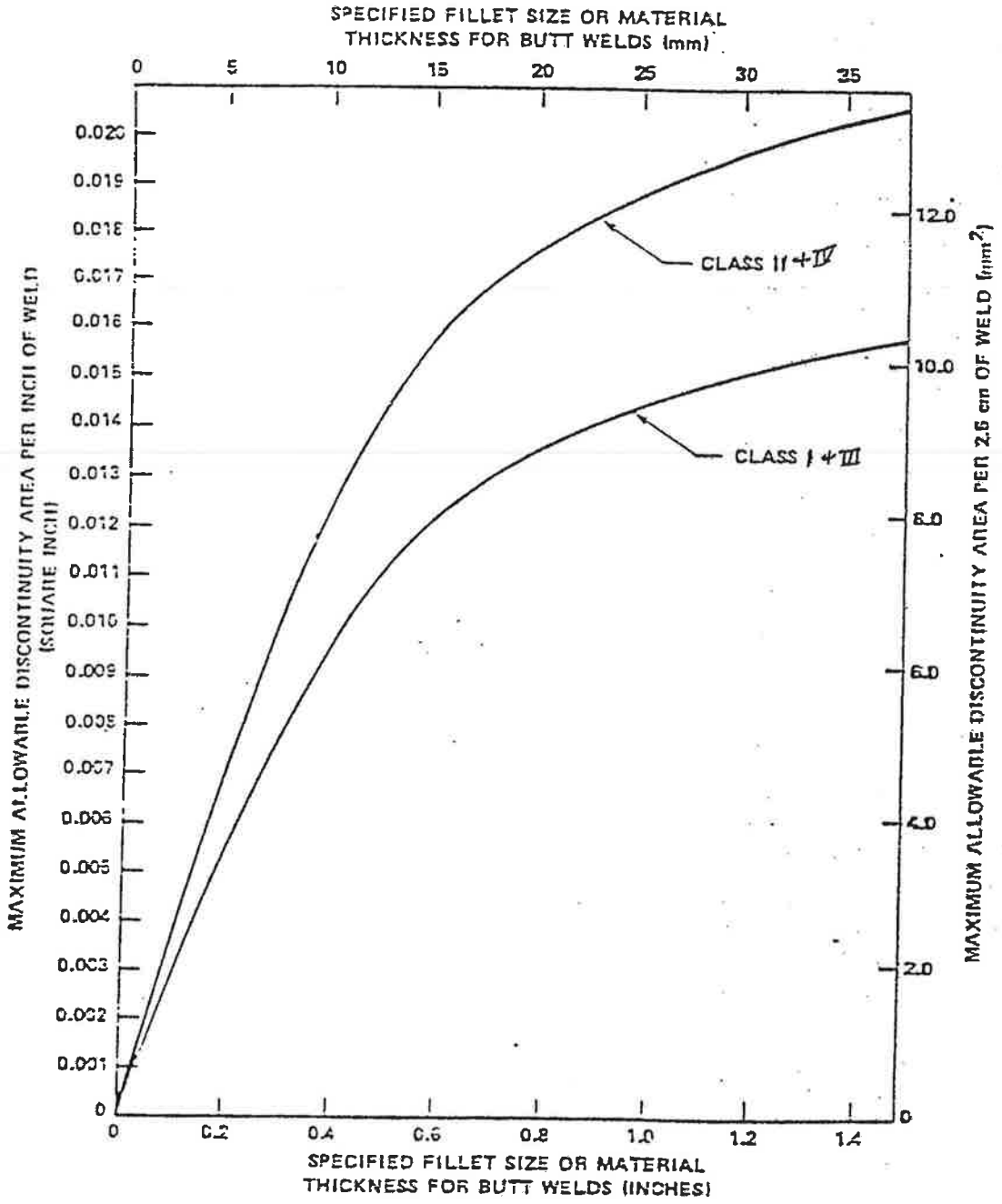
Downloaded from http://www.everyspec.com



INTERNAL DEFECTS

FIGURE 7

Downloaded from http://www.everyspec.com



EXTERNAL DISCONTINUITIES

FIGURE 8

Downloaded from http://www.everyspec.com

a. Any 2.5 cm (1 in.) of weld with maximum allowable area of Figure 8 shall have no more than one-half the maximum allowable area in each adjacent 2.5 cm (1 in.) of weld.

b. That 15.2 cm (6 in.), i.e. 7.6 cm (3 in.) to each side of the intersection, of weld intersection by another weld shall have the maximum allowable area of Figure 8 reduced by one-third.

c. There shall be no more than 15 discontinuities in any 2.5 cm (1 in.) of weld regardless of size or cumulative area loss.

3.11.1.6 Linear Discontinuities - Three or more discontinuities which are in line are unacceptable if the line extends more than 6 mm (1/4 in.) and the discontinuities occupy more than 50 percent of the length of the line. This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.11.1.7 Sharp Discontinuities - Any discontinuity that appears to have a crack-like extension shall be cause for rejection. If the longest accumulative dimension is more than five times the width at the smallest dimension, the indication shall be cause for rejection. This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.11.1.8 Cluster Discontinuities - Three or more discontinuities, each measuring 0.254 mm (0.010 in.) or more, touching or falling within a 6 mm (1/4 in.) diameter circle shall be classified as a cluster when the sum of their dimensions exceeds the allowable maximum dimension of an individual discontinuity (Figure 7). For butt welds, two clusters are unacceptable if separated by less than T. For fillet welds, two clusters are unacceptable if separated by less than the specified fillet sizes. This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.11.2 Class II - Internal quality of Class II fusion welds shall meet the requirements of 3.11.1.1, 3.11,1.2, 3.11.1.3 and the following paragraphs. Failure to meet any of the requirements shall be cause for rejection.

NOTE: One hundred percent (100%) radiographic inspection of Class II welds may be relaxed, at the discretion of the procuring agency, upon demonstration and certification of acceptable quality performance and after approval of a radiographic sampling plan.

Downloaded from http://www.everyspec.com

3.11.2.1 Maximum Discontinuity Size - The maximum dimension of an individual internal discontinuity (void and/or inclusions) as viewed normal to the weld surface for butt welds, and at an optimum angle for fillet welds shall not exceed the value obtained from Figure 7.

3.11.2.2 Scattered Discontinuities - Scattered internal discontinuities not exceeding the individual discontinuity limitations shall be evaluated for accumulative area per 2.5 cm (1 in.) of weld. In addition, all discontinuities connected to the root of a fillet weld (Figure 6) shall be included in the accumulative area. Area calculations shall be based on the best fit circle or rectangle. The area in any 2.5 cm (1 in.) of weld shall not exceed the value obtained from Figure 9.

3.11.2.3 Linear Discontinuities - Three or more discontinuities which are in a line are unacceptable if the line extends more than 12.5 mm (1/2 in.) and the discontinuities occupy more than 50 percent of the length of the line. This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.11.2.4 Sharp Discontinuities - Any discontinuity which appears to have a crack-like extension shall be cause for rejection. If the longest accumulative dimension is more than seven times the width at the smallest dimension the discontinuity shall be cause for rejection. This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.11.2.5 Cluster Discontinuities - Three or more discontinuities, each measuring 0.508 mm (0.020 in.) or more, touching or falling within a 6 mm (1/4 in.) diameter circle shall be classified as a cluster when the sum of their maximum dimensions exceeds the allowable maximum dimension of an individual discontinuity (Figure 7). For butt welds, two clusters are unacceptable if separated by less than half the material thickness (T/2). For fillet welds, two clusters are unacceptable if separated by less than half the specified fillet size (S/2). This requirement is not applicable to discontinuities connected to the root of fillet welds (Figure 6).

3.12 Weldment Surface Quality - This section sets forth requirements consistent with the strength requirement of 3.9.

3.12.1 Classes I and III - Class I and Class III fusion welds shall meet the following surface quality requirements. Failure to meet any one requirement shall be cause for rejection.

Downloaded from http://www.everyspec.com

3.12.1.1 Cracks - The weld metal and adjacent base metal shall contain no discernable cracks.

3.12.1.2 Improper Fusion - Incomplete penetration, laps or folds between the bead(s) and base metal shall be cause for rejection.

3.12.1.3 Close Spacing - Discontinuities that appear over-lapping, touching or connected shall be treated as a single discontinuity.

3.12.1.4 Maximum Discontinuity Size - The maximum dimension of individual surface discontinuities, such as rounded porosity and oxides shall not exceed T/3 or 1.65 mm (0.065 in.) for butt welds, and S/3 or 1.27 mm (0.050 in.) for fillet welds, whichever is smaller for each weld.

3.12.1.4.1 Any surface discontinuity within 2.5 cm (1 in.) of a weld intersection shall not exceed 0.254 mm (0.010 in.) in the greatest dimension.

3.12.1.5 Scattered Discontinuities - The sum of the areas of all individual surface discontinuities within any 2.5 cm (1 in.) of weld shall not exceed one-half the value of maximum discontinuity area from Figure 8. There shall be no more than fifteen individual surface discontinuities in any 2.5 cm (1 in.) of weld regardless of size or cumulative area.

3.12.1.6 Linear Discontinuities - Three or more discontinuities in a line are unacceptable if the line extends more than 6 mm (1/4 in.) and the discontinuities occupy more than 50 percent of the length of the line.

3.12.1.7 Sharp Discontinuities - Sharp discontinuities shall be cause for rejection if the maximum dimension exceeds 0.762 mm (0.030 in.).

3.12.1.8 Cluster Discontinuities - Three or more discontinuities each measuring 0.254 mm (0.010 in.) or more, touching or falling within a 6 mm (0.250 in.) diameter circle, shall be classified as a cluster when the sum of their maximum dimension exceeds T/3 or 1.65 mm (0.065 in.) for butt welds, and S/3 or 1.27 mm (0.050 in.) for fillet welds, whichever is smaller for each weld. Two clusters are unacceptable if separated by less than butt weld thickness (T) or less than specified fillet size (S).

3.12.2 Classes II and IV - Class II and Class IV welds shall meet the surface quality requirements of 3.12.1.1, 3.12.1.2, and 3.12.1.3 and the following paragraphs. Failure to meet any one requirement shall be cause for rejection.

Downloaded from http://www.everyspec.com

3.12.2.1 Maximum Discontinuity Size - Individual surface discontinuities such as rounded porosity and oxides, whose maximum dimension exceeds T/2 or 2.54 mm (0.100 in.) for butt welds and S/3 or 1.90 mm (0.075 in.) for fillet welds, whichever is smaller for each weld, shall be cause for rejection.

3.12.2.1.1 Any surface discontinuity within 2.5 cm (1 in.) of a weld intersection shall not exceed 0.508 mm (0.020 in.) in the greatest dimension.

3.12.2.2 Scattered Discontinuities - The sum of the areas of all individual surface discontinuities within any 2.5 cm (1 in.) of weld shall not exceed the value for the maximum discontinuity area from Figure 8.

3.12.2.3 Linear Discontinuities - Three or more discontinuities which are grouped in a line are unacceptable if the line extends more than 12.5 mm (1/2 in.) and the discontinuities occupy more than 50 percent of the length of the line.

3.12.2.4 Sharp Discontinuities - Sharp discontinuities viewed on the weldment surface shall be cause for rejection if the maximum dimension exceeds 1.52 mm (0.060 in).

3.12.2.5 Cluster Discontinuities - Three or more discontinuities, each measuring 0.508 mm (0.020 in.) or more, touching or falling within a 10 mm (.25 in.) diameter circle, shall be classified as a cluster when the sum of their dimension exceeds T/3 or 1.65 mm (0.065 in.) for butt welds, and S/3 or 1.27 mm (0.050 in.) for fillet welds, whichever is smaller for each weld. Two clusters are unacceptable if separated by less than half the butt weld material thickness (T/2) or by less than half the fillet weld specified size (S/2).

3.12.3 Class V - Class V welds shall meet the requirements of 3.8.2 only.

4. QUALITY ASSURANCE

4.1 General Inspection - The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to and approved by the procuring agency. Inspection and test records shall be kept complete and upon request, made available to the procuring agency, or its designated representative. The procuring agency, or its designated representative, reserves the right to perform any or all of the inspections set forth in the specification to ensure than the end item conforms to the prescribed requirements.

Downloaded from http://www.everyspec.com

4.2 Pre-weld and Weld Inspection

4.2.1 Documentation - Documentation relative to the production weld shall be inspected for conformance with 3.1.

4.2.2 Filler Metal - Filler metal shall be examined for conformance to 3.2.2 and the qualified welding schedule.

4.2.3 Shielding Gas - Inert shielding gas shall be examined for conformance to 3.2.3 and the qualified welding schedule.

4.2.4 Joints and Tooling - The joints and tooling shall be inspected for conformance to 3.4.

4.2.5 Welding Equipment - Welding equipment shall be inspected for conformance of equipment settings to the qualified welding schedule (3.1).

4.2.6 Quality Control - Quality control shall certify that each production weld was made within the range of operating parameters established for each qualification weld schedule. All departures shall be noted and referred to the MRB for disposition.

4.3 Post Weld Inspection

4.3.1 Visual Inspection - The weld metal and adjacent base metal shall be visually inspected, without the aid of optical magnification, to assure compliance with the requirements of 3.8.2. The weld shall be in the as-welded condition for initial weld inspection, except that surface smut and loose oxide shall have been removed.

4.3.2 Dimensional Inspection - Dimensional inspection shall be performed on Classes I, II, III, and IV welds to assure compliance with the requirements of 3.10.

4.3.3 Internal Quality Inspection - Nondestructive inspection shall be performed to assure compliance with the internal quality requirements of 3.11. Radiographic technique is the preferred inspection method; however, other techniques may be used in lieu of radiography if approved by the procuring agency.

4.3.3.1 Nondestructive inspection procedures shall be qualified in accordance with the requirements of 3.8.1.1.

4.3.3.2 Nondestructive inspection procedures employing radiographic inspection techniques shall meet the criteria of MIL-STD-453, Radiographic Inspection Methods.

Downloaded from http://www.everyspec.com

4.3.3.3 A three to seven-power optical magnifier shall be used as an aid in examination of radiographs to afford closer examination of suspect areas and to determine image dimensions.

4.3.3.4 When reliability of inspection and critical flaw detection so dictate, redundant and/or complementing inspection techniques and procedures shall be employed.

4.3.4 Surface quality inspection - Nondestructive inspection shall be performed to assure compliance with the surface quality requirements of 3.12. Penetrant technique is the prefferred inspection method; however, other techniques may be used in lieu of penetrant if approved by the procuring agency.

4.3.4.1 Nondestructive inspection procedures shall be qualified in accordance with the requirements of 3.8.1.1.

4.3.4.2 Nondestructive inspection procedures employing penetrant inspection shall also meet the criteria of MSFC-STD-366 and MIL-I-6866 dye penetrant inspection methods. Weldments which are machined, ground, or otherwise mechanically worked, causing disruption or smearing of the material surface, shall be etched to remove the masking material, prior to penetrant application. Removal of 0.0004 inches of aluminum material by etching generally assures smeared material removal.

4.3.5 Records - A continuous audit of weldment production quality shall be maintained. Resulting records shall include the location of repairs, type of defects repaired, procedures used, and inches of repair per total inches of weld. These records shall be summarily accounted on a quarterly basis, with such accounting made available to the procuring agency upon request.

5. PREPARATION FOR DELIVERY

This action is not applicable to this specification.

6. NOTES

6.1 Intended use - Weld guideline and acceptance criteria for aerospace flight equipment and ground support equipment.

6.2 Ordering Data - Procurement documents should specify the title, number and date of this specification.

6.3 Definitions - Definitions pertaining to welding as used herein conform to the standard definitions of AWS A3.0 and the following paragraphs.

Downloaded from http://www.everyspec.com

6.3.1 Material Thickness - The minimum material thickness of the thinnest joint member per drawing tolerance is designated "T".

6.3.2 Weld Intersection - As used herein, the term weld intersection refers to the meeting of two (or more) welds at a point where the second weld may or may not completely cross the first weld.

6.3.3 Welding Schedule - A detailed written procedure set forth as a permanent record which specifies the complete details regarding pre-weld preparation, welding parameters and all pre- and post-weld operations affecting the weld quality and/or properties of the joint.

6.3.4 Optimum Angle - Optimum angle is defined as the angle nearest to the normal view, considering geometry constraints which prevent access of x-ray equipment.

6.4 Symbols

6.4.1 Welding Symbols - The standard welding symbols that are accepted for designation on drawings are listed in AWS A.2.0.

6.4.2 Nondestructive Testing Symbols - The standard nondestructive testing symbols that are accepted for use on drawings are listed in AWS A.2.2.

6.5 Changes - Requests for deviation from, or waiver of, applicable paragraphs of this specification shall be directed to the procuring agency with supporting data and rationale to substantiate the request, and to the Materials and Processes Laboratory, Marshall Space Flight Center, Alabama 35812.

Notice: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Downloaded from http://www.everyspec.com

Custodian:

NASA- George C. Marshall Space Flight Center

Preparing Agency:

George C. Marshall Space Flight Center

Downloaded from http://www.everyspec.com

Specification: Welding, Aluminum Alloys

Approved by:

R. J. Schwinghamer
Director
Materials and Processes Laboratory