



April 20, 2004  
Supersedes October 2, 2001

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## **ALUMINUM WELDING**

### **GENERAL REQUIREMENTS**

The welding qualification requirements for fabrication or repair of any highway aluminum structure shall be in accordance with the American Welding Society (AWS) D1.2-97 Structural Aluminum Welding Code for Class II Structures.

### **WELDING PROCESS**

All welding shall be done by the Gas Metal Arc Welding process (GMAW) unless the engineer grants specific approval.

### **ELECTRODES**

All electrodes shall be of the type specified on the plans or in the specifications. Currently this electrode is ER 5356 for welding aluminum alloy 6061.

### **MATERIALS**

All materials for test plates shall be 6061-T6 and furnished by the fabricator.

### **PROCEDURE QUALIFICATION**

A Welding Procedure Specification (WPS) shall be prepared in accordance with 4.2 and Annex E of the AWS D1.2 Code.

Qualification of the written welding procedure shall be in accordance with Section 4, Part C, using the materials, Procedure Qualification Record (PQR) joint preparation, cleaning and limiting variables from Paragraph 4.14.

### **PROCEDURE ACCEPTANCE CRITERIA**

#### **Groove welds:**

Visual examination shall be in accordance with paragraph 4.6.2 reprinted at the end of this IM). The tensile strength shall be a minimum of 24 ksi (165 MPa) when fracture occurs in the weld metal. A minus 5% tolerance shall be allowed if fracture is outside the weld metal.

The guided bend surface of the weld and heat affected zone shall contain no discontinuities exceeding the following dimensions when visual inspection is made: 1/8 in. (3.2 mm) measured in any direction. 3/8 in. (9.5 mm) for the sum of all discontinuities exceeding 1/32 in. (0.8 mm). 1/4 in. (6.4 mm) maximum for corner cracks, except when that crack resulted from a visible inclusion or other fusion-type discontinuities then 1/8 in. (3.2 mm) maximum shall apply. (Re: 4.8.3)

**Fillet Welds:**

Visual examination shall be in accordance with Paragraph 4.6.3 (reprinted at the end of this IM). The broken surface of the fracture test shall be examined visually. To pass, it must show complete penetration to the root and have no inclusion or porosity larger than 3/32 in. (2.4 mm) in the greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 3/4 in. (19 mm) in each 4 in. (100 mm) segment.

The macroetched specimen for the fillet weld test shall show complete penetration to the root of the joint.

**POSITION AND TESTS FOR PROCEDURE WELDS**

Procedure qualification - type and position limitations

<u>Qualification Test</u>	<u>Type of Weld and Position of Welding Qualified Plate</u>		
	<u>Plate or pipe Positions</u>	<u>Groove</u>	<u>Fillet</u>
<u>Weld</u> Plate-groove Complete Joint Penetration	1G	1G	1F
	2G	1G, 2G	1F, 2F
	3G	1G, 3G	1F, 3F
	4G	1G, 4G	1F, 4F
Plate-fillet	1F		1F
	2F		1F, 2F
	3F		3F
	4F		4F

**PROCEDURE TEST SPECIMENS REQUIRED - GROOVE WELDS**

<u>Test Weld Thickness</u> T - inch	<u>Test Weld Thickness</u> T - mm	<u>Number of sample Welds Per Position</u>	<u>Visual Insp.</u>	<u>Reduced Section Tension</u>	<u>Root Bend</u>	<u>Face Bend</u>	<u>Side Bend</u>	<u>Qualification Thickness mm(in.)</u>	
								<u>Min.</u>	<u>Max.</u>
1/8 ≤ T ≤ 3/8 in.	3 ≤ T ≤ 10	1	Yes	2	2	2	-----	1/8(3 mm)	2T
3/8 < T < 1 in.	10 < T < 25	1	Yes	2	---	---	4	T/2	2T
T ≥ 1 in.	T ≥ 25	1	Yes	2	---	---	4	T/2	Any

**PROCEDURE TEST SPECIMENS REQUIRED - FILLET WELDS**

Test specimens required

Test Specimen	Fillet size	Number of Welds Per Procedure	Macroetch	Test Spec. Req'd.		Sizes Qualified	
				Fracture Test	Root Bend	Plate Thickness	Fillet Size
<b>Tests on plate</b>							
Fillet Weld Test Option 1	Single pass Max size to be used in Construction	1 in each position to be used	2 faces	2	----	Unltd.	Max tested single pass and smaller
	Multiple pass, min size to be used in Construction	1 in each position to be used	2 faces	2	----	Unltd.	Min tested multiple pass and larger
Fillet Weld Test option 2	Max size to be used in Construction	1 in each position to be used	----	----	2	Unltd.	All

**WELDER PERFORMANCE**

All welders and tackers shall be qualified prior to welding on any highway bridge or structure. The qualification of welders and tackers shall be in accordance with these instructions. Certification shall be for a period of one year, but shop welders may be extended annually, based on a letter from the fabricator, certifying that the welder or tacker has been engaged in the process for which he is qualified without interruption of more than six months during the preceding twelve months.

Field welders shall be qualified for a period of one year. Those welders who have successfully passed their qualification tests without failure for two consecutive years, requalification will only be required every two years.

Welder requalification may be required at any time there is a specific reason to question his/her ability to make sound welds.

**Table 4.8**  
**Number and Type of Test Specimens and Range of Thickness Qualified—**  
**Welder and Welding Operator Qualification (see 4.19 and 4.23.3)**  
**(Dimensions in Inches)**

1. Tests on Plate

Type of Weld	Thickness (T) of Test Plate as Welded, in.	Visual Inspection	Number of Specimens					Plate Thickness Qualified, in.	
			Bend Tests <sup>2</sup> All Positions			Fillet Weld Fracture	Macroetch Test	Min	Max <sup>3</sup>
			Face	Root	Side				
Groove	< 3/8	Yes	1	1	—	—	—	T	2T
Groove	3/8	Yes	1	1	—	—	—	1/8	2T
Groove	Over 3/8 and under 1	Yes	—	—	2	—	—	1/8	2T
Groove	1 or over	Yes	—	—	2	—	—	1/8	Unlimited
Fillet <sup>1</sup>	≤ 1/8	Yes	—	—	—	1	1	T	Larger of 2T or 3/16
	1/8 < T < 3/8	Yes	—	—	—	1	1	T/2	2T
	≥ 3/8	Yes	—	—	—	1	1	T/2	Unlimited

Notes:

1. See Figure 4.29.

2. Radiographic examination of the welder or welding operator test plate may be made in lieu of the bend test (see 4.5.3).

3. Qualifies for welding fillet welds on material of unlimited thickness.

**WELDER PERFORMANCE QUALIFICATION TYPE OF WELD**  
**& POSITION LIMITATIONS**

Qualification Test	Plate or pipe positions	Type of Weld & Position of Welding Qualified			
		Plate		Pipe	
Weld		Groove	Fillet	Groove	Fillet
Plate-groove	1G	1G	1F,2F	1G	1F, 2FR
	2G	1G,2G	1F,2F	1G	1F,2FR
	3G	1G,3G	1F,2F,3F	1G	1F,2FR
	4G	1G,4G	1F,2F,4F	1G	1F,2FR
	3G & 4G	All	All	1G	1F,2FR
Plate-fillet	1F		1F		1F
	2F		1F,2F		1F,2FR
	3F		1F,2F,3F		1F,2FR
	4F		1F,2F,4F		1F,2FR
	3F & 4F		All		1F,2FR

**Table 4.8**  
**Number and Type of Test Specimens and Range of Thickness Qualified—**  
**Welder and Welding Operator Qualification (see 4.23.3)**  
**(Dimensions in Millimeters)**

1. Tests on Plate

Type of Weld	Thickness (T) of Test Plate as Welded, mm	Visual Inspection	Number of Specimens					Plate Thickness Qualified, mm	
			Bend Tests <sup>2</sup> All Positions			Fillet Weld Fracture	Macroetch Test	Min	Max <sup>3</sup>
			Face	Root	Side				
Groove	< 10	Yes	1	1	—	—	—	T	2T
Groove	10	Yes	1	1	—	—	—	3	2T
Groove	Over 10 and under 25	Yes	—	—	2	—	—	3	2T
Groove	25 or over	Yes	—	—	2	—	—	3	Unlimited
Fillet <sup>1</sup>	≤ 3	Yes	—	—	—	1	1	T	Larger of T or 5
	3 < T < 10	Yes	—	—	—	1	1	T/2	2T
	≥ 10	Yes	—	—	—	1	1	T/2	Unlimited

Notes:

1. See Figure 4.29.
2. Radiographic examination of the welder or welding operator test plate may be made in lieu of the bend test (see 4.5.3).
3. Qualifies for welding fillet welds on material of unlimited thickness.

**FILLET WELD QUALIFICATION**

Fillet welds between parts having a dihedral angle of less than 75 degrees, the welder shall weld a groove weld test plate. Parts having a dihedral angle of 75 degrees to 135 degrees shall weld a fillet weld test plate.

**LIMITATION OF VARIABLES**

When welding in the vertical position, a change in the direction of welding shall require requalification.

Qualification of a tacker shall qualify as a welder of fillet welds in the position qualified.

**PERFORMANCE ACCEPTANCE CRITERIA**

Visual examination shall be in accordance with paragraph 4.6.2 for groove welds (reprinted at the end of this IM).

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The guided bend surface of the weld and heat affected zone shall contain no discontinuities exceeding the following dimensions when visual inspection is made: 1/8 in. (3 mm) measured in any direction. 3/8 in. (10 mm) for the sum of all the discontinuities exceeding 1/32 in. (0.8 mm), but less than or equal to 1/8 in. (3 mm) for 1½ inch-wide specimens (38 mm). 1/4 in. (6 mm) maximum for corner cracks, except when that crack resulted from a visible inclusion or other fusion-type discontinuity, then 1/8 in. (3 mm) maximum shall apply. Visual examination shall be in accordance with paragraph 4.6.3 for fillet welds (reprinted at the end of this IM).

**Fillet fracture test:** The 6 in. (150 mm) performance specimen, center section, shall be examined visually on the broken surface. To pass it must show complete fusion to the root and have no inclusion or porosity larger than 3/32 in. (2 mm) in the greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 3/4 in. (19 mm) in the 6 in. (150 mm) length.

The macroetch specimen for the fillet weld test (option 1) shall show complete penetration to the root of the joint.

**4.6.2 Acceptance Criteria—Visual Examination—Groove Welds, Plate and Pipe.** The visual examination of the test weldment shall satisfy the following acceptance criteria:

- (1) Both the face and root surfaces shall be free of cracks.
- (2) All craters shall be filled to the full cross section of the weld.
- (3) The edges of the weld shall blend smoothly with the base metal.
- (4) Underfill shall not exceed 0.01 in. (0.25 mm).
- (5) The root shall show (a) complete fusion for complete joint penetration groove welds, or (b) penetration equal to or greater than the weld size specified for partial joint penetration groove welds.
- (6) The maximum melt-through on groove welds in pipe or tubing shall not exceed 1/8 in. (3 mm).
- (7) The root concavity shall not exceed 1/16 in. (2 mm).
- (8) Total weld thickness shall be equal to or greater than the thickness of the base metal, but the weld reinforcement shall not exceed the value listed in Figure 3.2(D) or (E).

**MAXIMUM REINFORCEMENT FOR A GIVEN PLATE THICKNESS—JOINT WELDED FROM BOTH SIDES**

THICKNESS, t		MAXIMUM REINFORCEMENT	
in.	mm	in.	mm
$t \leq 3/8$	$t \leq 10$	3/32	2
$3/8 < t \leq 3/4$	$10 < t \leq 19$	1/8	3
$t > 3/4$	$t > 19$	3/16	5

**(D) ACCEPTABLE PROFILE, DOUBLE GROOVE WELD IN BUTT JOINT**

**MAXIMUM REINFORCEMENT FOR A GIVEN PLATE THICKNESS—JOINT WELDED FROM ONE SIDE**

THICKNESS, t		MAXIMUM REINFORCEMENT	
in.	mm	in.	mm
$t \leq 1/4$	$t \leq 6$	3/32	2
$1/4 < t \leq 1/2$	$6 < t \leq 13$	1/8	3
$1/2 < t \leq 1$	$13 < t \leq 25$	5/32	4
$t > 1$	$t > 25$	3/16	5

**(E) ACCEPTABLE PROFILE, GROOVE WELD IN BUTT JOINT WELDED FROM ONE SIDE**

**4.6.3 Acceptance Criteria—Visual Examination of Fillet Welds for Plate or Pipe.** The visual examination of the test weldment shall satisfy the following acceptance criteria:

- (1) The surface of the weld shall be free from cracks.
- (2) All craters shall be filled to the full cross-section of the weld.
- (3) The edges of the weld shall blend smoothly with the base metal.
- (4) Underfill shall not exceed 0.01 in. (0.25 mm).
- (5) The leg lengths shall meet the requirements of the WPS.
- (6) The weld shall exhibit complete fusion in the root and to the base metal by the macroetch test.
- (7) A concave root surface (suck-back) on the side of the base metal opposite the weld metal shall be permitted. This concavity shall not exceed 1/32 in. (1 mm) and reinforcement shall be added to the weld with a height equal to the concavity dimension.

Figure 4.20-Location of Test Specimen for WPS Qualification-Plate (See 4.9.1 & 4.15.4.1)

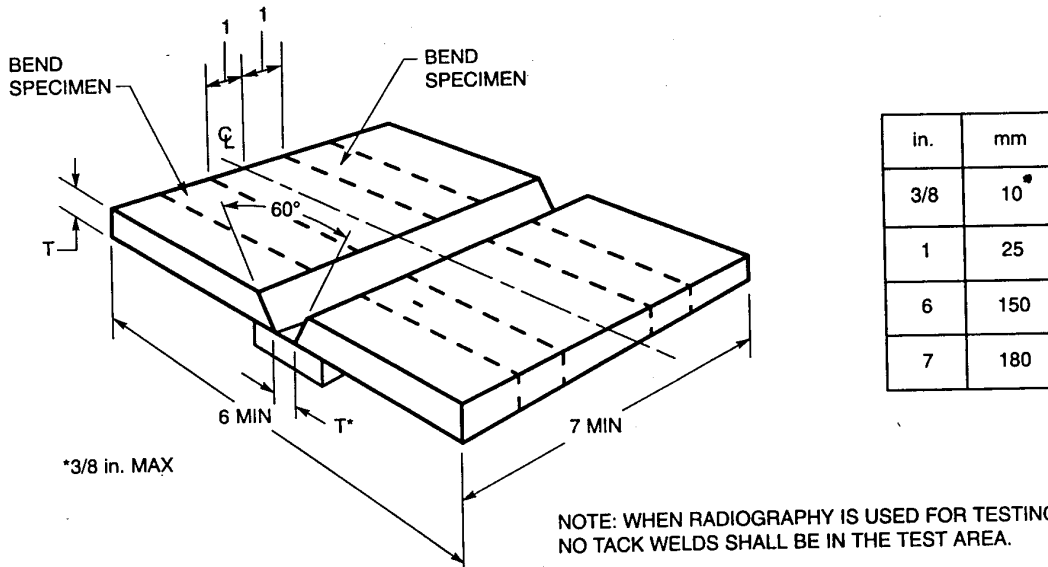
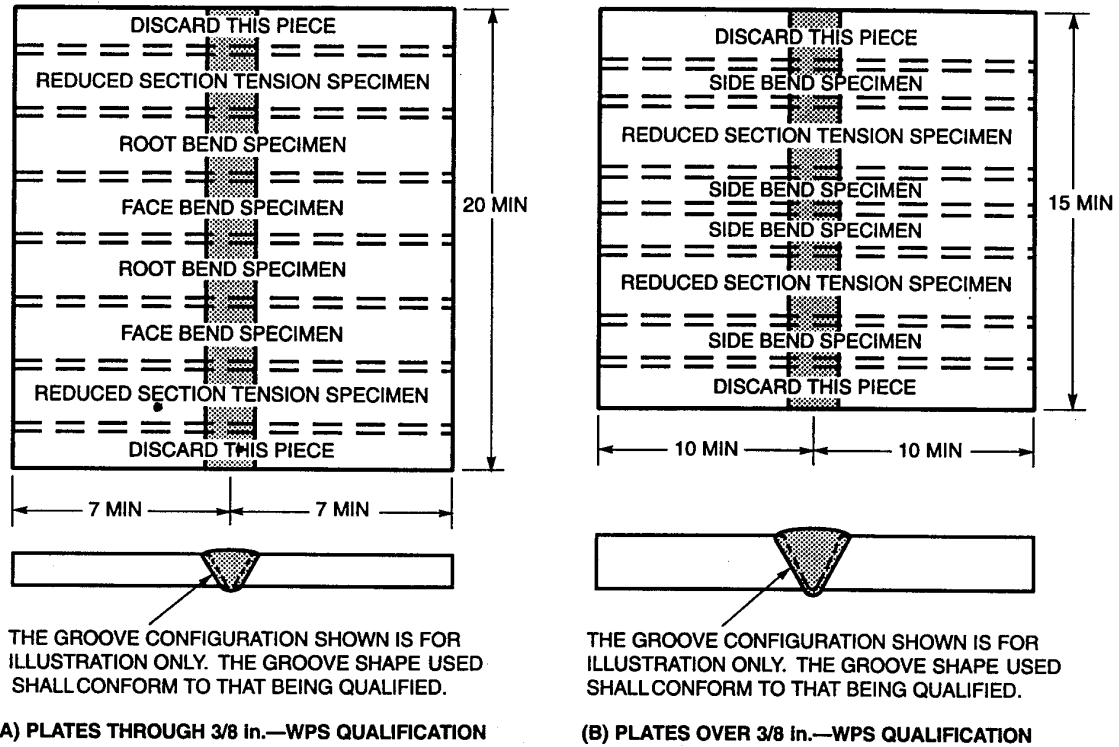
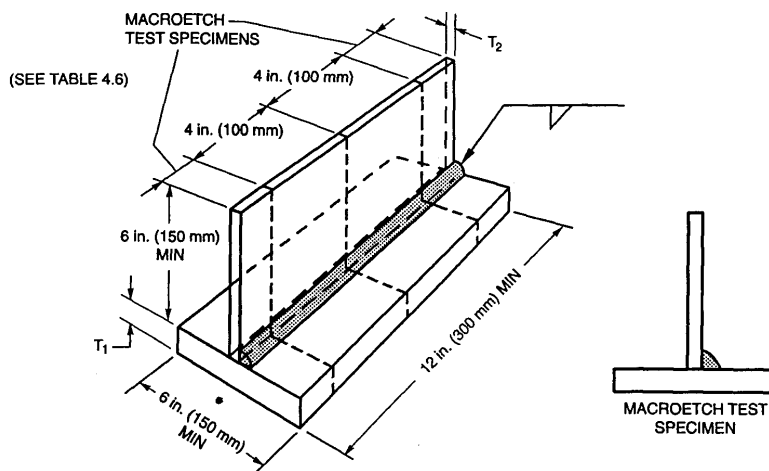


Figure 4.26 - Test Plate for Qualification in All Positions: Plate Thickness  $T > 1/8$  in. ( $T > 3$  mm) (See 4.19.1)





Inches			Millimeters		
Weld Size	T <sub>1</sub> min*	T <sub>2</sub> min*	Weld Size	T <sub>1</sub> min*	T <sub>2</sub> min*
3/16	1/2	3/16	5	13	5
1/4	3/4	1/4	6	19	6
5/16	1	5/16	8	25	8
3/8	1	3/8	10	25	10
1/2	1	1/2	13	25	13
5/8	1	5/8	16	25	16
3/4	1	3/4	19	25	19
> 3/4	1	1	> 19	25	25

\*Note: Where the maximum plate thickness used in production is less than the value shown in the table, the maximum thickness of the production pieces may be substituted for T<sub>1</sub> and T<sub>2</sub>.

Figure 4.17-Fillet Weld Soundness Test for WPS Qualification-Option 1-Plate (See 4.10.1.1)

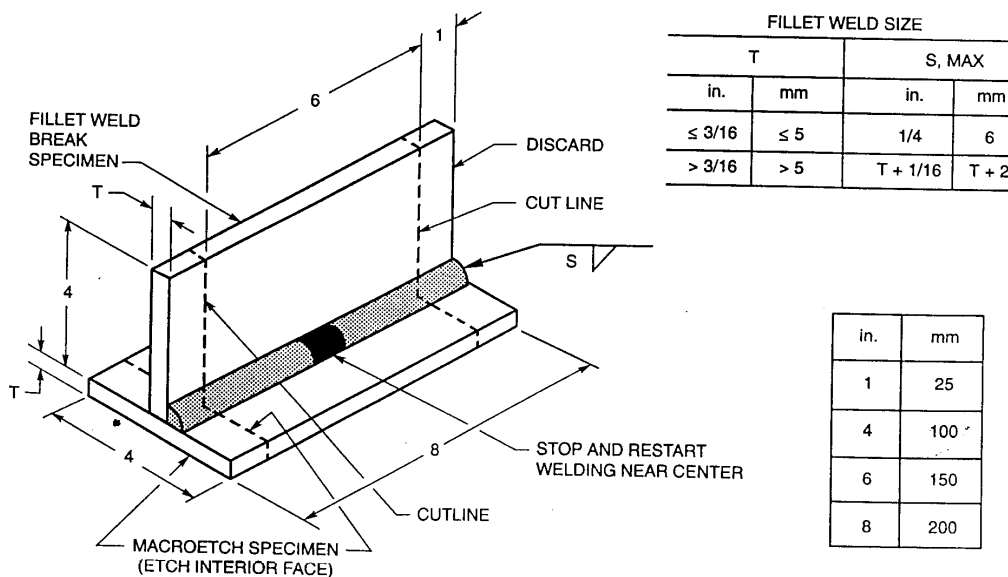


Figure 4.32-Fillet Weld or Tack Welder Performance Qualification-Plate (See 4.19.4.1)