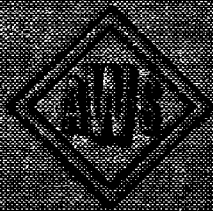


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AWS D14.4-77

**American Welding Society
Standard**

**Classification and Application
of Welded Joints for
Machinery and Equipment**



AMERICAN WELDING SOCIETY



AWS D14.4-77

Classification and Application of Welded Joints for Machinery and Equipment

Prepared by
AWS Committee on
Machinery and Equipment

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors, August 30, 1975

AMERICAN WELDING SOCIETY, INC.
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Foreword

This standard establishes common acceptance criteria for classifying and applying welds suitable in the manufacture of machines and equipment. It also covers design, workmanship and quality control requirements (including acceptance criteria for nondestructive examination). It is the intent of this standard to serve only as a guide and not to restrict the use of other proven methods and procedures which achieve acceptable results.

American industry is rapidly converting to the use of metric units. Accordingly, the AWS Board of Directors has decided that all documents published after June 1, 1976, will use metric units first with the U.S. Customary equivalents included parenthetically throughout the text, tables, and figures. The metric units used in this standard are those of the Systeme International d'Unites (SI) which is the internationally accepted metric system.

Comments or inquiries on this standard are welcomed. They should be addressed to the Secretary, AWS Committee on Machinery and Equipment, American Welding Society, 2501 N.W. 7th Street, Miami, Florida 33125.

Classification and Application of Welded Joints for Machinery and Equipment

1. Scope

1.1 This standard sets forth the classification of welded joints for use in the design and manufacture of machinery and equipment subjected to static and dynamic loading.

1.2 This standard also provides practices that can be used for qualification and examination of welded joints used in fabrication of machinery and equipment.

1.3 It is not the intent of this standard to restrict the use of other proven methods and procedures which achieve acceptable results and which have been agreed to in writing by the supplier and customer.

1.4 Although the SI dimensions are listed first, the U.S. Customary dimensions are to be regarded as the standard.

2. Classification of Welded Joints

2.1 Welded joints are divided into six classifications (see Fig. 2.1) based upon the design of the joint and anticipated performance. Joint efficiency shall be based on the allowable unit design stress for the base metal where matching weld metal is used. Otherwise, the joint efficiency shall be determined using the allowable unit stress for the weaker component of the joint.

2.1.1 Class I. Complete joint penetration; butt joints with the root of the first side chipped or gouged and ground back to sound metal¹ and reinforcements ground or machined flush with the direction of removal parallel to the principal stress.

2.1.2 Class II. Complete joint penetration; butt and T-joints with root of first side chipped or gouged and ground back to sound metal¹ before depositing second side.

2.1.3 Class III. Complete joint penetration; butt, T- and corner joints welded from both sides or one side only using backing strips which are not removed after welding.

1. Back gouging is not necessary where process and procedure have satisfactorily proven that good root tie-in is obtained.

2.1.4 Class IV. Complete and partial joint penetration; butt, T- and corner joints and fillet welded lap, T- and corner joints. Complete joint penetration welds may be welded from one side without the use of backing. Partial joint penetration groove welds and fillet welded joints shall be welded on both sides.

2.1.5 Class V. Partial joint penetration; butt, T- and corner joints and fillet plug or slot welded lap, T- and corner joints. Partial joint penetration groove welds and fillet welded joints may be welded on one side only.

2.1.6 Class VI. Butt, T-, corner, lap, and edge joints and plug welds; structural welded joints of secondary importance not subject to dynamic loading; joints and welds of secondary importance in strength.

2.2 Intermittent Welded Joints. Intermittent partial joint penetration groove welds in butt, T- and corner joints and intermittent welded lap joints and plug welds are placed in Class IV or VI.

3. Welded Joint Design

3.1 Basic Unit Stresses

3.1.1 Basic unit stresses shall be the allowable unit stress specified by the applicable base metal specification except that the basic unit shear stress on net section shall be 72 percent of the basic allowable stress in tension.

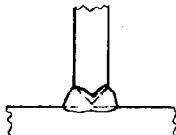
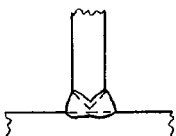
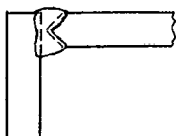
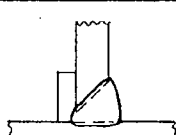
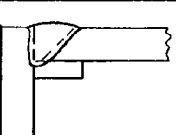
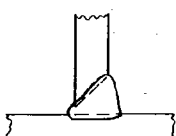
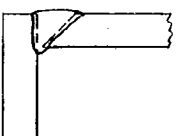
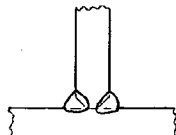
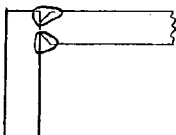
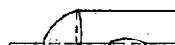
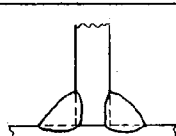
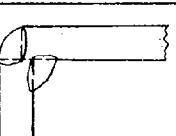
3.1.2 Basic unit stresses on the effective areas of weld metal (see 3.2) shall be as follows:

3.1.2.1 Complete Joint Penetration – Welded Joints. The unit stresses shall be the same as for the base metal joined.

3.1.2.2 Partial Joint Penetration Welds in Butt Joints and Fillet, Plug and Slot Welds. The permissible unit stresses shall not exceed 72 percent of the basic allowable stress in tension for the base metal.

3.1.3 Welded joints subject to repeated variations or reversals of stress shall be designed so that the maximum stress does not exceed the basic allowable stresses or the allowable fatigue stress as determined in Fig. 3.1.3.

2/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

Class	Joint efficiency ¹		Configuration of welded joints ³		
	Static	Dynamic ²			
I	100%	100%			
II	100%	75%			
III	90%	60%			
					
IV	80%	40%			
					
					

Note: d = diameter

1. The allowable range of stress (Fig. 3.1.3) must be multiplied by the joint efficiency to establish the permissible design stress.
2. 20 000 Hz minimum.
3. Details of weld joint (square-groove, V-groove, root opening, etc.) as required for the welding process to be used.

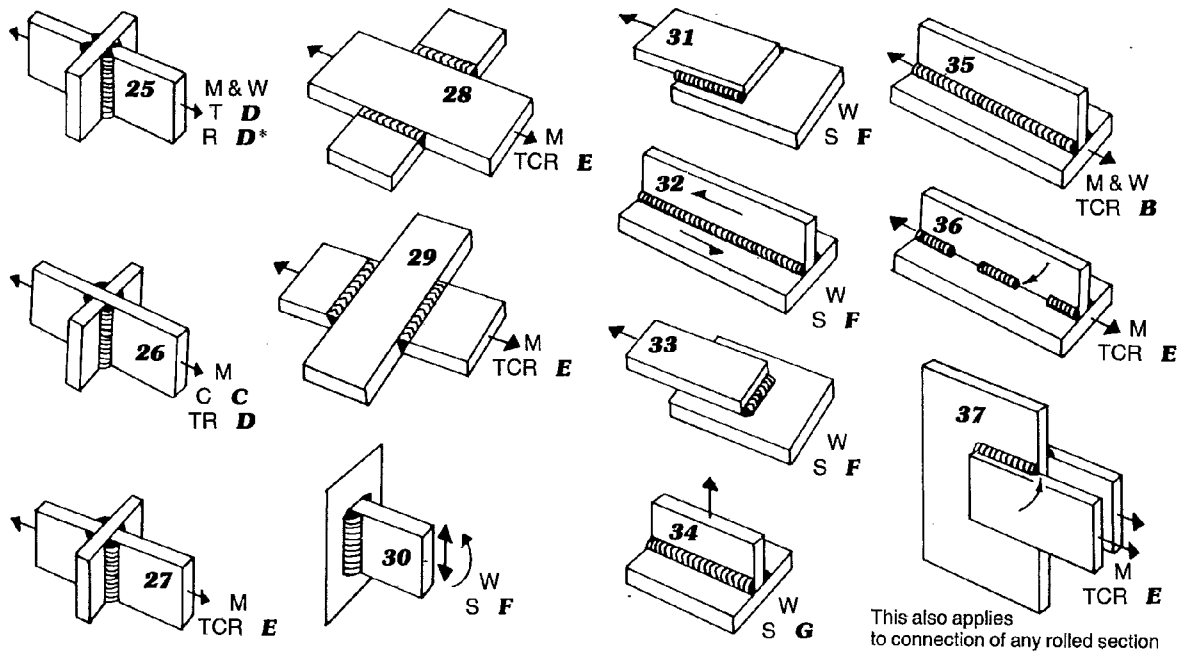
Fig. 2.1 – Classification of welded joints

Class	Joint efficiency ¹		Configuration of welded joints ³		
	Static	Dynamic ²			
V	50%	20%			
VI	20%	—			

Note: d = diameter

1. The allowable range of stress (Fig. 3.1.3) must be multiplied by the joint efficiency to establish the permissible design stress.
2. 20 000 Hz minimum.
3. Details of weld joint (square-groove, V-groove, root opening, etc.) as required for the welding process to be used.

Fig. 2.1 cont. — Classification of welded joints



← Curved arrow indicates region of application of allowable fatigue stresses.

← Straight arrow indicates applied forces.

Grind in the direction of stressing only. When slope is mentioned (e.g. 1 in 2-1/2), the value given is maximum. Less slope is permissible.

S = shear
T = tension
C = compression
R = reversal
M = stress in base metal
W = stress in weld metal
τ = allowable steady shear stress
F = force

*For those categories marked with an asterisk in the case of reversal use

$$\sigma_{\max} = \frac{\sigma_{sr}}{1 - 0.6K}$$

Hz	Allowable range of stress — MPa (ksi)						
	A	B	C	D	E	F	G
20 000 to 100 000 ~	276 (40)	228 (33)	193 (28)	165 (24)	117 (17)	117 (17)	103 (15)
100 000 to 500 000 ~	221 (32)	172 (25)	145 (21)	117 (17)	83 (12)	97 (14)	83 (12)
500 000 to 2 000 000 ~	165 (24)	117 (17)	97 (14)	69 (10)	48 (7)	76 (11)	62 (9)
Over 2 000 000 ~	165 (24)	103 (15)	83 (12)	62 (9)	41 (6)	62 (9)	55 (8)

Shall not exceed steady allowables

$$\text{Allowable fatigue stress} = \frac{\sigma_{sr}}{1 - K}$$

$\sigma_{\max}$ or $\tau_{\max}$ = maximum allowable fatigue stress

σ_{sr} or τ_{sr} = allowable range of stress (see table)

$$K = \frac{\sigma_{\min}}{\sigma_{\max}} = \frac{M_{\min}}{M_{\max}} = \frac{F_{\min}}{F_{\max}} = \frac{\tau_{\min}}{\tau_{\max}} = \frac{S_{\min}}{S_{\max}}$$

Fig. 3.1.3 cont. — Allowable range of stress (σ_{sr} , τ_{sr})

6/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

3.1.4 For joining materials, the filler metals found in Table 3.1.4 shall be used.

3.2 Effective Weld Areas

3.2.1 Groove Welds. The effective weld area of complete joint penetration groove welds shall be the effective weld length multiplied by the effective throat thickness.

3.2.1.1 The effective weld length for any groove weld, square or skewed, shall be the width of the part joined, perpendicular to the direction of stress.

3.2.1.2 The effective throat thickness of complete joint penetration groove welds shall be the thickness of the thinner piece of base metal joined. No increase shall be permitted for weld reinforcement.

3.2.2 Fillet Welds. The effective area shall be the effective weld length multiplied by the effective throat thickness. Stress in a fillet weld shall be considered as applied to this effective area for any direction of applied load.

3.2.2.1 The effective length of a straight fillet weld shall be the overall length of the full size fillet including end returns.

3.2.2.2 The effective length of a curved fillet weld shall be the length of the line generated by the centerpoint of the effective throat thickness. For a fillet weld in a hole or slot, when the weld area computed from this length is greater than the area found in 3.2.4, the latter area shall be used as the effective area.

3.2.2.3 The effective throat thickness shall be the shortest distance from the root to the face of the diagrammatic weld.

3.2.2.4 The minimum fillet weld size to develop to full strength of the thinner member joined is given in Table 3.2.2.4. These values are only applicable when the filler metal is properly matched with the base metal; the welds are loaded statically and the thinner plate or leg is fillet welded continuously on both sides (double fillet weld).

3.2.3 Lap Joints. The effective weld area shall be the effective fillet weld area (see 3.2.2). Plug and slot welds in lap joints may be used to transmit shear (see 3.2.4).

3.2.4 Plug and Slot Welds

3.2.4.1 The effective area shall be the nominal area of the hole or slot in the plane of the faying surface. On this effective area, these welds shall be computed to resist shear stresses only.

3.2.4.2 The thickness of plug or slot welds in materials 16 mm (5/8 in.) thick or less shall be equal to the thickness of the material. The thickness of plug or slot welds in material over 16 mm (5/8 in.) thick shall be at least one-half the thickness of the material but not less than 16 mm (5/8 in.).

3.2.5 Partial Joint Penetration Groove Welds

3.2.5.1 The effective weld area shall be the effective weld length multiplied by the effective throat (see Fig. 3.2.5).

3.2.5.2 For a combined partial joint penetration groove weld and fillet weld, the effective weld area shall be the effective weld length multiplied by the shortest dis-

Table 3.1.4 — Base metal and weld metal relationship

Material strength level		Filler metal ¹
MPa	psi	
310 to 520	45 000 to 75 000	E60XX, E70XX, E80XX ² , E90XX ² , E100XX ² , E110XX ²
520 to 590	75 000 to 85 000	E80XX, E90XX ² , E100XX ² , E110XX ²
590 to 660	85 000 to 95 000	E90XX, E100XX ² , E110XX ²
660 to 720	95 000 to 105 000	E100XX, E100XX ²
720 to 790	105 000 to 115 000	E110XX

1. Filler metals for use with welding processes other than SMAW shall be of the same filler metal classification as indicated above for each base metal strength.

2. For joining materials of different strength levels, the lower strength level shall govern.

tance from the root to the face of the diagrammatic weld. For joint preparation of less than 60 degrees, see Fig. 3.2.5.

3.3 Details of Welded Joints

3.3.1 Joint Qualification

3.3.1.1 Carbon and low alloy steel joints which conform to the detail requirements given herein and which are to be welded using manual shielded metal arc or submerged arc procedures are designated as prequalified and may be used without performing additional joint welding procedure qualification tests.

3.3.1.2 Other joints and materials may be used only if it is adequately demonstrated, by procedure qualification in accordance with Section 6, that the proposed joint welding procedure meets the requirements of the specification and the application.

3.3.2 Fillet Weld Details for Carbon and Low Alloy Steels

3.3.2.1 The details of fillet welds made by manual shielded metal arc welding, submerged arc welding, gas metal arc welding or flux cored arc welding, which may be used without joint welding procedure qualification, are listed in 3.3.2.2 through 3.3.2.6 and detailed in Fig. 3.3.2.1.

3.3.2.2 The minimum fillet weld size, except that of fillet welds used to reinforce groove welds, shall be as shown in Table 3.3.2.2.

3.3.2.3 The maximum fillet weld size permitted along edges of material shall be:

3.3.2.3.1 The thickness of the material, for material less than 6 mm (1/4 in.) thick.

3.3.2.3.2 1.5 mm (1/16 in.) less than the thickness of material for material 6 mm (1/4 in.) or more in thickness, unless the weld is designated on the drawing to be built out to obtain full throat thickness.

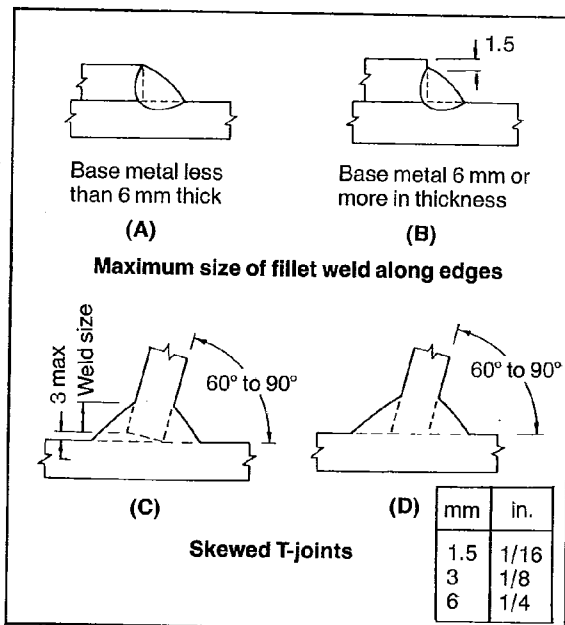
Table 3.2.2.4 – Minimum size of full strength double fillet welds

Thinner plate thickness (t)		Full strength ¹ weld ($s = \frac{3}{4} t$) ²		Thinner plate thickness (t)		Full strength ¹ weld ($s = \frac{3}{4} t$) ²	
mm	in.	mm	in.	mm	in.	mm	in.
6	1/4	5	3/16	35	1-3/8	25	1
8	5/16	6	1/4	38	1-1/2	29	1-1/8
10	3/8	8	5/16	41	1-5/8	32	1-1/4
11	7/16	10	3/8	45	1-3/4	35	1-3/8
13	1/2	10	3/8	51	2	38	1-1/2
14	9/16	11	7/16	54	2-1/8	41	1-5/8
16	5/8	13	1/2	57	2-1/4	45	1-3/4
19	3/4	14	9/16	60	2-3/8	45	1-3/4
22	7/8	16	5/8	64	2-1/2	48	1-7/8
25	1	19	3/4	67	2-5/8	51	2
27	1-1/8	22	7/8	70	2-3/4	51	2
32	1-1/4	25	1	76	3	57	2-1/4

1. Filler metal properties match with base metal in strength.

2. s = leg size of fillet weld.

Note: The fillet sizes listed do not take into consideration the effective throat thickness obtainable from the GMAW, FCAW, and SAW processes.



All dimensions in millimeters except angles

Fig. 3.3.2.1 – Details for fillet welds

3.3.2.4 Fillet welds in holes or slots in lap joints may be used to transmit shear or to prevent buckling or separation of lapped parts. These fillet welds may overlap. Fillet welds in holes or slots are not to be considered as plug or slot welds.

3.3.2.5 Fillet welds may be used in skew joints that have an included angle of not less than 60 degrees (see Fig. 3.3.2.1).

3.3.2.6 The minimum length of an intermittent fillet weld shall be 32 mm (1-1/4 in.).

Table 3.3.2.2 – Minimum fillet weld size

Material thickness of thicker part joined		Minimum size of fillet weld	
mm	in.	mm	in.
To 6 inclusive	To 1/4 inclusive	3	1/8
Over 6 to 13	Over 1/4 to 1/2	5	3/16
Over 13 to 19	Over 1/2 to 3/4	6	1/4
Over 19 to 38	Over 3/4 to 1-1/2	8	5/16
Over 38 to 57	Over 1-1/2 to 2-1/4	10	3/8
Over 57 to 152	Over 2-1/4 to 6	13	1/2
Over 152	Over 6	16	5/8

Note: The weld size need not exceed the thickness of the thinner part joined.

3.3.3 Plug and Slot Weld Details for Carbon and Low Alloy Steels

3.3.3.1 Plug and slot welds in lap joints may be used to transmit shear or to prevent the buckling or separation of lapped parts.

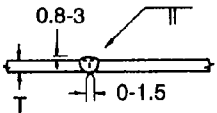
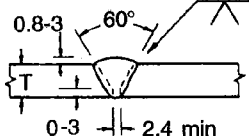
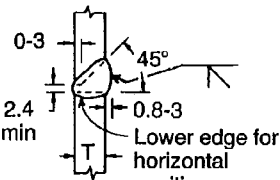
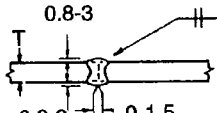
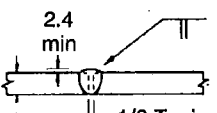
3.3.3.2 The diameter of the hole for a plug weld should be not less than the thickness of the part containing it plus 8 mm (5/16 in.), preferably rounded to the next greater odd 1.5 mm (1/16 in.), nor shall it be greater than 2-1/4 times the thickness of the weld.

3.3.3.3 The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

3.3.3.4 The length of a slot for a slot weld shall not exceed ten times the thickness of the weld. The width of the slot shall not be less than the thickness of the part containing it plus 8 mm (5/16 in.), preferably rounded to the next greater odd 1.5 mm (1/16 in.), nor shall it be greater than 2-1/4 times the thickness of the weld.

3.3.3.5 The ends of the slot shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part containing it, except those ends which extend to the edge of the part.

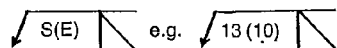
8/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

Welds Joints	Square-groove weld (1)	Single-V-groove weld (2)	Single-bevel-groove weld (4)
Butt joint (B) $T \leq 13$	 Effective throat (E)=T max T=3 B-P1a*	 Effective throat (E)=T max T=13 B-P2*	 Effective throat (E)=T max T=13 B-P4*
	Root need not be chipped before welding second side  Effective throat (E)=T max T=6 B-P1b		
	 Effective throat (E)=$\frac{3}{4} T$ max T=6 B-P1c*		

All dimensions in millimeters except angles

Notes:

1. Groove depth (S) and effective throat (E) should be shown on the weld symbol as follows:

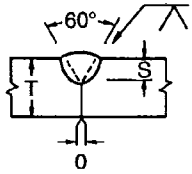
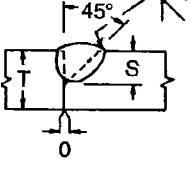
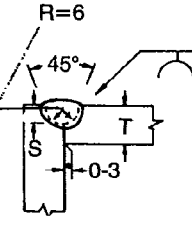
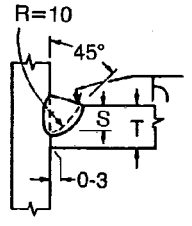
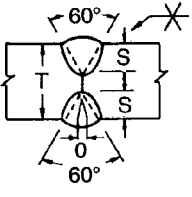
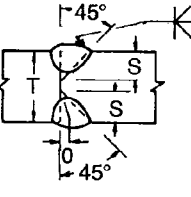
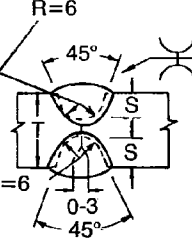
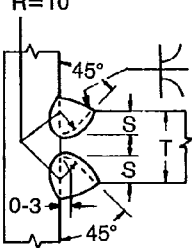


2. Refer to legend, p.16, for symbols.

*Joints welded from one side

mm	in.
0.8	1/32
1.5	1/16
2.4	3/32
3	1/8
6	1/4
10	3/8
13	1/2

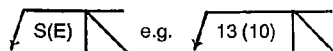
Fig. 3.2.5 – Partial joint penetration (P) prequalified shielded metal arc welded joints

Welds Joints		V-groove weld	Bevel-groove weld	U-groove weld	J-groove weld
		Single-V-groove weld (2)	Single-bevel-groove weld (4)	Single-U-groove weld (6)	Single-J-groove weld (8)
Butt (B), T- (T) or corner (C) joint	Minimum root face of joint shall be 3 mm	 Effective throat (E)=S BC-P2	 Effective throat (E)=S-3 BTC-P4*	 Effective throat (E)=S BC-P6*	 Effective throat (E)=S BTC-P8*
		Double-V-groove weld (3)	Double-bevel-groove weld (5)	Double-U-groove weld (7)	Double-J-groove weld (9)
		 Effective throat (E)=S B-P3	 Effective throat (E)=S-3 BTC-P5*	 Effective throat (E)=S B-P7	 Effective throat (E)=S BTC-P9*

All dimensions in millimeters except angles

Notes:

1. Groove depth (S) and effective throat (E) should be shown on the weld symbol as follows:



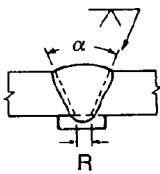
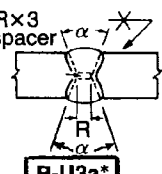
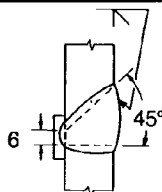
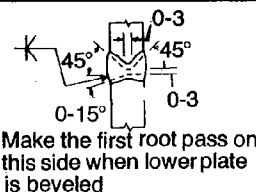
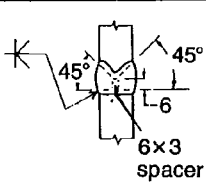
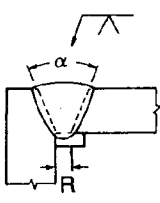
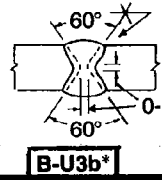
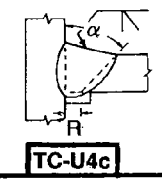
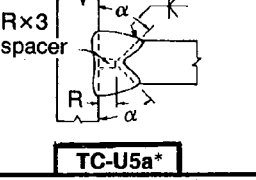
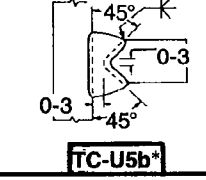
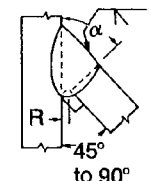
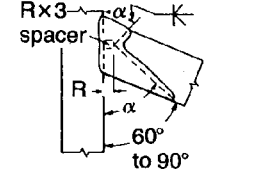
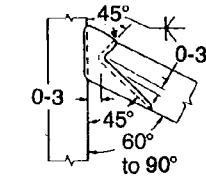
2. Refer to legend, p.16, for symbols.

mm	in.
3	1/8
6	1/4
10	3/8
13	1/2

*For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operation without excessive edge melting.

Fig. 3.2.5 cont. – Partial joint penetration (P) prequalified shielded metal arc welded joints

10/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

Welds Joints	V-groove weld		Bevel-groove weld		
	Single V-groove (2)	Double V-groove (3)	Single bevel-groove (4)	Double bevel-groove (5)	
Butt joint (B)	 B-U2a	 B-U3a*	 B-U4a**	 B-U5a*	 *B-U5b**
	 C-U2a	 B-U3b*	 TC-U4c	 TC-U5a*	 TC-U5b*
T-joint (T) or corner joint (C)			 TC-U4d	 TC-U5c*	 TC-U5d*

All dimensions in millimeters except angles

Limitations for joints
B-U2a, B-U3a* and C-U2a

α	R	Permitted welding positions
45°	6	All positions
30°	10	Flat and overhead only
20°	13	Flat and overhead only

Limitations for joints
TC-U4c, TC-U4d, TC-U5a* and TC-U5c*

α	R	Permitted welding positions
45°	6	All positions
30°	10	Flat and overhead only

mm	in.
3	1/8
6	1/4
10	3/8
13	1/2
16	5/8

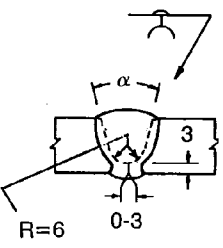
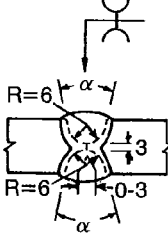
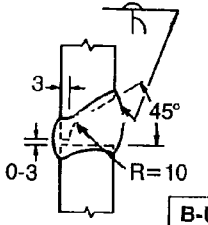
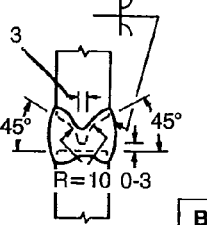
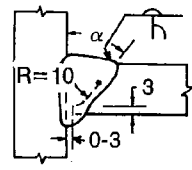
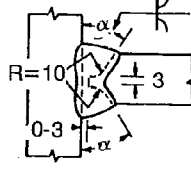
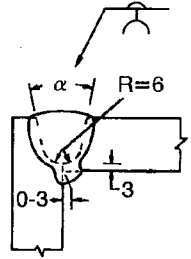
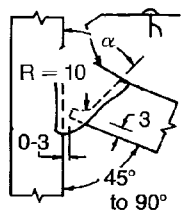
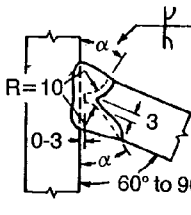
Notes:

- Gouge roots of joints without backing before welding other side.
- If fillet welds are used to reinforce groove welds in T- and corner joints, they shall be equal to T/4 but need not exceed 10 mm. Groove welds in T- and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 10 mm. T is the thickness of the groove weld.
- Refer to legend, p.16, for symbols.

*The use of these welds preferably shall be limited to base metal thickness of 16 mm or larger.

**The use of these welds is recommended for the horizontal or flat position.

Fig. 3.3.4.1.1 – Complete joint penetration prequalified shielded metal arc welded joints – base metal of unlimited thickness (U)

Welds Joints	U-groove weld		J-groove weld	
	Single-U-groove (6)	Double-U-groove (7)	Single-J-groove (8)	Double-J-groove (9)
Butt joint (B)				
				
T- joint (T) or corner joint (C)				

All dimensions in millimeters except angles

Limitations of joints
B-U6, B-U7* and C-U6

α	Permitted welding positions
45°	All positions
20°	Flat and overhead only

Limitations of joints
TC-U8a, TC-U8b, TC-U9a* and TC-U9b*

α	Permitted welding positions
45°	All positions
30°	Flat and overhead only

mm	in.
3	1/8
6	1/4
10	3/8
16	5/8

Notes:

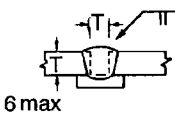
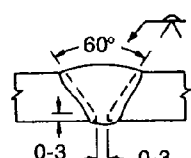
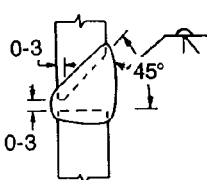
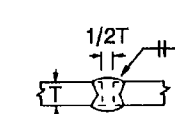
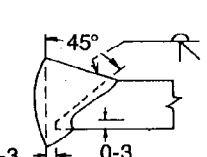
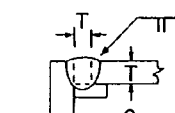
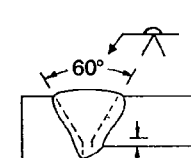
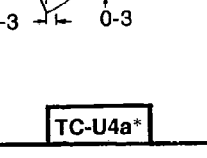
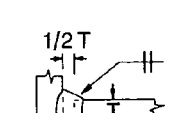
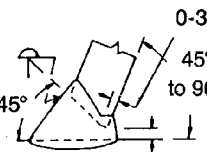
- Gouge roots of joints without backing before welding other side.
- If fillet welds are used to reinforce groove welds in T- and corner joints, they shall be equal to T/4 but need not exceed 10 mm. Groove welds in T- and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 10 mm. T is the thickness of the groove weld.
- Refer to legend, p.16, for symbols.

*The use of these welds preferably shall be limited to base metal thickness of 16 mm or larger.

**The use of these welds is recommended for the horizontal or flat position.

**Fig. 3.3.4.1.1 cont. — Complete joint penetration prequalified shielded metal arc welded joints—
base metal of unlimited thickness (U)**

12/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

Welds Joints	Square-groove weld (1)	Single-V-groove weld (2)	Single-bevel-groove weld (4)
Butt joint (B)	 6 max B-L1a	 60° 0-3 0-3 B-U2	 0-3 45° 0-3 B-U4
	 1/2T 6 max B-L1b		 45° 0-3 0-3 B-U4
T-joint (T) or corner joint (C)	 6 max C-L1a	 60° 0-3 0-3 C-U2	 45° 0-3 0-3 TC-U4a*
	 1/2T 6 max TC-L1b		 45° 45° to 90° 0-3 0-3 TC-U4b*

All dimensions in millimeters except angles

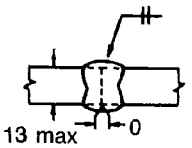
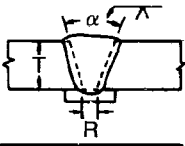
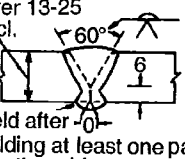
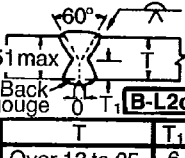
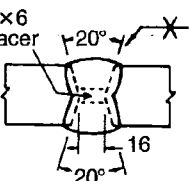
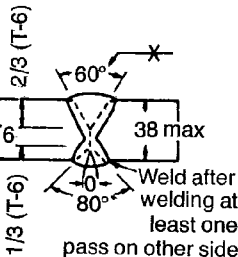
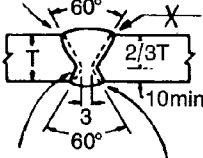
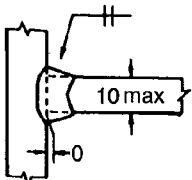
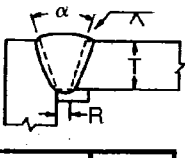
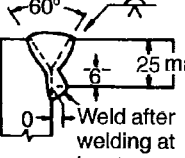
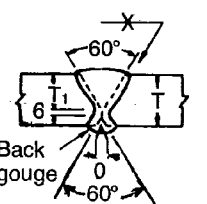
Notes:

1. Gouge the roots of joints without backing before welding the other side.
2. If fillet welds are used to reinforce groove welds in T- and corner joints, they shall be equal to $T/4$ but need not exceed 10 mm. Groove welds in T- and corner joints shall be reinforced with fillet welds equal to $T/4$ but not more than 10 mm. T is the thickness of the groove weld.
3. Refer to legend, p. 16, for symbols.

*For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operation without excessive edge melting.

mm	in.
3	1/8
6	1/4
10	3/8

Fig. 3.3.4.1.2 – Complete joint penetration prequalified shielded metal arc welded joints – base metal of limited thickness (L)

Welds Joints	Square-groove weld (1)	V-groove weld																																								
		Single-V-groove (2)	Double-V-groove (3)																																							
Butt joint (B)	 B-L1-S	 B-L2a-S B-U2-S Over 13-25 incl.  B-L2b-S  B-L2c-S <table><tr><th>T</th><th>T₁</th></tr><tr><td>Over 13 to 25</td><td>6</td></tr><tr><td>Over 25 to 38</td><td>13</td></tr><tr><td>Over 38 to 51</td><td>16</td></tr></table>	T	T ₁	Over 13 to 25	6	Over 25 to 38	13	Over 38 to 51	16	 B-U3a-S  B-L3-S	Single or multiple pass submerged arc weld in flat position after manual welding is completed on other side  Shielded metal arc weld first with low hydrogen electrodes B-U3b-S																														
	T	T ₁																																								
	Over 13 to 25	6																																								
	Over 25 to 38	13																																								
Over 38 to 51	16																																									
T-joint (T) or corner joint (C)	 TC-L1-S	 C-L2a-S C-U2-S  C-L2b-S	 B-U3c-S <table><tr><th colspan="3">Limitations for joints</th></tr><tr><th></th><th>α</th><th>R</th><th>Maximum thickness (T)</th></tr><tr><td>B-L2a-S C-L2a-S</td><td>30°</td><td>6</td><td>13</td></tr><tr><td>B-U2-S C-U2-S</td><td>20°</td><td>16</td><td>Unlimited</td></tr></table>	Limitations for joints				α	R	Maximum thickness (T)	B-L2a-S C-L2a-S	30°	6	13	B-U2-S C-U2-S	20°	16	Unlimited	<table><tr><th>T</th><th>T₁</th></tr><tr><td>Over 51</td><td>64</td><td>35</td></tr><tr><td>64</td><td>76</td><td>45</td></tr><tr><td>76</td><td>92</td><td>54</td></tr><tr><td>92</td><td>102</td><td>60</td></tr><tr><td>102</td><td>121</td><td>70</td></tr><tr><td>121</td><td>140</td><td>83</td></tr><tr><td>140</td><td>159</td><td>95</td></tr></table> For T>159 or T≤51 T₁=2/3(T-6)	T	T ₁	Over 51	64	35	64	76	45	76	92	54	92	102	60	102	121	70	121	140	83	140	159	95
	Limitations for joints																																									
		α	R	Maximum thickness (T)																																						
B-L2a-S C-L2a-S	30°	6	13																																							
B-U2-S C-U2-S	20°	16	Unlimited																																							
T	T ₁																																									
Over 51	64	35																																								
64	76	45																																								
76	92	54																																								
92	102	60																																								
102	121	70																																								
121	140	83																																								
140	159	95																																								

Notes:

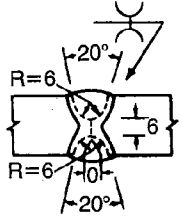
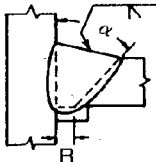
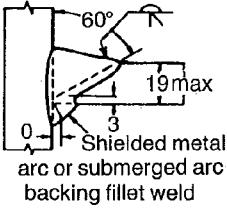
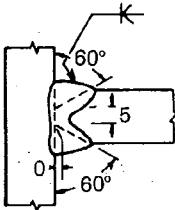
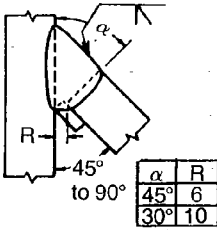
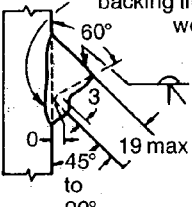
1. If fillet welds are used to reinforce groove welds in T- and corner joints, they shall be equal to T/4 but need not exceed 10 mm. Groove welds in T- and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 10 mm. T is the thickness of the groove weld.
2. Refer to legend, page 16, for symbols.

All dimensions in millimeters except angles

mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
3	1/8	16	5/8	45	1-3/4	64	2-1/2	92	3-5/8	140	5-1/2
6	1/4	25	1	51	2	70	2-3/4	95	3-3/4	152	6
10	3/8	35	1-3/8	54	2-1/8	76	3	102	4	159	6-1/4
13	1/2	38	1-1/2	60	2-3/8	83	3-1/4	121	4-3/4		

Fig. 3.3.5.1 – Complete joint penetration prequalified submerged arc welded joints – base metal of limited thickness (L) and unlimited thickness (U)

14/CLASSIFICATION AND APPLICATION OF WELDED JOINTS FOR MACHINERY AND EQUIPMENT

Welds Joints	Bevel-groove weld		U-groove weld
	Single-bevel-groove (4)	Double-bevel-groove (5)	Double-U-groove (7)
Butt joint (B)			 B-U7-S
T-joint (T) or corner joint (C)	 TC-U4a-S	 TC-L4a-S	 TC-U5-S
	 TC-U4b-S	 TC-L4b-S	

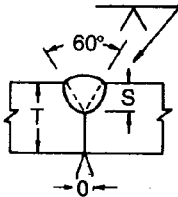
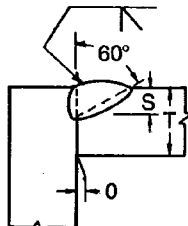
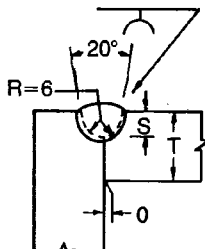
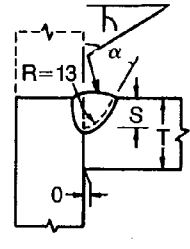
All dimensions in millimeters except angles

Notes:

1. If fillet welds are used to reinforce groove welds in T- and corner joints, they shall be equal to T/4 but not exceed 10 mm. Groove welds in T- and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 10 mm. T is the thickness of the groove weld.
2. Refer to legend, page 16, for symbols.

mm	in.	mm	in.
3	1/8	10	3/8
5	3/16	19	3/4
6	1/4		

Fig. 3.3.5.1 cont. – Complete joint penetration prequalified submerged arc welded joints – base metal of limited thickness (L) and unlimited thickness (U)

Welds Joints		V-groove weld	Bevel-groove weld	U-groove weld	J-groove weld						
		Single-V-groove weld (2)	Single-bevel-groove weld (4)	Single-U-groove weld (6)	Single-J-groove weld (8)						
Butt (B), T-(T) or corner (C) joints	Minimum root face of joint shall be 6 mm				 <table border="1" data-bbox="1185 822 1318 904"><tr><th>Joint</th><th>α</th></tr><tr><td>C-P8-S</td><td>20°</td></tr><tr><td>T-P8-S</td><td>45°</td></tr></table>	Joint	α	C-P8-S	20°	T-P8-S	45°
		Joint	α								
		C-P8-S	20°								
		T-P8-S	45°								
Effective throat (E) = S*	Effective throat (E) = S*	Effective throat (E) = S*	Effective throat (E) = S*								
BC-P2-S	TC-P4-S	BC-P6-S	C-P8-S T-P8-S								
		</									

All dimensions in millimeters except angles

Note: Refer to legend, p. 16, for symbols

*Minimum effective throat = T/6

mm	in.
6	1/4
13	1/2

Fig. 3.3.5.2—Partial joint penetration (P) prequalified submerged arc welded joints

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Legend for Figs. 3.2.5 through 3.3.5.2**Symbols for joint types**

- B—butt joint
- C—corner joint
- T—T-joint
- BC—butt or corner joint
- TC—T- or corner joint
- BTC—butt, T-, or corner joint

Symbols for base metal thickness and penetration

- L—limited thickness—complete joint penetration
- U—unlimited thickness—complete joint penetration
- P—partial joint penetration

Symbols for weld types

- 1—square-groove
- 2—single-V-groove
- 3—double-V-groove
- 4—single-bevel-groove
- 5—double-bevel-groove
- 6—single-U-groove
- 7—double-U-groove
- 8—single-J-groove
- 9—double-J-groove

Symbols for welding processes if not shielded metal arc

- S—submerged arc welding
- G—gas metal arc welding
- F—flux cored arc welding

3.3.3.6 The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum center-to-center spacing in a longitudinal direction on any line shall be two times the length of the slot.

3.3.3.7 The thickness of plug or slot welds in material 16 mm (5/8 in.) or less in thickness shall be equal to the thickness of the material. In material over 16 mm (5/8 in.) in thickness, it shall be at least one-half the thickness of the material but not less than 16 mm (5/8 in.).

3.3.4 Carbon and Low Alloy Steel Groove Welds Made by Manual Shielded Metal Arc Welding

3.3.4.1 Complete Joint Penetration Welds

3.3.4.1.1 Complete joint penetration groove welds made by manual shielded metal arc processes in butt, T- and corner joints which may be used without performing the prescribed joint welding procedure qualification tests are detailed in Fig. 3.3.4.1.1 and are subject to the limitations specified in 3.3.4.1.2.

3.3.4.1.2 Dimensions of groove welds specified on design or detail drawings may deviate from the dimensions shown in Fig. 3.3.4.1.2 only within the following limits:

- (1) The specified thickness of material is the maximum nominal thickness that may be used.
- (2) The root face of the joints is zero unless dimensioned otherwise. It may be detailed to exceed zero, or the specified dimension, by not more than 1.5 mm (1/16

in.). It may not be detailed less than the specified dimension.

(3) The root opening of the joints is minimum. It may be detailed to exceed the dimension shown by not more than 1.5 mm (1/16 in.).

(4) The groove angle is minimum. It may be detailed to exceed the dimension shown by not more than 10 degrees.

(5) The radii of J- and U-grooves are minimum. They may be detailed to exceed the dimensions shown by not more than 3 mm (1/8 in.). U-grooves may be prepared prior to or after fitting.

(6) Double-groove welds may have grooves of unequal depth but the depth of the more shallow groove shall not be less than one-fourth the thickness of the thinner part joined.

3.3.4.2 Partial Joint Penetration Welds

3.3.4.2.1 Groove welds without steel backing, welded from one side, and groove welds welded from both sides but without back gouging are considered partial joint penetration groove welds.

3.3.4.2.2 Partial joint penetration groove welds made by the manual shielded metal arc process in butt, T- and corner joints, which may be used without performing the joint welding procedure qualification tests, are detailed in Fig. 3.2.5 and are subject to limitations specified in 3.3.4.2.3.

3.3.4.2.3 Dimensions of groove welds specified on design or detail drawings may deviate from the dimensions shown in Fig. 3.2.5 within the following limits:

(1) The groove angle is minimum. It may be detailed to exceed the dimension shown by not more than 10 degrees.

(2) The radius of the U- and J-grooves is minimum. It may be detailed to exceed the dimension shown by not more than 3 mm (1/8 in.). U-grooves may be prepared prior to or after fitting.

(3) Double-groove welds may have grooves of unequal depth, provided that the weld deposit on each side of the joint conforms to the limitations shown in Fig. 3.2.5.

3.3.4.2.4 The effective throat thickness of partial joint penetration square-, bevel- or V-groove welds shall be as detailed in Fig. 3.2.5.

3.3.5 Carbon and Low Alloy Steel Groove Welds Made by Submerged Arc Welding

3.3.5.1 Complete Joint Penetration Welds

3.3.5.1.1 Complete joint penetration groove welds made by submerged arc processes in butt, T- and corner joints which may be used without performing the joint welding procedure qualification tests are detailed in Fig. 3.3.5.1 and are subject to the limitations specified in 3.3.5.1.2.

3.3.5.1.2 Dimensions of groove welds specified on design or detailed drawings may deviate from the dimensions shown in Fig. 3.3.5.1 within the following limits:

- (1) The specified thickness of material is the maximum nominal thickness that may be used.

(2) The root faces of the joints are maximum.

(3) The root openings of closed joints shall be detailed as zero, without deviation. The root openings of open joints with backing are minimum. They may be detailed to exceed the dimensions shown by not more than 1.5 mm (1/16 in.).

(4) The groove angle is minimum. It may be detailed to exceed the dimension shown by not more than 10 degrees.

(5) The radius of the U-groove is minimum. It may be detailed to exceed the dimension shown by not more than 3 mm (1/8 in.). U-grooves may be prepared prior to or after fitting.

3.3.5.2 Partial Joint Penetration Welds

3.3.5.2.1 Partial joint penetration groove welds made by submerged arc welding in butt, T- and corner joints which may be used without performing the joint welding procedure qualification tests are detailed in Fig. 3.3.5.2 and are subject to the limitations specified in 3.3.5.2.2.

3.3.5.2.2 Dimensions of partial joint penetration groove welds specified on design or detailed drawings may deviate from the dimensions shown in Fig. 3.3.5.2 within the following limits:

(1) The root opening shall be detailed as zero, without deviation.

(2) The groove angle is minimum. It may be detailed to exceed the dimensions shown by not more than 10 degrees.

(3) The radii of the U- and J-grooves are minimum. They may be detailed to exceed the dimensions shown by not more than 3 mm (1/8 in.). U-grooves may be prepared prior to or after fitting.

(4) If the root face is less than 6 mm (1/4 in.) there shall be at least one initial manual pass, where necessary, to prevent burn-through.

(5) Double-groove welds may have grooves of unequal depth, subject to the limitations of Fig. 3.3.5.2.

3.3.5.2.3 The minimum thickness of material for a single partial joint penetration groove weld shall be 19 mm (3/4 in.) and for a double partial penetration groove weld it shall be 32 mm (1-1/4 in.). The effective throat thicknesses of single or double V-, bevel-, J- and U-groove welds, related to the minimum groove depth for a given permissible thickness of material, shall be as shown in Fig. 3.3.5.2.

4. Workmanship

4.1 General

4.1.1 All applicable paragraphs of this section shall be observed in the production and inspection of weldments produced by any process acceptable under this standard.

4.1.2 All items of equipment for welding and oxygen cutting shall be so designed and manufactured and be in such condition as to enable qualified welders, welding

operators and tackers to follow qualified procedures and attain the results required by this standard.

4.1.3 Welding shall not be done when the ambient temperature is lower than -18°C (0°F), when surfaces are wet, exposed to rain, snow, or high wind, or when welders are exposed to inclement weather conditions.

4.1.4 The sizes and lengths of welds shall not be less than or substantially more than those specified by design requirements and detailed drawings. The location of welds shall not be changed.

4.2 Preparation of Materials

4.2.1 Surfaces and edges to be welded shall be smooth, uniform and free from fins, tears, cracks and other defects which would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to them shall be free from scale, slag, rust, grease or other foreign material that will prevent proper welding or produce objectionable fumes.

4.2.2 Oxygen or arc cutting may be employed in the preparation of base metal for welding if all scale, slag, gouges or other irregularities on the cut surface shall be removed by mechanical means after cutting.

4.2.3 Backing strips, rings and spacer blocks shall be of the same general type of material as the base metal for similar metal welds. For dissimilar metal welds, the backing material shall be as specified in the design drawings or approved welding procedure.

4.2.4 All tack welds shall be made using the same grade welding electrode or filler metal as the final weld. Tack welds incorporated in the final weld shall be deposited, by qualified welders using an approved welding procedure, after examination shows them to be of good quality and free of cracks. Tack welds not deposited by qualified welders shall be removed.

4.2.5 Complete penetration joint welding procedures, where the joint is welded from both sides, shall require either back gouging of the underside of the root pass before welding the second side or it shall be demonstrated by actual welding tests that back gouging may be omitted without detriment to the joint. Back gouging shall require removal of the underside of the root pass to sound metal as indicated by liquid penetrant or magnetic particle inspection before welding. Procedures which omit back gouging shall demonstrate that the weld is free of defective metal as indicated by macrographic examination of weld cross sections and side-bend tests.

4.2.6 Each pass of deposited weld metal shall be thoroughly cleaned using slagging picks, grinding wheels or wire brushes. Pneumatic chippers may be used provided they do not peen or distort the weld.

4.2.7 Preheating and interpass temperature control shall insure that the full thickness of the weld joint preparation and adjacent weld metal is the temperature specified in the welding procedure. Unless otherwise specified by the approved welding procedure, the minimum preheat and interpass temperature shall be 16°C (60°F).

Table 5—Weld quality assurance requirements

Weld class (see Fig. 2.1)	Ultrasonic or radiographic inspection	Magnetic particle or liquid penetrant inspection	Visual inspection	Dimensional inspection
I	yes (100%)	yes (100%)	yes (100%)	yes (100%)
II	yes	yes	yes	yes
III		yes	yes	yes
IV			yes	yes
V			yes	
VI			yes	

4.2.8 Where required by contract plans or specifications, welded assemblies shall be stress relieved by heat treating. The temperature shall be uniformly controlled during heating and cooling so that the maximum differential throughout the assembly does not exceed 38° C (100° F) at any time. After a temperature of 593±28° C (1100±50° F) is reached, the temperature of the assembly shall be held within these limits for one hour per 25 mm of thickness of maximum section.

5. Quality Control Requirements and Procedures

The service performance of a welded joint may be adversely affected by the presence of discontinuities. The weld tolerance for discontinuities depends upon the size, shape and orientation of the discontinuities within the stress system and the severity of the stress imposed. Non-destructive inspection procedures do not necessarily reveal the influences of discontinuities within a stress system. Weld tolerance for discontinuities may be regulated to the severity of the stress imposed and the sensitivity of the inspection procedure. This approach is used in the development of quality control requirements for the several classes of weldments as established in Table 5. The extent of quality examination, when required, shall be determined by the particular application and use.

6. Qualification

Part A

General Qualification Requirements

6.1 Approved Procedures

6.1.1 Welding procedures which conform in all respects to the applicable provisions of Section 2, Classification of Welded Joints, Section 3, Welded Joint Design, Section 4, Workmanship and Section 5, Quality Control Requirements and Procedures, whichever are applicable, shall be considered as prequalified and are exempt from tests or qualification.

6.1.2 A prequalified procedure to be used shall be prepared by the manufacturer, fabricator or contractor as a written procedure specification and shall be available to those authorized to examine it.

6.2 Other Procedures. Except for procedures exempt in 6.1, joint welding procedures employed in executing contract work under this standard shall be qualified to the satisfaction of the Engineer prior to use as prescribed in Part B of this section. The Engineer, at his discretion, may accept evidence of previous qualification of the joint welding procedures to be employed.

6.3 Welders, Welding Operators and Tackers

6.3.1 All welders, welding operators and tackers employed under this standard shall have been qualified by the tests prescribed in Part C of this section. The Engineer, at his discretion, may accept evidence of previous qualification of the welders, welding operators and tackers to be employed.

6.3.2 Radiographic examination of a welder's or welding operator's qualification test plate may be made in lieu of the guided-bend tests prescribed in Part B of this section.

6.4 Qualification Responsibility. Each manufacturer or contractor shall conduct the tests required by this standard to qualify the welding procedures and the welders, welding operators and tackers who will apply these procedures.

Part B

Welding Procedure Qualification

6.5 Welding procedures listed in this standard and qualified in accordance with the requirements of AWS D1.1, Structural Welding Code, shall be considered to have qualified under the tests prescribed herein subject to the limitation of variables in 6.6. Any requalifications or new qualifications shall be made in accordance with the requirements of this standard.

6.6 Limitation of Variables

6.6.1 When it is necessary to establish a welding procedure by qualification as required by 6.2 or contract specifications, the following rules apply and the procedure shall be recorded by the manufacturer or contractor as a procedure specification.

6.6.1.1 Qualification of a welding procedure established with carbon or low alloy steel, not listed in 6.6.1.2, and having minimum specified yield strength less than 345 MPa (50 000 psi), shall qualify the procedure for

welding any other carbon or low alloy steel or combination having a minimum specified yield strength equal to or less than that of the base metal used in the test.

6.6.1.2 Qualification of a welding procedure established with ASTM A242, A441, A537 Grade A, A 572 Grade 50, A588, API 5LX Grade 42, or ABS Grade AH, DH or EH shall be considered as procedure qualification for welding the other steels of this group, combinations of them, or carbon or low alloy steels having a lower minimum specified yield strength.

6.6.1.3 Qualification of a welding procedure established with carbon or low alloy steel having a minimum specified yield strength greater than 345 MPa (50 000 psi) shall qualify the procedure for welding only base metals of the same material specification and grade or type having the same minimum specified yield strength as the base metal tested, reduction in yield strength for increase in material thickness excepted. (For example, a procedure qualified with a 25 mm (1 in.) thick 690 MPa (100 000 psi) yield strength base metal also qualifies for a 76 mm (3 in.) thick 620 MPa (90 000 psi) yield strength base metal of the same material specification.)

6.6.1.4 Qualification of a welding procedure established with a combination of carbon or low alloy steel of different minimum specified yield strengths, one of which is greater than 345 MPa (50 000 psi), shall qualify the procedure for welding that high yield strength base metal to any other of those base metals having a minimum specified yield strength equal to or less than that of the lower strength base metal used in the test.

6.6.2 The changes set forth in the following schedule shall be considered essential changes in a welding procedure and shall require establishing a new procedure by qualification. When a combination of welding processes is used, the variables applicable to each process shall apply.

6.6.2.1 Shielded Metal Arc Welding

(1) A change increasing filler metal strength level; e.g., a change from E70XX to E80XX but not vice versa.

(2) A change from a low hydrogen type electrode to a non-low-hydrogen type of electrode but not vice versa.

(3) An increase in the diameter of the electrode used, greater than that called for in the procedure specification.

(4) A change of more than 15 percent above or below the specified mean arc voltage and amperage for each size electrode used.

(5) For a specified groove, a change of more than ± 25 percent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.

(6) A change in position in which welding is done as defined in 6.9.

(7) A change in the type of groove; e.g., a change from a V- to a U-groove.

(8) A change, exceeding tolerances of 3.3.4.1, in the shape of any one type of groove involving:

(a) A decrease in the included angle of the groove or

(b) A decrease in the root opening of the groove or

(c) An increase in the root face of the groove or

(d) The omission, but not the inclusion, of backing material

(9) A decrease of more than 14° C (25° F) in the minimum specified preheat temperature.

(10) In the case of vertical welding, a change from the progression specified for any pass from upward to downward or vice versa.

6.6.2.2 Submerged Arc Welding

(1) A change in electrode and flux combination not covered by AWS A5.17, Specification for Bare Carbon Steel Electrodes and Fluxes for Submerged Arc Welding.

(2) A change increasing filler metal strength level.

(3) A change in electrode diameter when using an alloy flux.²

(4) A change in the number of electrodes used; e.g., single electrode to multiple electrodes, or vice versa.

(5) A change in the type of current (ac or dc) or polarity when welding quenched and tempered steel or when using an alloy flux.

(6) A change of more than 10 percent above or below the specified mean amperage for each size electrode used.

(7) A change of more than 7 percent above or below the specified mean arc voltage for each size electrode used.

(8) A change of more than 15 percent above or below the specified mean travel speed.

(9) A change of more than ± 10 percent or 3 mm (1/8 in.), whichever is greater, in the longitudinal spacing of the arcs.

(10) A change of more than ± 10 percent or 1.5 mm (1/16 in.), whichever is greater, in the lateral spacing of the arcs.

(11) A change of more than ± 10 percent degrees in the angular position of any parallel electrode.

(12) A change in the angle of electrodes in machine or automatic welding of more than:

(a) ± 3 degrees in the direction of travel

(b) ± 5 degrees normal to the direction of travel

(13) For a specified groove, a change of more than ± 25 percent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.

(14) A change in position in which welding is done as defined in 6.9.

(15) A change in the type of groove; e.g., a change from a V- to a U-groove.

(16) A change, exceeding tolerances of 3.3.5, in the shape of any one type of groove involving:

(a) A decrease in the included angle of the groove or

2. An alloy flux is defined as a flux upon which the alloy content of the weld metal is largely dependent.

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- (b) A decrease in the root opening of a groove or
- (c) An increase in the root face of a groove or
- (d) The omission, but not the inclusion, of backing material

(17) A decrease of more than 14° C (25° F) in the minimum specified preheat temperature.

(18) An increase in the diameter of the electrode used, greater than that called for in the procedure specification.

6.6.2.3 Gas Metal Arc Welding

(1) A change in electrode type and method of shielding not covered by AWS A5.18, Specification for Mild Steel Electrodes for Gas Metal Arc Welding.

(2) A change increasing filler metal strength level.

(3) A change in electrode diameter.

(4) A change in the number of electrodes used; e.g., single electrode to multiple electrodes or vice versa.

(5) A change from a single gas to any other single gas or to a mixture of gases or a change in specified percentage composition of gas mixture not covered by AWS A5.18, Specification for Mild Steel Electrodes for Gas Metal Arc Welding.

(6) A change of more than 10 percent above or below the specified mean amperage for each size electrode used.

(7) A change of more than 7 percent above or below the specified mean arc voltage for each size electrode used.

(8) A change of more than 10 percent above or below the specified mean travel speed.

(9) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of shielding gas or mixture.

(10) For a specified groove, a change of more than 25 percent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.

(11) A change in the position in which welding is done as defined in 6.9.

(12) A change in the type of groove; e.g., a change from a V- to U-groove.

(13) A change from the dimensions of the joint qualified involving:

(a) A decrease in the included angle of the groove or

(b) A decrease in the root opening of a groove or

(c) An increase in the root face of a groove or

(d) The omission, but not the inclusion, of backing material

(14) A decrease of more than 14° C (25° F) in the minimum specified preheat temperature.

(15) In vertical welding, a change from the progression specified for any pass from upward to downward or vice versa.

(16) A change in type of welding current (ac or dc), polarity or mode of metal transfer across arc.

6.6.2.4 Flux Cored Arc Welding

(1) A change in electrode type and method of shielding not covered by AWS A5.20, Specification for Mild Steel Electrodes for Flux Cored Arc Welding.

(2) A change increasing filler metal strength level.

(3) An increase in the diameter of electrode used over that called for in the procedure specification.

(4) A change in the number of electrodes used; e.g., single electrode to multiple electrodes or vice versa.

(5) A change from a single gas to any other single gas or to a mixture of gases or a change in specified percentage composition of gas mixture not covered by AWS A5.20, Specification for Mild Steel Electrodes for Flux Cored Arc Welding.

(6) A change of more than 10 percent above or below the specified mean amperage for each size electrode used.

(7) A change of more than 7 percent above or below the specified mean arc voltage for each size electrode used.

(8) A change of more than 10 percent above or below the specified mean travel speed.

(9) An increase of 25 percent or more or a decrease of 10 percent or more in the rate of flow of shielding gas or mixture.

(10) For a specified groove, a change of more than ± 25 percent in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.

(11) A change in the position in which welding is done as defined in 6.9.

(12) A change in the type of groove; e.g., a change from a V- to a U-groove.

(13) A change from the dimensions of the joint qualified involving:

(a) A decrease in the included angle of the groove or

(b) A decrease in the root opening of a groove or

(c) An increase in the root face of a groove or

(d) The omission, but not the inclusion, of backing material

(14) A decrease of more than 14° C (25° F) in the minimum specified preheat temperature.

(15) In vertical welding, a change from the progression specified for any pass from upward to downward or vice versa.

(16) A change in type of welding current (ac or dc), polarity or mode of metal transfer across arc.

6.6.2.5 Electroslag and Electrogas Welding

(1) A significant change in filler metal or consumable guide metal composition.

(2) A change in consumable guide metal core cross-sectional area exceeding 30 percent.

(3) A change in flux system (cored, magnetic electrode, external flux, etc.).

(4) A change in flux composition including consumable guide coating.

(5) A change in shielding gas composition of any one constituent of more than 5 percent of the total flow.

(6) A change in welding current exceeding ± 20 percent.

(7) A change in groove design, other than square groove, increasing groove cross-sectional area.

(8) A change in joint thickness (t) outside the

limits of 0.5 T to 1.1 T where T is the thickness used for the procedure qualification.

(9) A change in number of electrodes.

(10) A change from single pass to multiple pass or vice versa.

(11) A change to a combination with any other welding process or method.

(12) A change in postweld heat treatment.

6.6.3 The following changes in a qualified electroslag or electrogas procedure shall require requalification of the procedure by radiographic or ultrasonic testing in accordance with the requirements of Part A or B of Section 7.

6.6.3.1 A change in filler metal diameter exceeding 0.8 mm (1/32 in.).

6.6.3.2 A change in filler metal oscillation traverse speed exceeding 254 mm/min (10 ipm.).

6.6.3.3 A change in filler metal oscillation traverse dwell time exceeding two seconds except as necessary to compensate for variation in joint opening.

6.6.3.4 A change in filler metal oscillation traverse length affecting proximity of filler metal to the molding shoes by more than 3 mm (1/8 in.).

6.6.3.5 A change in flux burden exceeding 30 percent.

6.6.3.6 A change in shielding gas flow rate exceeding 25 percent.

6.6.3.7 A change in design of molding shoes, either fixed or movable, as follows:

(1) Nonfusing solid to water cooled or vice versa

(2) Metallic to nonmetallic or vice versa

(3) Nonfusing to fusing or vice versa

(4) A reduction in any cross-sectional dimension or area of solid nonfusing shoe exceeding 25 percent

6.6.3.8 A change of welding position from vertical by more than 10 degrees.

6.6.3.9 A change from alternating current to direct current, or vice versa, or a change in polarity for direct current.

6.6.3.10 A change in welding power volt-ampere characteristics from constant voltage to constant current or vice versa.

6.6.3.11 A change in voltage exceeding 10 percent.

6.6.3.12 A change in square groove root opening exceeding 6 mm (1/4 in.).

6.6.3.13 A change in groove design other than square groove, reducing groove cross-sectional area.

6.6.3.14 A change in speed of vertical travel, if not an automatic function of arc length or deposition rate, exceeding 20 percent except as necessary to compensate for variation in joint opening.

6.7 Types of Tests and Purposes. The types of tests outlined below are to determine the mechanical properties and soundness of welded joints made under a given procedure specification. The tests used are as follows:

6.7.1 Tests for Groove Welds

(1) Reduced section tension test (for tensile strength)

(2) Root-bend test (for soundness)

(3) Face-bend test (for soundness)

(4) Side-bend test (for soundness)

(5) All-weld-metal test (for mechanical properties — electroslag or electrogas)

6.7.2 Test for Fillet Welds. Macroetch test (for soundness).

6.8 Base Metal and Its Preparation. The base metal and its preparation for welding shall comply with the procedure specification. For all types of welded joints, the length of the weld and the dimensions of the base metal shall be such as to provide sufficient material for the required test specimens.

6.9 Position of Test Welds. All welds that will be encountered in actual construction shall be classified as being (1) flat, (2) horizontal, (3) vertical, or (4) overhead, in accordance with the definitions of welding positions given in Figs. 6.9 (A) and (B). Each procedure shall be tested in the manner illustrated for each position for which it is to be qualified.

6.9.1 Groove Plate Test Welds (see Fig. 6.9.1). When making the tests to qualify groove welds, test plates shall be welded in the following positions:

(1) Position 1G (flat). The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side (see Fig. 6.9.1A).

(2) Position 2G (horizontal). The test plates shall be placed in an approximately vertical plane with the groove approximately horizontal (see Fig. 6.9.1B).

(3) Position 3G (vertical). The test plates shall be placed in an approximately vertical plane with the groove approximately vertical (see Fig. 6.9.1C).

(4) Position 4G (overhead). The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the underside (see Fig. 6.9.1D).

6.9.2 Groove Pipe Test Welds (see Fig. 6.9.2). When making the tests to qualify groove welds, test pipe shall be welded in the following positions:

(1) Position 1G (pipe horizontal rolled). The test pipe shall be placed with its axis horizontal and the groove approximately vertical. The pipe shall be rotated during welding so the weld metal is deposited from the upper side (see Fig. 6.9.2A).

(2) Position 2G (pipe vertical). The test pipe shall be placed with its axis vertical and the welding groove approximately horizontal. The pipe shall not be rotated during welding (see Fig. 6.9.2B).

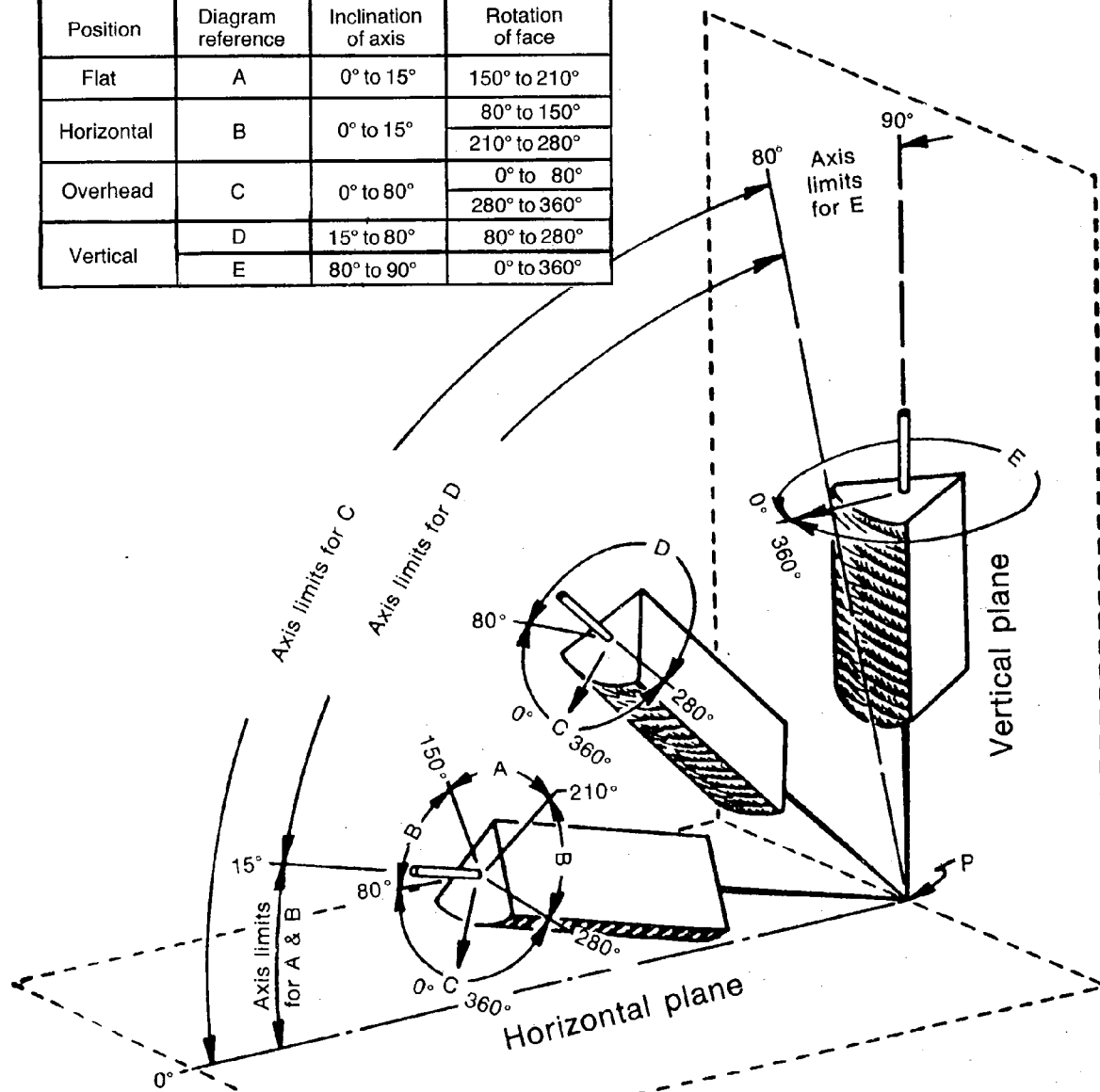
(3) Position 5G (pipe horizontal fixed). The test pipe shall be placed with its axis horizontal and the groove approximately vertical. The pipe is not rotated during welding (see Fig. 6.9.2C).

(4) Position 6G (pipe inclined fixed). The test pipe shall be inclined at 45 degrees with the horizontal. The pipe is not rotated during welding (see Figs. 6.9.2 D and E).

(5) Position 6GR. Test for complete joint penetration groove welds of tubular T, K and Y connections. The test pipe shall be inclined at 45 degrees with the horizontal. The pipe or tube is not rotated during welding (see Fig. 6.9.2E).

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Tabulation of positions of groove welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	80° to 150°
			210° to 280°
Overhead	C	0° to 80°	0° to 80°
			280° to 360°
Vertical	D	15° to 80°	80° to 280°
	E	80° to 90°	0° to 360°



Notes:

1. The horizontal reference plane is taken to lie always below the weld under consideration.
2. Inclination of axis is measured from the horizontal reference plane toward the vertical.
3. Angle of rotation of face is determined by a line perpendicular to the theoretical face of the weld and which passes through the axis of the weld. The reference position (0°) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0°) when looking at point P.

Fig. 6.9(A) – Positions of groove welds

Tabulation of positions of fillet welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	125° to 150°
			210° to 235°
Overhead	C	0° to 80°	0° to 125°
			235° to 360°
Vertical	D	15° to 80°	125° to 235°
	E	80° to 90°	0° to 360°

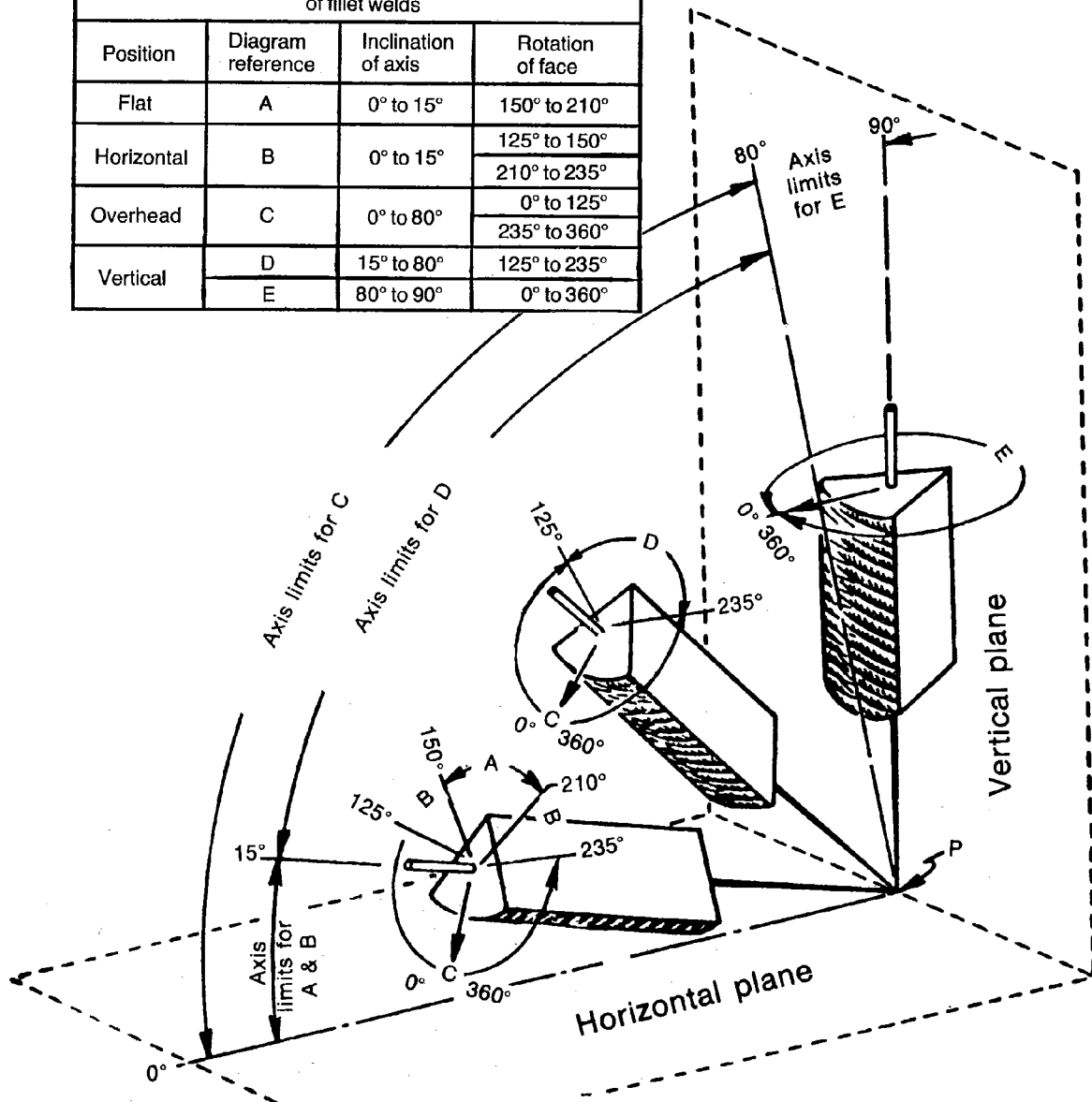


Fig. 6.9(B) – Positions of fillet welds

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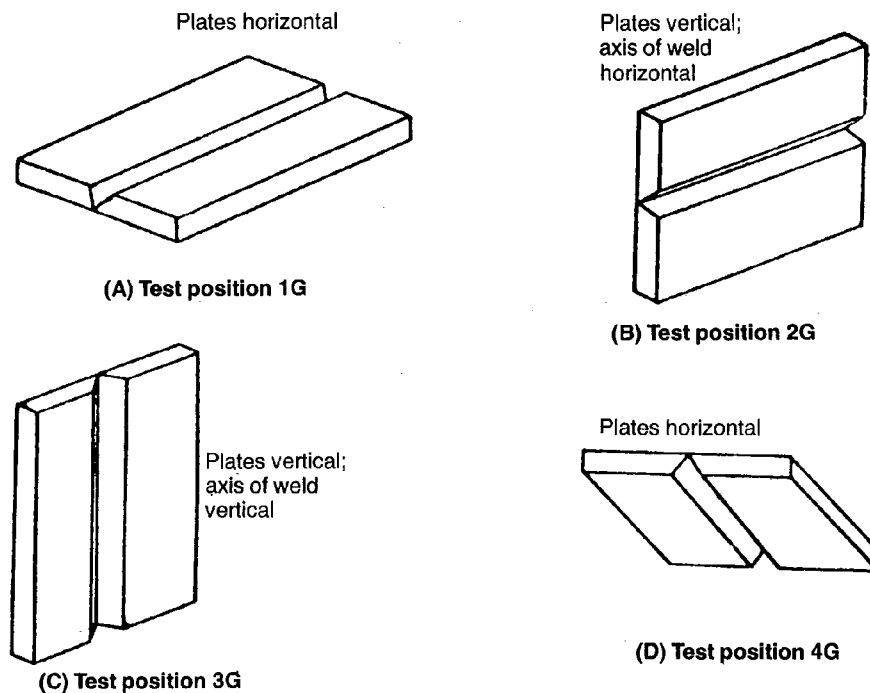


Fig. 6.9.1 – Positions of test plates for groove welds

6.9.3 Fillet Welds (see Fig. 6.9.3). In making the tests to qualify fillet welds, test plates shall be welded in the positions outlined below:

(1) Position 1F (flat). The test plates shall be placed so that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical (see Fig. 6.9.3A).

(2) Position 2F (horizontal). The test plates shall be placed so that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface (see Fig. 6.9.3B).

(3) Position 3F (vertical). The test plates shall be placed in an approximately vertical plane and each fillet weld deposited on the vertical surface (see Fig. 6.9.3C).

(4) Position 4F (overhead). The test plates shall be placed so that each fillet weld is deposited on the underside of the horizontal surface and against the vertical surface (see Fig. 6.9.3D).

6.10 Welding Procedure. The welding procedure shall comply in all respects with the procedure specification.

6.11 Test Specimens—Number, Type and Preparation

6.11.1 Complete Joint Penetration Groove Welds

6.11.1.1 The type and number of specimens that must be tested to qualify a welding procedure are shown in Table 6.11.1.1 together with the range of thickness that is qualified for use in construction. The range is based on the thickness of the test plate, pipe or tubing used in making

the qualification. In addition to these tests, the test plate for gas metal arc, flux cored arc, electroslag and electrogas welding shall be radiographically or ultrasonically tested.

6.11.1.2 Qualification of groove welds for T- or corner joints shall be butt joints having the same groove configuration as the T- or corner joint to be used in construction.

6.11.1.3 Test specimens shall be prepared by cutting the test plate pipe or tubing as shown in Figs. 6.11.1.3A through E, whichever is applicable. The specimens shall be prepared for testing in accordance with Figs. 6.11.1.3F through K as applicable.

6.11.2 Partial Joint Penetration Groove Welds. A sample of the type of groove design, the same as the joint to be used in construction except that the depth of groove need not exceed 25 mm (1 in.), shall be made and a macroetched cross section prepared to demonstrate that the designated effective throat thickness is obtained and that the requirements of the procedure specification are met.

6.11.3 Fillet Welds. For fillet welds, two test welds shall be made for each procedure and position to be used in construction. For each type of test weld, one shall be made with the maximum size single pass fillet weld and one with the minimum size multiple pass fillet weld that will be used in construction. For fillet welds, five macroetch specimens shall be cut as shown in Fig. 6.11.1.3K. One end of each macroetch specimen shall be smoothed before etching.

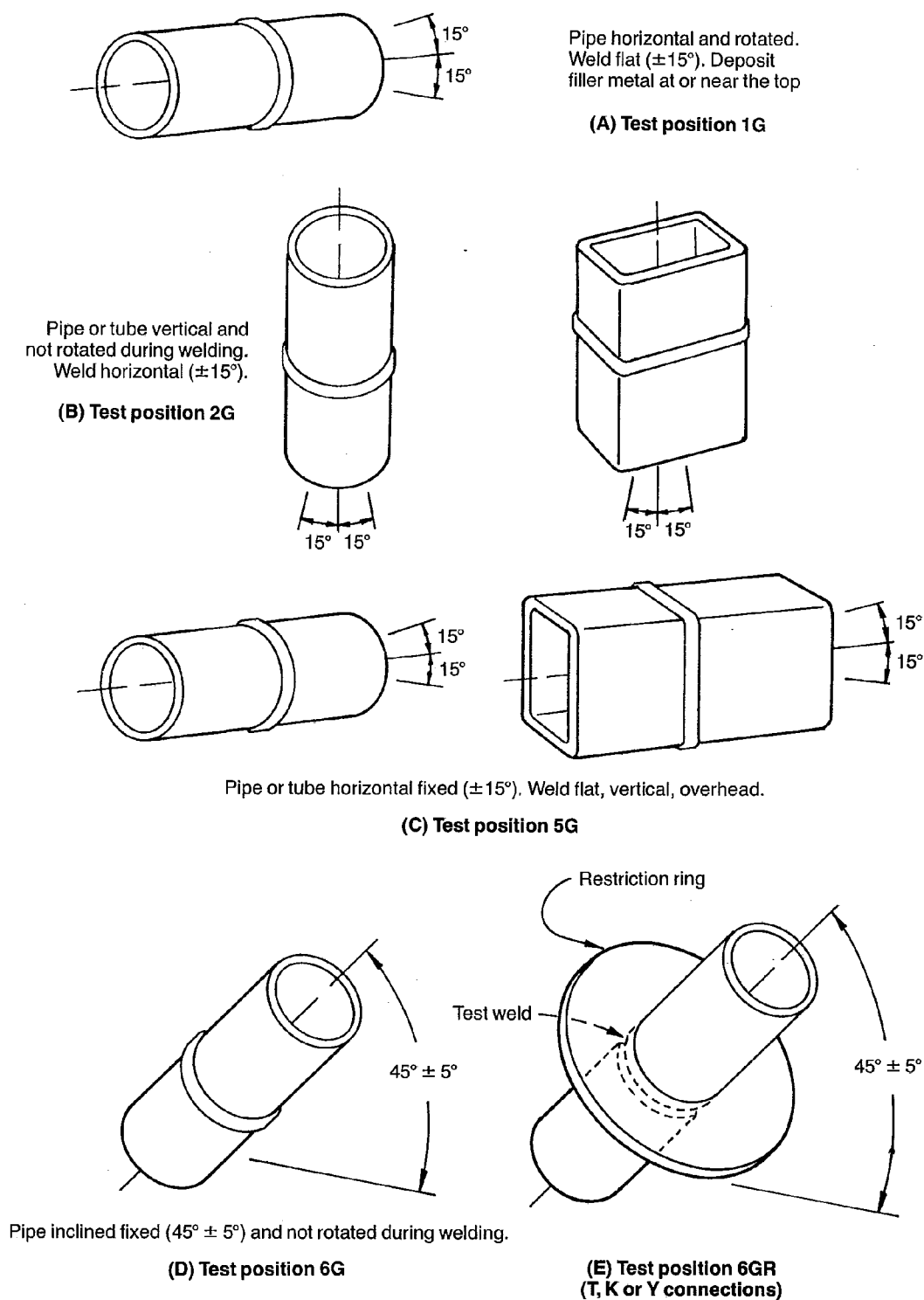


Fig. 6.9.2 – Positions of test pipe or tubing for groove welds

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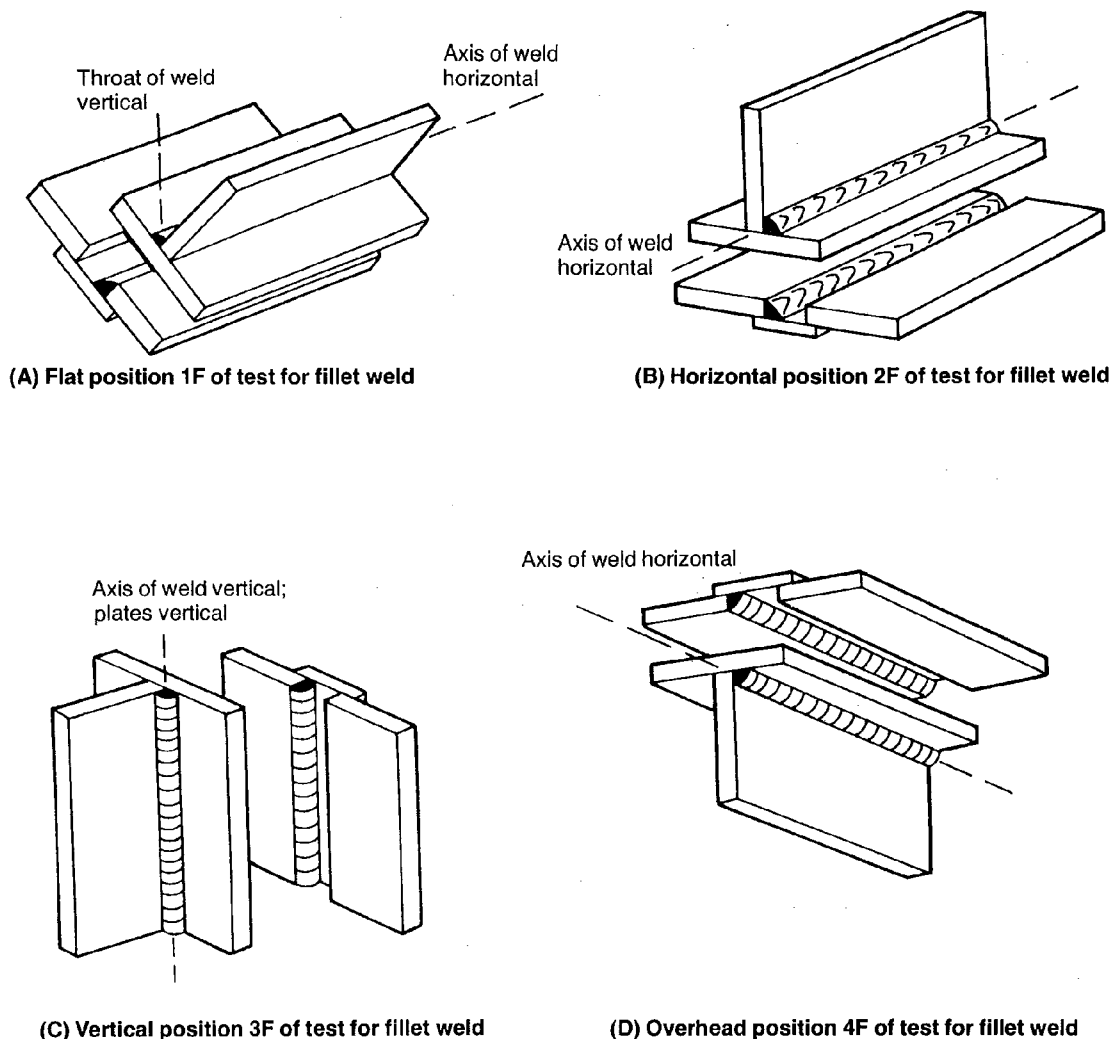


Fig. 6.9.3—Positions of test plates for fillet welds

6.11.4 When required by the filler metal specification applicable to the weld metal being tested, test specimens may be aged at 93° to 104° C (200° to 220° F) for 48 ± 2 hours.

6.12 Method of Testing Specimens

6.12.1 Reduced Section Tension Specimens. Before testing, the least width and corresponding thickness of the reduced section shall be measured in meters. The specimen shall be ruptured under tensile load and the maximum load in newtons shall be determined. The cross-sectional area shall be obtained as follows: cross-sectional area = width × thickness. The tensile strength in pascals shall be obtained by dividing the maximum load by the cross-sectional area.

6.12.2 Macroetch Test. Etching shall be with a suitable solution to give a clear definition of the weld.

6.12.3 Root-, Face- and Side-Bend Specimens. Each specimen shall be bent in a jig having the contour shown in Fig. 6.28.1 and otherwise substantially in accordance with that figure. Any convenient means may be used to move the plunger member with relation to the die member.

The specimen shall be placed on the die member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet weld soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with the side showing the greater defects, if any, directed toward the gap. The plunger shall force the specimen into the die until

Table 6.11.1.1 — Number and type of test specimens and range of thickness qualified — procedure qualification

Test plate thickness*	Maximum plate thickness qualified*	Pipe size of sample weld	Pipe or tube size qualified	Pipe or tube wall thickness qualified		Number of sample welds per position	Visual inspection	Number and type of tests required					All weld metal tension (See Fig. 6.11.1.3G)
								Reduced section tension (See Fig. 6.11.1.3F)	Root bend (See Fig. 6.11.1.3H)	Face bend (See Fig. 6.11.1.3H)	Side bend (See Fig. 6.11.1.3I)		
Plate test													
10	19	—	—	—	1	Yes	2	2	2	—	—	—	—
Over 19 and under 25	T	—	—	—	1	Yes	2	—	—	4	—	—	—
25 and over	Unlimited	—	—	—	1	Yes	2	—	—	4	—	—	—
Electroslag and electrogas welding**													
T	0.5T-1.1T	—	—	—	1	Yes	2	—	—	4	1	1	1
Pipe test													
—	—	51 Sch. 80 or 76 Sch. 40	19 through 102	1.6	17	Yes	2	2	2	—	—	—	—
—	—	152 Sch. 80 or 203 Sch. 120	102 and over	4.7	Any	Yes	2	—	—	4	—	—	—
—	—	Large diam. job size pipe	Diam. < 610 test diam. and over	t < 19 1/2t-2t	1	Yes	2	—	—	4	—	—	—
—	—		Diam. ≥ 610 610 and over	t ≥ 19 10 Any	1	Yes	2	—	—	4	—	—	—
All dimensions in millimeters													
*T is the test plate thickness.													
***Impact tests may be required if specified.													
Note: Radiographic or ultrasonic testing may be required prior to mechanical testing.													

*T is the test plate thickness.

**Impact tests may be required if specified.

Note: Radiographic or ultrasonic testing may be required prior to mechanical testing.

All dimensions in millimeters											
mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
1.6	0.063	10	3/8	25	1	102	4	4			
4.7	0.187	17	0.674	51	2	152	6	6			
10	0.375	19	3/4	76	3	203	8	8			
						610	24	24			

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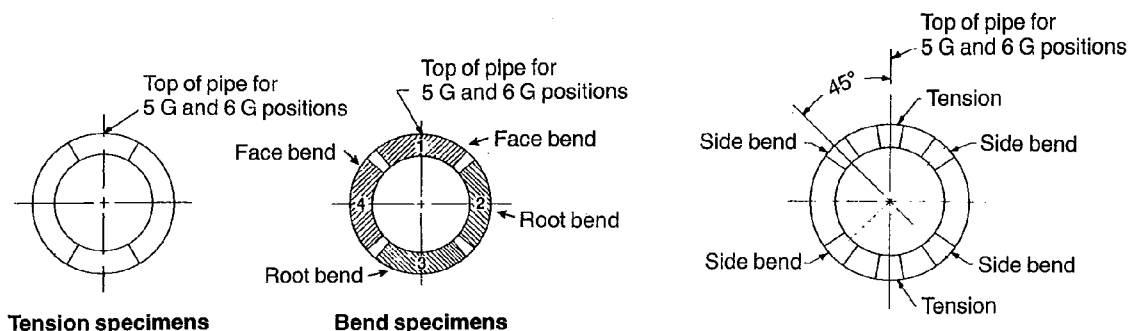
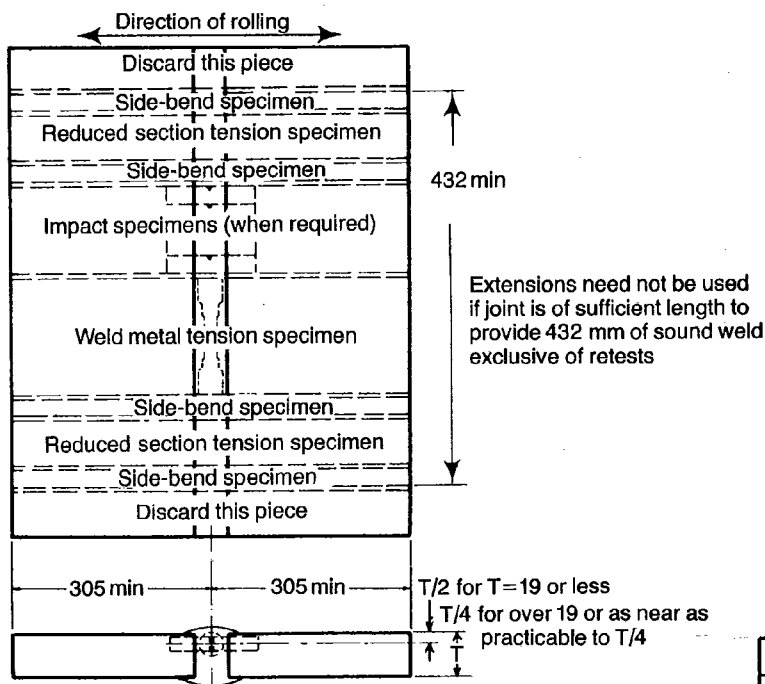


Fig. 6.11.1.3(A) – Location of test specimens on welded test pipe – 51 mm (2 in.) or 76 mm (3 in.) in diameter

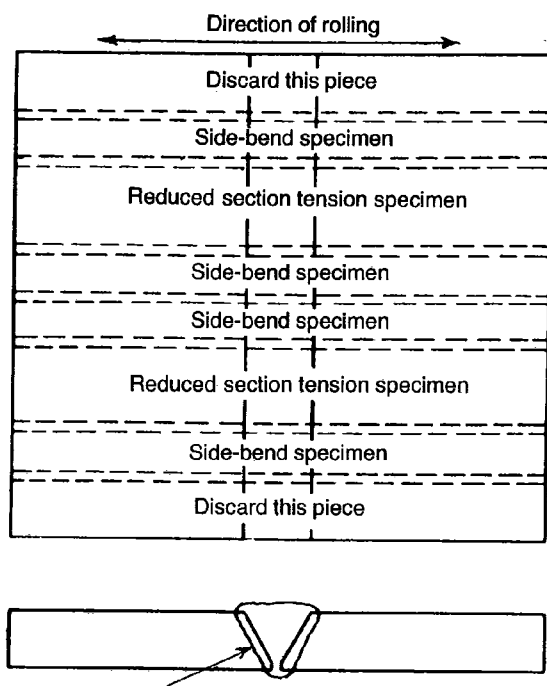
Fig. 6.11.1.3(B) – Location of test specimens on welded test pipe – 152 mm (6 in.) or 203 mm (8 in.) diameter



Groove configuration shown is for illustration only (see 6.6.2). The groove shape used shall conform to that being qualified.

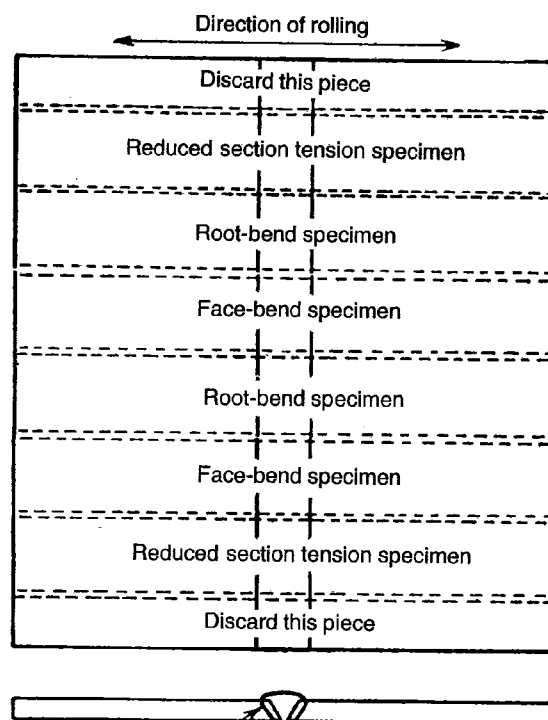
All dimensions in millimeters

Fig. 6.11.1.3(C) – Location of test specimens on welded test plate – electroslag and electrogas welding – procedure qualification



Groove configuration shown is for illustration only (see 6.6.2). The groove shape used shall conform to that being qualified.

Fig. 6.11.1.3(D) – Location of test specimens on welded test plate over 19 mm (3/4 in.) thick – procedure qualification



Groove configuration shown is for illustration only (see 6.6.2). The groove shape used shall conform to that being qualified.

Fig. 6.11.1.3(E) – Location of test specimens on welded test plate 10 mm (3/8 in.) thick – procedure qualification

the specimen becomes U-shaped. The weld and heat-affected zones shall be centered and shall be completely within the bent portion of the specimen after testing.

When using the wraparound jig, the specimen shall be firmly clamped on one end so that the specimen does not slide during the bending operation. The weld and heat-affected zones shall be completely within the bent portion of the specimen after testing. Test specimens shall be removed from the jig when the outer roll has been moved 180 degrees from the starting point.

6.12.4 All-Weld-Metal Tension Test. The test specimen shall be tested in accordance with ASTM A370, Mechanical Testing of Steel Products.

6.12.5 The radiographic procedure and technique shall be in accordance with the requirements of Part A of Section 7.

6.12.6 The ultrasonic procedure and technique shall be in accordance with the requirements of Part B of Section 7.

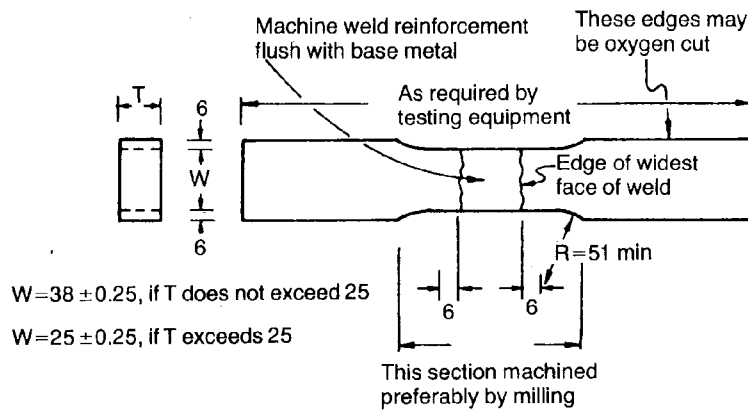
6.13 Test Results Required. The requirements for the test results shall be as follows:

6.13.1 Reduced Section Tension Test. The tensile strength shall be not less than the minimum of the specified tensile range of the base metal used.

6.13.2 Root-, Face- and Side-Bend Tests. The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect, exceeding 3 mm (1/8 in.) measured in any direction, is present after the bending shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.

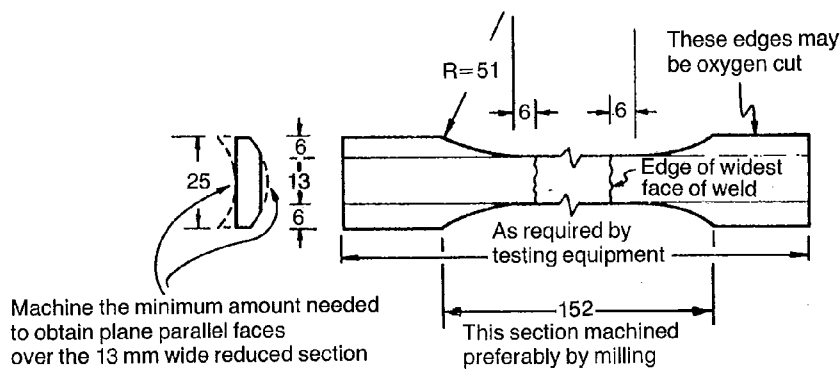
6.13.3 Macroetch Tests. The specimens shall be examined for defects and any which have defects prohibited by Part E of Section 7 shall be considered as failed. The specimens shall have the designated effective throat for partial joint penetration groove welds. Fillet weld specimens shall show fusion to the root, but not necessarily beyond, and both legs shall be equal to within 3 mm (1/8 in.). Convexity and concavity shall not exceed the limits specified in Part E of Section 7.

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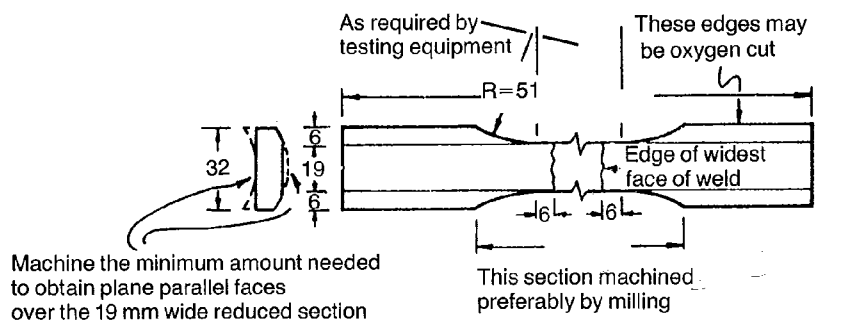


For plates over 38 mm thick, specimens may be cut into the minimum number of approximately equal strips not exceeding 38 mm in thickness. Test each strip and average the results.

Test plate



Test pipe 51 mm (2 in.) and 76 mm (3 in.) diameter

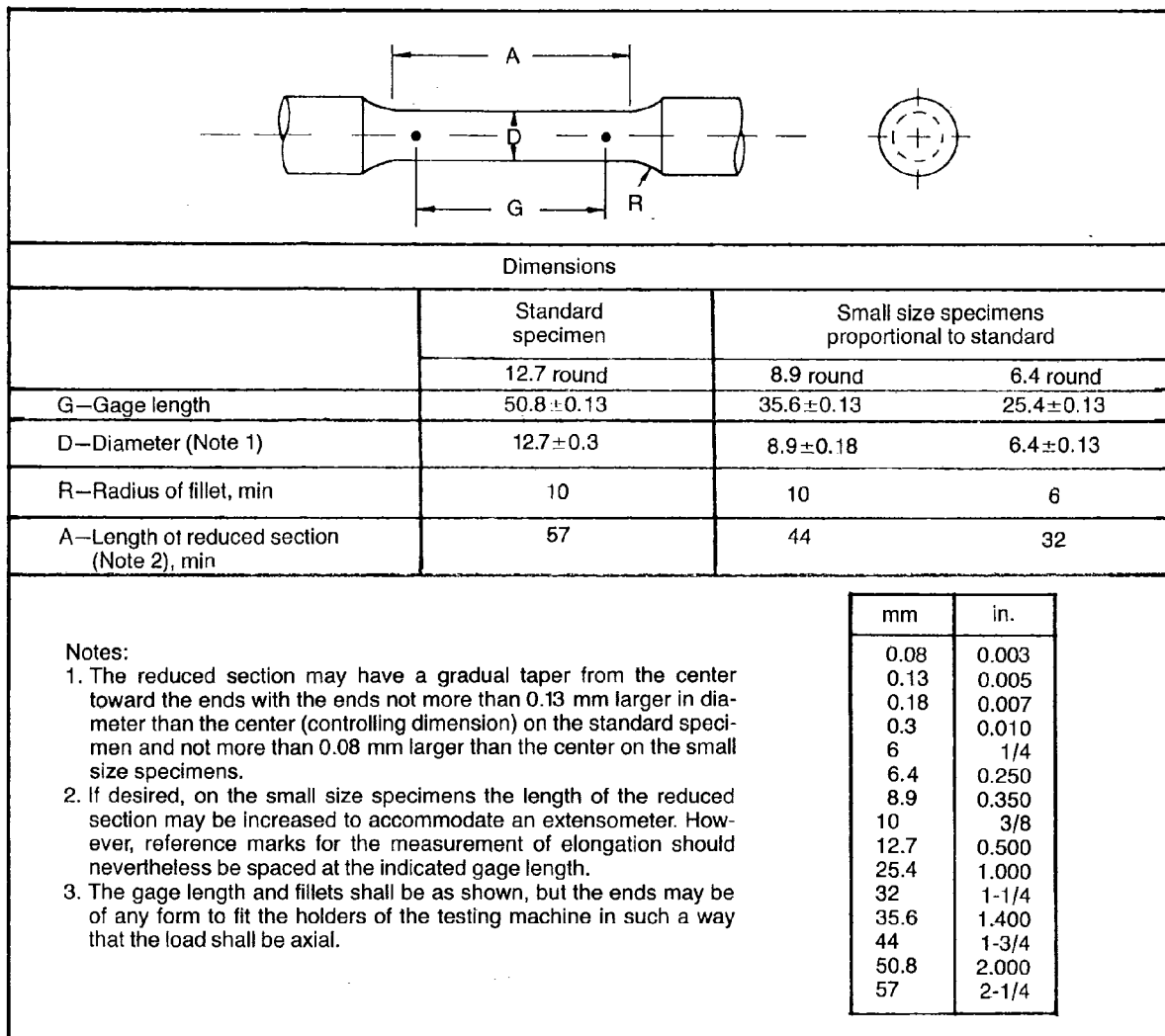


Test pipe 152 mm (6 in.) and 203 mm (8 in.) diameter

mm	in.
0.25	0.001
6	1/4
13	1/2
19	3/4
25	1
32	1-1/4
38	1-1/2
51	2
152	6
203	8

All dimensions in millimeters

Fig. 6.11.1.3(F) – Reduced section tension specimens



All dimensions in millimeters

Fig. 6.11.1.3(G) — All-weld-metal tension specimens

6.13.4 All-Weld-Metal Tension (Electroslag and Electrode). The mechanical properties shall not be less than those specified in the filler metal requirements.

6.13.5 Nondestructive Testing

(1) For acceptable qualification, the weld, as revealed by the radiograph or ultrasonic testing, shall conform to the requirements of Parts A and B of Section 7, whichever are applicable.

(2) For acceptable qualification, the pipe weld, when inspected visually, shall conform to the following requirements:

(a) The weld shall be free of cracks.

(b) All craters shall be filled to the full cross section of the weld.

(c) The face of the weld shall be at least flush with the outside surface of the pipe and the weld shall merge smoothly with the base metal. Undercut shall not exceed 0.4 mm (1/64 in.). Weld reinforcement shall not exceed the following:

Pipe wall thickness		Reinforcement, max	
mm	in.	mm	in.
9 and less	3/8 and less	2	3/32
Over 10 to 19 incl.	Over 3/8 to 3/4 incl.	3	1/8
Over 19	Over 3/4	5	3/16

(d) The root of the weld shall be inspected and there shall be no evidence of cracks, incomplete fusion or

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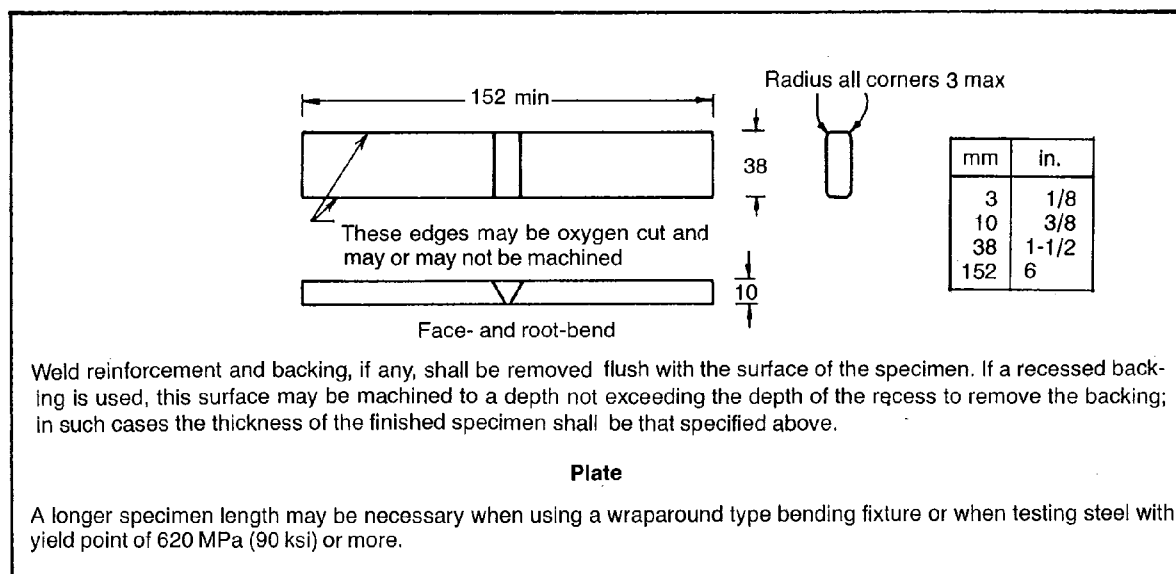


Fig. 6.11.1.3(H) – Face- and root-bend specimens

inadequate joint penetration. A concave root surface is permitted within the limits shown below, provided the total weld thickness is equal to or greater than that of the base metal.

(e) The maximum root surface concavity shall be 1.5 mm (1/16 in.) and the maximum melt-thru shall be 3 mm (1/8 in.).

6.14 Records. Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

6.15 Retests. If any one test specimen fails to meet the test requirements when all the other test specimens meet the test requirements, two retests for that particular type of test specimen may be performed with specimens cut from the same procedure qualification test material. The results of both retest specimens must meet the test requirements. For material over 38 mm (1-1/2 in.) in thickness, failure of a specimen shall require testing of all specimens of the same type from two additional locations in the test material.

Part C Welder Qualification

6.16 General. The qualification tests described herein are specially devised tests to determine the welder's ability to

produce sound welds. It is not intended that the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the procedure specification.

6.17 Qualification Tests Required

6.17.1 The qualification tests for welders performing manual and semiautomatic operations shall be as follows:

6.17.1.1 Groove weld qualification test for plate of unlimited thickness

6.17.1.2 Groove weld qualification test for plate of limited thickness

6.17.1.3 Fillet weld qualification test for fillet welds only – option 1 or option 2 – contractor's option.

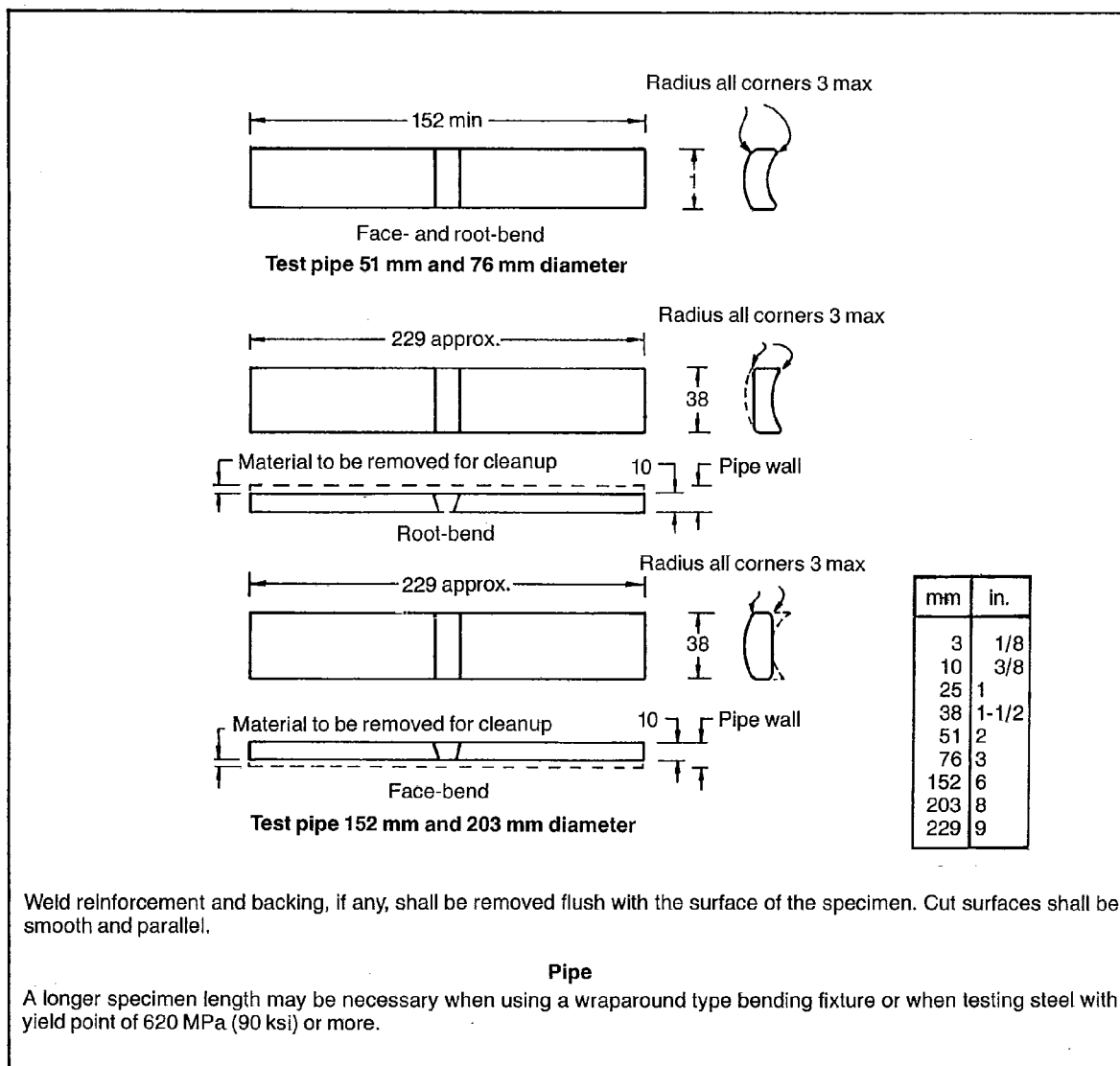
6.17.2 The pipe or tubing qualification tests for welders performing manual and semiautomatic operations shall be as follows:

6.17.2.1 Groove weld qualification test for butt joints on pipe or square or rectangular tubing

6.17.2.2 Groove weld qualification test for T, K, or Y connections on pipe or square or rectangular tubing

6.17.2.3 Groove weld qualification test for butt joints on square or rectangular tubing tested on flat plate.

6.17.3 The welder making a complete joint penetration plate groove weld procedure qualification test meeting the requirements is thereby qualified for that process and test position for plates and square or rectangular tubing of thicknesses equal to or less than the thickness of the test plate welded, unless it is 25 mm (1 in.) or more in thickness, in which case he will be qualified for all thicknesses.



All dimensions in millimeters

Fig. 6.11.1.3(H) cont. – Face- and root-bend specimens

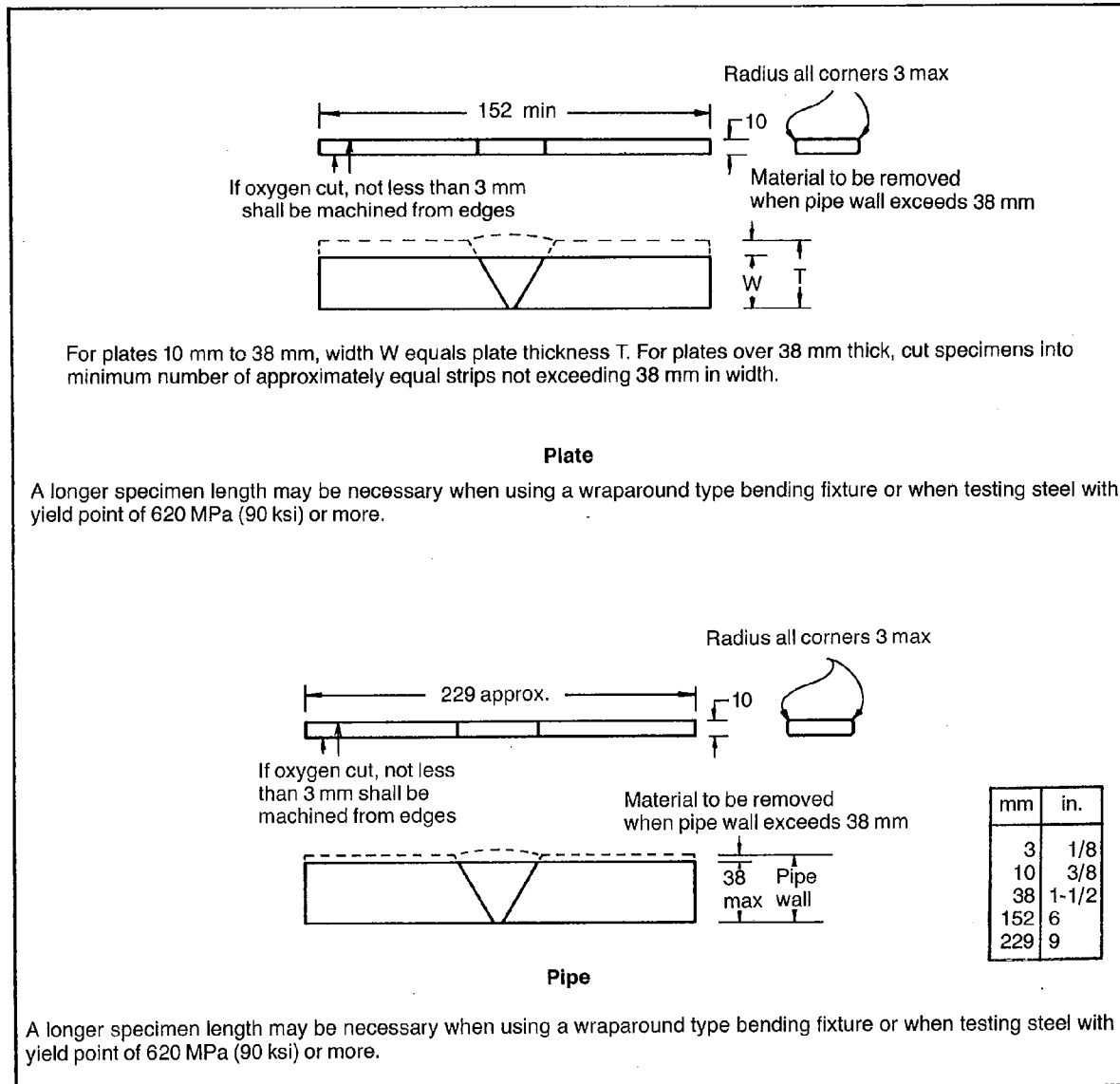
6.17.4 The welder making a complete joint penetration groove weld pipe procedure qualification test without backing strip meeting the requirements is thereby qualified for that process and test position for piping having a wall thickness equal to or less than the wall thickness of the test pipe welded, unless it is 19 mm (3/4 in.) or more in

thickness, in which case he will be qualified for all thicknesses.

6.18 Limitation of Variables. For the qualification of a welder, the following rules shall apply:

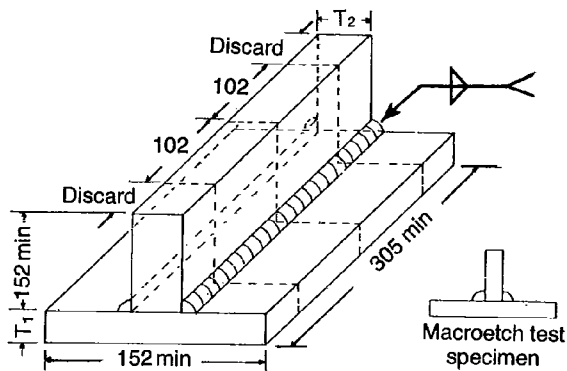
6.18.1 A welder shall be qualified for each type of steel and process used.

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All dimensions in millimeters

Fig. 6.11.1.3(J) – Side-bend specimens



Weld size		T ₁		T ₂	
mm	in.	mm	in.	mm	in.
5	3/16	13	1/2	5	3/16
6	1/4	19	3/4	6	1/4
8	5/16	25	1 min	8	5/16
10	3/8	25	1 min	10	3/8
13	1/2	25	1 min	13	1/2
16	5/8	25	1 min	16	5/8
19	3/4	25	1 min	19	3/4
>19	> 3/4	25	1 min	25	1

mm	in.	mm	in.	mm	in.
102	4	152	6	305	12

All dimensions in millimeters

Fig. 6.11.1.3(K) – Fillet weld soundness test for procedure qualification

6.18.2 A welder qualified for manual shielded metal arc welding with an electrode identified in the table below shall be considered qualified to weld or tack weld with any other electrode in the same group designation and with any electrode listed in a numerically lesser group designation:

Group designation	AWS electrode classification*
F4	EXX15, EXX16, EXX18
F3	EXX10, EXX11
F2	EXX12, EXX13, EXX14
F1	EXX20, EXX24, EXX27, EXX28

*The letters "XX" used in the classification designations in this table represent the various strength levels in ksi (60, 70, 80, 90, 100, 110 and 120) of deposited weld metal.

6.18.3 A welder qualified with an approved electrode and shielding medium combination shall be considered qualified to weld or tack weld with any other approved electrode and shielding medium combination for the process used in the qualification test.

6.18.4 A change in the position of welding, other than those changes previously qualified, shall require requalification.

6.18.5 A change from one diameter wall pipe grouping to another, shown in Table 6.27.1, shall require requalification.

6.18.6 When the pipe or tubing is in the 5G or 6G position, a change in the direction of welding, from bottom to top or top to bottom, shall require requalification.

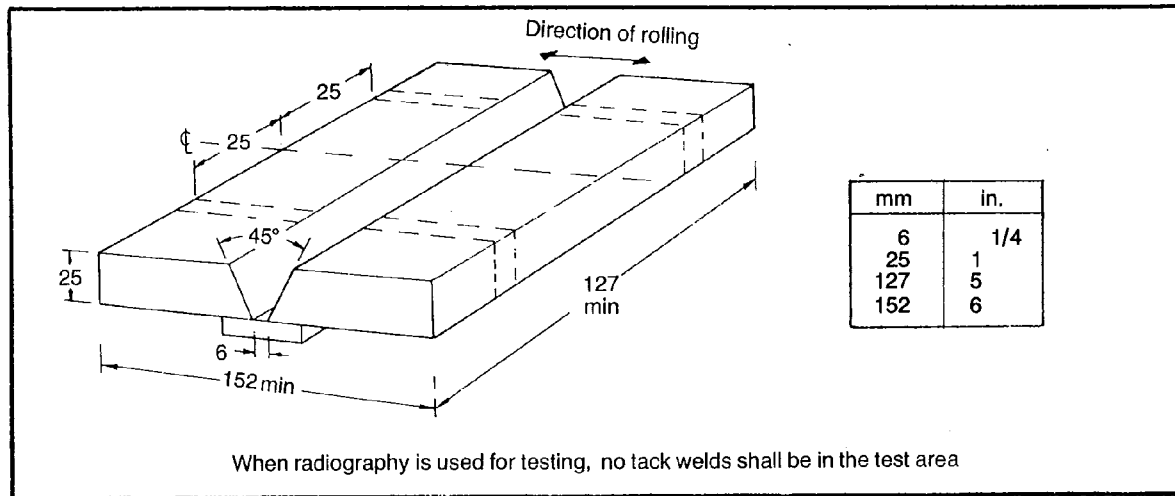
6.19 Groove Weld Plate Qualification Test for Plate of Unlimited Thickness. Joint detail as follows: 25 mm (1 in.), single-V-groove, 45 degree included angle, 6 mm (1/4 in.) root opening with backing (see Fig. 6.19A). For horizontal position qualification, the joint detail may be (contractor's option) as follows: single-bevel-groove, 45 degree groove angle, 6 mm (1/4 in.) root opening with backing (see Fig. 6.19B). Backing must be at least 10 × 76 mm (3/8 × 3 in.) if radiography is used for testing without removal of backing. It must be at least 10 × 25 mm (3/8 × 1 in.) for mechanical testing after the backing is removed. Minimum length of welding groove shall be 127 mm (5 in.).

6.20 Groove Weld Plate Qualification Test for Plate of Limited Thickness. Joint detail as follows: 10 mm (3/8 in.) plate, single-V-groove, 45 degree included angle, 6 mm (1/4 in.) root opening with backing (see Fig. 6.20A). For horizontal position qualification, the joint detail may be (contractor's option) as follows: single-bevel-groove, 45 degree groove angle, 6 mm (1/4 in.) root opening with backing (see Fig. 6.20B). Backing must be at least 10 × 76 mm (3/8 × 3 in.) if radiography is used for testing without removal of backing. It must be at least 10 × 25 mm (3/8 × 1 in.) for mechanical testing or, if radiography is used, for testing after the backing is removed. Minimum length of welding groove shall be 127 mm (5 in.).

6.21 Groove Weld Qualification Test for Butt Joints on Pipe or Square or Rectangular Tubing. The joint detail shall be in accordance with a qualified welding procedure specification for a single-welded pipe butt weld or shall be as follows: for pipe diameter, wall thickness as required, single-V-groove, 60 degree included angle, 3 mm (1/8 in.) maximum root face and 3 mm (1/8 in.) root opening without backing strip (see Fig. 6.21A), or single-V-groove, 60 degree included angle and suitable root opening with backing (see Fig. 6.21B).

6.22 Groove Weld Qualification Test for T, K, or Y Connections on Pipe or Square or Rectangular Tubing. The joint detail shall be as follows: single bevel, 37-1/2 degree included angle with bevel on pipe or tube at least 13 mm (1/2 in.) in thickness; the square edge pipe or tube shall be at least 5 mm (3/16 in.) thicker than the beveled pipe thickness; 1.5 mm (1/16 in.) maximum root face and 3 mm (1/8 in.) root opening. A restriction ring shall be placed on the thicker material within 13 mm (1/2

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All dimensions in millimeters except angles

Fig. 6.19(A) – Test plate for unlimited thickness – welder qualification

in.) of the joint and shall extend at least 152 mm (6 in.) beyond the surface of the pipe or tube (see Fig. 6.22).

6.23 Fillet Weld Qualification Test for Fillet Welds Only

6.23.1 Option 1 – Test Plate. T-test in accordance with Fig. 6.23.1.

6.23.2 Option 2 – Test Plate. Soundness test in accordance with Fig. 6.23.2.

6.24 Position of Test Welds (See Table 6.24)

6.24.1 Groove Plate Test Welds

6.24.1.1 Qualification in the 1G (flat) position qualifies for flat position groove welding of plate, pipe and tubing, flat and horizontal position fillet welding of plate and flat position fillet welding of pipe and tubing.

6.24.1.2 Qualification in the 2G (horizontal) position qualifies for flat and horizontal position groove and flat and horizontal position fillet welding plate, pipe and tubing.

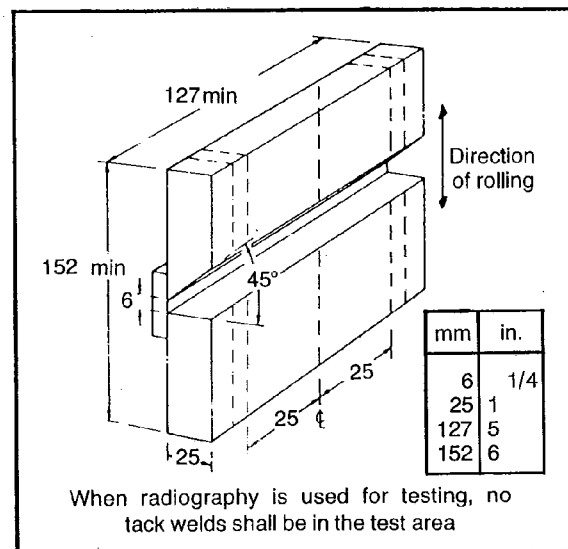
6.24.1.3 Qualification in the 3G (vertical) position qualifies for flat, horizontal, and vertical position groove and flat, horizontal and vertical position fillet welding of plate.

6.24.1.4 Qualification in the 4G (overhead) position qualifies for flat and overhead position groove and flat, horizontal and overhead position fillet welding of plate.

6.24.2 Groove Pipe Test Welds

6.24.2.1 Qualification in the 1G (pipe horizontal rolled) position qualifies for flat position groove welding of pipe, tubing and plate, flat position fillet welding of pipe and tubing and flat and horizontal position fillet welding of plate.

6.24.2.2 Qualification in the 2G (pipe vertical) position qualifies for flat and horizontal position groove and

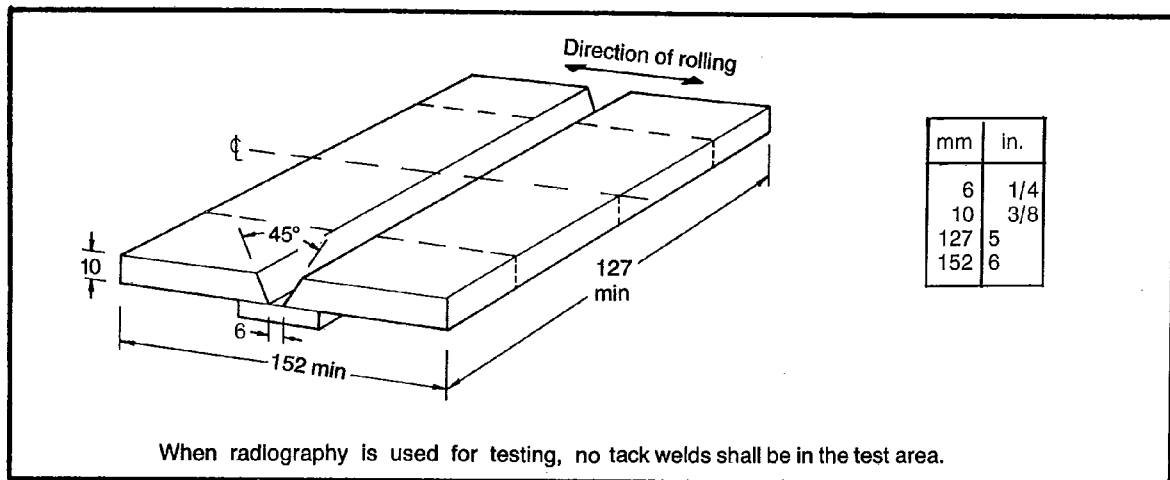


All dimensions in millimeters except angles

Fig. 6.19(B) – Optional test plate for unlimited thickness – horizontal position – welder qualification

flat and horizontal position fillet welding of pipe, tubing and plate.

6.24.2.3 Qualification in the 5G (pipe horizontal fixed) position qualifies for flat, vertical and overhead position groove and flat, vertical and overhead position fillet welding of pipe, tubing and plate.



All dimensions in millimeters except angles

Fig. 6.20 (A) – Test plate for limited thickness – welder qualification

6.24.2.4 Qualification in the 6G (inclined fixed) position qualifies for all position groove and all position fillet welding of pipe, tubing and plate.

6.24.2.5 Qualification for T, K, or Y connections in the 6G (inclined fixed) position qualifies for groove welding T, K, and Y connections, groove and fillet welding in all positions of pipe, tubing and plate.

6.24.3 Fillet Weld Test

6.24.3.1 Qualification in the 1F (flat) position qualifies for flat position fillet welding of plate, pipe and tubing.

6.24.3.2 Qualification in the 2F (horizontal) position qualifies for flat and horizontal position fillet welding of plate, pipe and tubing.

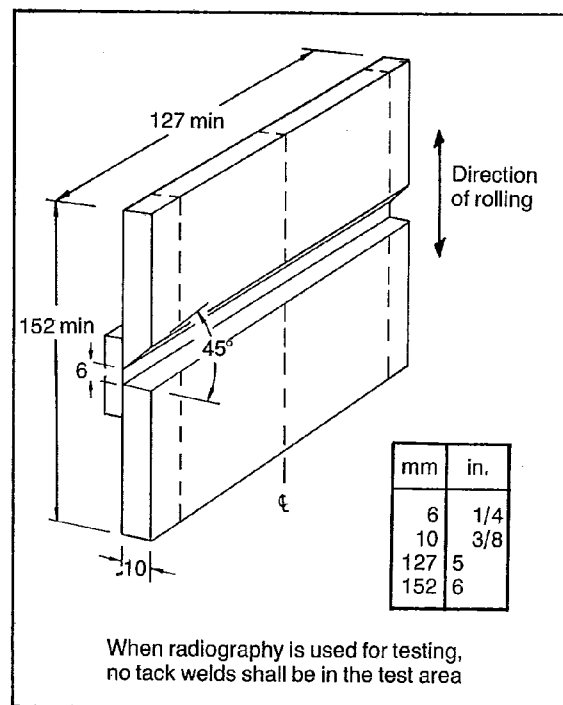
6.24.3.3 Qualification in the 3F (vertical) position qualifies for flat, horizontal and vertical position fillet welding of plate.

6.24.3.4 Qualification in the 4F (overhead) position qualifies for flat, horizontal and overhead position fillet welding of plate.

6.24.4 Qualification on groove plate test weld in 1G (flat) or 2G (horizontal) position also shall qualify for butt welding pipe with a backing in the same position qualified. If no backing is used in the groove plate test weld, this also shall qualify for groove welding pipe with or without backing in the same position qualified.

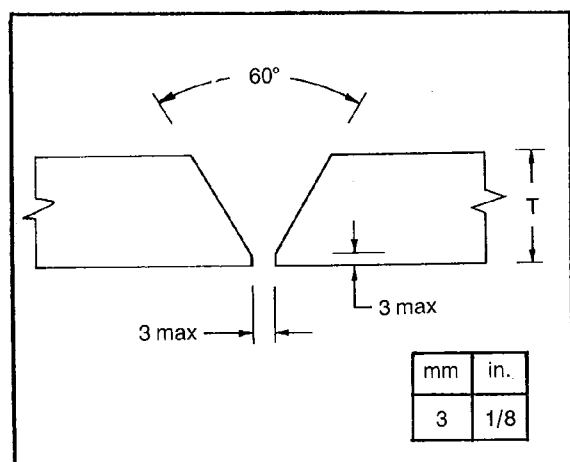
6.25 Base Metal. The base metal used shall comply with the procedure specification.

6.26 Welding Procedure. The welder shall follow the welding procedure specified by the procedure specification.



All dimensions in millimeters except angles

Fig. 6.20(B) – Optional test plate for limited thickness – horizontal position – welder qualification



All dimensions in millimeters except angles

Fig. 6.21(A) – Plate and pipe butt joint – welder qualification – without backing

6.27 Test Specimens – Number, Type and Preparation

6.27.1 The type and number of test specimens that must be tested to qualify a welder by mechanical testing are shown in Table 6.27.1 together with the range of thickness that is qualified for use in construction by the thickness of the test plate, pipe or tubing used in making the qualification. Radiographic testing of the test weld, except for fillet welds, may be used at the contractor's option in lieu of mechanical testing.

6.27.2 Guided-bend test specimens shall be prepared by cutting the test plate, pipe or tubing as shown in Figs. 6.19A, 6.19B, 6.20A, 6.20B, 6.23.2 or 6.27.2, whichever are applicable, to form specimens approximately rectangular in cross section. The specimens shall be prepared for testing in accordance with Figs. 6.11.1.3F through J, whichever are applicable.

6.27.3 The fillet weld break and macroetch test specimens shall be cut from the test joint as shown in Fig. 6.23.1. The end of the macroetch specimen shall be smooth for etching.

6.27.4 If radiography is used in lieu of the prescribed bend tests, the weld reinforcement need not be ground or otherwise smoothed for inspection unless its surface irregularities or juncture with the base metal would cause objectionable weld defects to be obscured in the radiograph. If the backing is removed for radiography, the root shall be ground flush with the base metal.

6.28 Method of Testing Specimens

6.28.1 Root-, Face- and Side-Bend Specimens. Each specimen shall be bent in a jig having the contour shown in Fig. 6.28.1 and shall be otherwise substantially in accordance with that figure. Any convenient means may be used to move the plunger member with relation to the die member.

The specimen shall be placed on the die member of the jig with the weld at midspan. Face-bend specimens shall

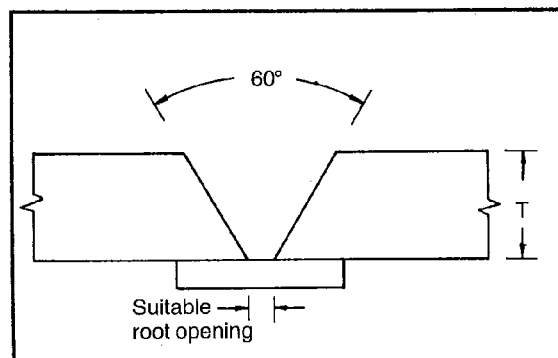


Fig. 6.21(B) – Pipe test butt joint – welder qualification – with backing

be placed with the face of the weld directed toward the gap; root-bend and fillet weld soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap.

The plunger shall force the specimen into the die until the specimen becomes U-shaped. The weld and heat-affected zones shall be centered and completely within the bent portion of the specimen after testing.

When using the wraparound jig, the specimen shall be firmly clamped on one end so that the specimen cannot slide during the bending operation. The weld and heat-affected zones shall be completely within the bent portion of the specimen after testing. Test specimens shall be removed from the jig when the outer roll has been moved 180 degrees from the starting point.

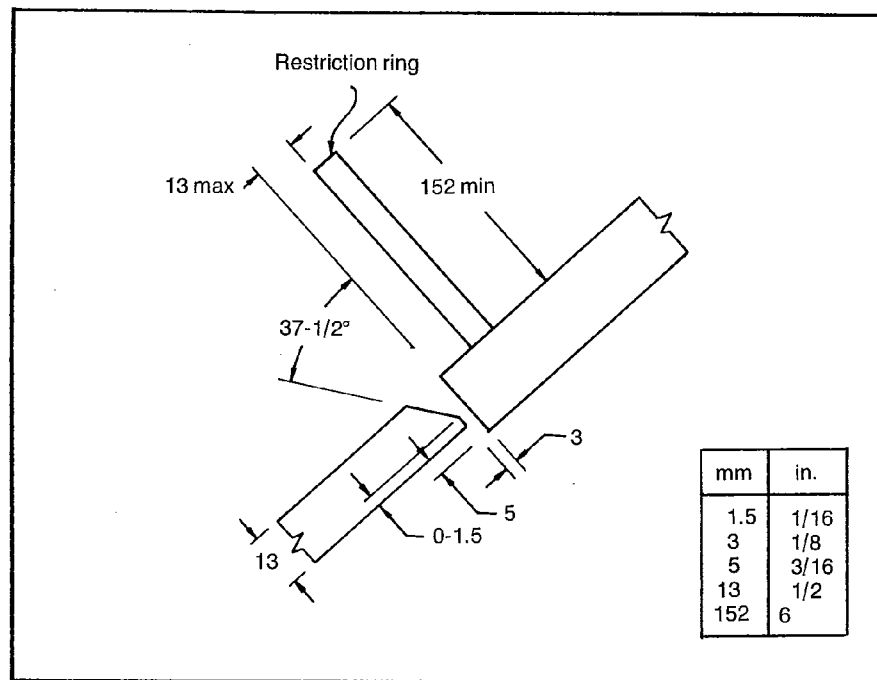
6.28.2 Fillet Weld Break Test. The entire length of the fillet weld shall be examined visually and then the 152 mm (6 in.) long specimen shall be loaded in such a way that the root of the weld shall be in tension. The load shall be steadily increased or repeated until the specimen fractures or bends flat upon itself.

6.28.3 Macroetch Test. Etching shall be made by using a suitable solution to give a clear definition of the weld.

6.28.4 Radiographic Test. The radiographic procedure and technique shall be in accordance with the requirements of Part A of Section 7. Only the center half of the length of the test plate or 50 percent of the test pipe shall be subject to testing.

6.29 Test Results Required

6.29.1 Root-, Face- and Side-Bend Tests. The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect, exceeding 3 mm (1/8 in.) measured in any direction, is present after the bending, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.



All dimensions in millimeters except angles

Fig. 6.22 – Test joint for T, K and Y connections on pipe or square or rectangular tubing – welder qualification

6.29.2 Fillet Weld Break Test

6.29.2.1 In order to pass the visual examination, the fillet weld shall present a reasonably uniform appearance and shall be free of overlap, cracks and excessive undercut. There shall be no porosity visible on the surface of the weld.

6.29.2.2 The specimen shall pass the test if it bends flat upon itself. If the fillet weld fractures, the fractured surface shall show complete penetration into the root of the joint and shall exhibit no incomplete fusion to the base metal nor any inclusion or porosity larger than 2 mm (3/32 in.) in greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 10 mm (3/8 in.) in the 152 mm (6 in.) long specimen.

6.29.3 Macroetch Test. The specimen shall be examined for defects and if defects prohibited by Part E of Section 7 are found, it shall be considered as failed. The weld shall show fusion to the root but not necessarily beyond the root and both legs shall be equal within 3 mm (1/8 in.). Convexity and concavity shall not exceed the limits specified in Part E of Section 7, i.e., 1.5 mm (1/16 in.) for an 8 mm (5/16 in.) test weld.

6.29.4 Radiographic Test. For acceptable qualification, the weld, as revealed by the radiograph, shall conform to the requirements of Part A of Section 7.

6.29.5 For acceptable qualification, the pipe weld when examined visually shall conform to the following requirements:

6.29.5.1 The weld shall be free of cracks.

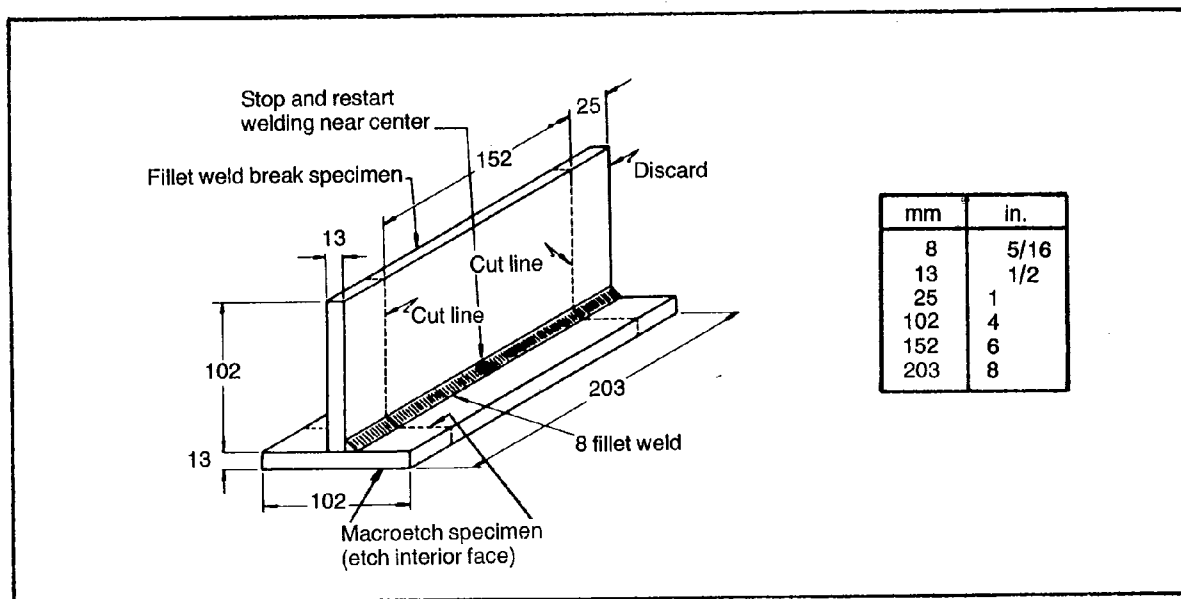
6.29.5.2 All craters shall be filled to the full cross section of the weld.

6.29.5.3 The face of the weld shall be at least flush with the outside surface of the pipe and the weld shall merge smoothly with the base metal. Undercut shall not exceed 0.4 mm (1/64 in.). Weld reinforcement shall not exceed the following:

Pipe wall thickness		Reinforcement	
mm	in.	mm	in.
10 and less	3/8 and less	2	3/32
Over 10 to 19	Over 3/8 to 3/4 incl.	3	1/8
Over 19	Over 3/4	5	3/16

6.29.5.4 The root of the weld shall be inspected and there shall be no evidence of cracks, incomplete fusion or inadequate joint penetration. A concave root surface is permitted within the limits shown below provided the total weld thickness is equal to or greater than that of the base metal.

6.29.5.5 The maximum root surface concavity shall be 1.5 mm (1/16 in.) and the maximum melt-thru shall be 3 mm (1/8 in.).



All dimensions in millimeters

Fig. 6.23.1 – Fillet weld break and macroetch test plate – welding operator qualification – option 1

6.30 Retests. In case a welder fails to meet the requirements of one or more test welds, a retest may be allowed under the following conditions:

6.30.1 An immediate retest may be made consisting of two test welds of each type failed; all test specimens shall meet all the requirements specified for such welds.

6.30.2 A retest may be made provided there is evidence that the welder has had further training or practice. In this case a complete retest shall be made.

6.31 Period of Effectiveness. The welder's qualification specified herein shall be considered in effect indefinitely unless (1) the welder will not be engaged in a given process of welding for which he is qualified for a period exceeding six months or unless (2) there is some specific reason to question a welder's ability. In case (1) the requalification test need be made only in the 10 mm (3/8 in.) thickness.

6.32 Records. Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

Part D

Welding Operator Qualification

6.33 General. The qualification tests described herein are specially devised to determine the welding operator's ability to produce sound welds. It is not intended that the

qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the procedure specification.

6.34 Limitation of Variables. For the qualification of a welding operator, the following rules shall apply:

6.34.1 A welding operator shall be separately qualified for each type of steel.

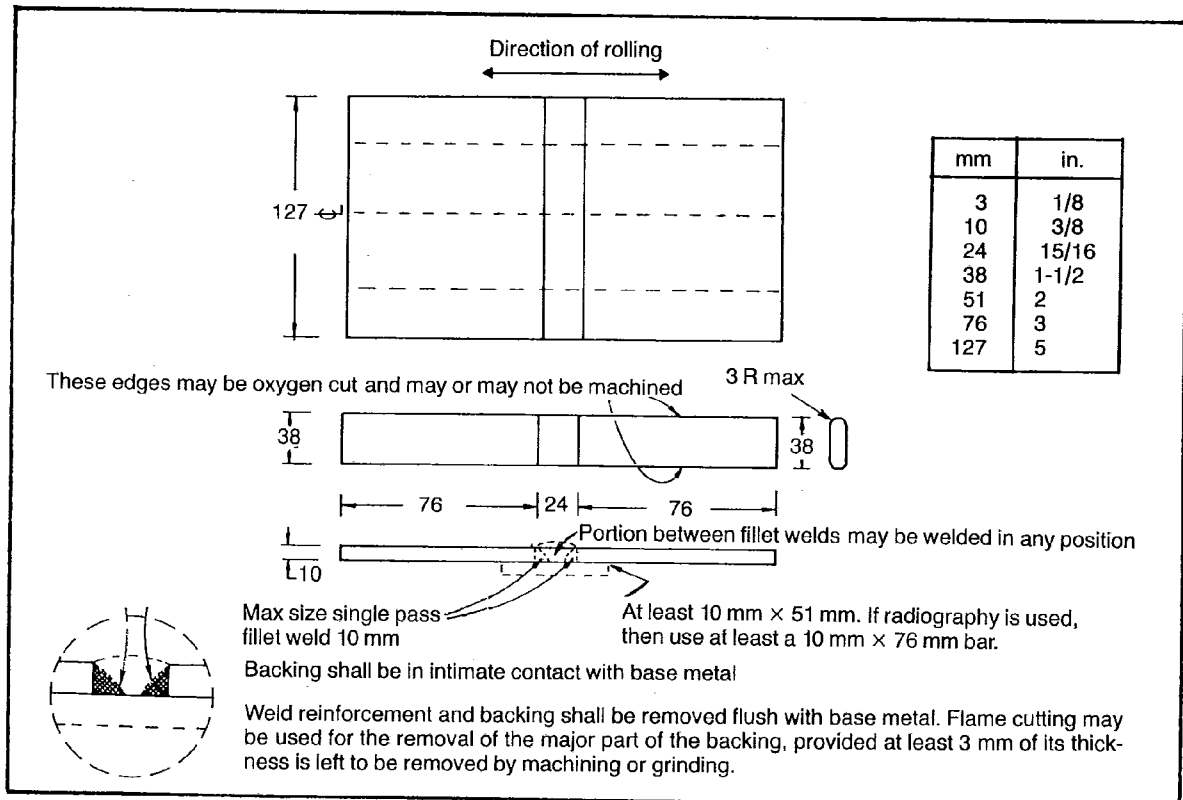
6.34.2 For other than electroslag or electrogas welding, a welding operator qualified to weld with multiple electrodes shall be qualified to weld with a single electrode but not vice versa.

6.34.3 An electroslag or electrogas welding operator qualified with an approved electrode and shielding medium combination shall be considered qualified to weld with any other approved electrode and shielding medium combination for the process used in the qualification test.

6.34.4 A change in the position in which welding is done, as defined in 6.9, shall require requalification.

6.35 Qualification Tests Required

6.35.1 The qualification test for a welding operator for other than electroslag or electrogas shall have a joint detail as follows: 25 mm (1 in.) plate, single-V-groove, 20 degree included groove angle, 16 mm (5/8 in.) root opening with backing. Backing must be at least 10 × 76 mm (3/8 × 3 in.) if radiography is used for testing without removal of backing. It must be at least 10 × 38 mm (3/8 ×



All dimensions in millimeters

Fig. 6.23.2 – Fillet weld root bend test plate – welding operator qualification – option 2

1-1/2 in.) for mechanical testing or if radiography is used for testing after the backing is removed. Minimum length of welding groove shall be 381 mm (15 in.) (see Fig. 6.35.1). This test will qualify the welding operator for groove and fillet welding in materials of unlimited thickness.

6.35.2 The qualification test for an electroslag or electrogas welding operator shall consist of welding a joint of the maximum thickness of material to be used in construction; however, the thickness of the material of the test weld need not exceed 38 mm (1-1/2 in.) (see Fig. 6.35.2). If a test weld is made in the 38 mm (1-1/2 in.) thickness, no test need be made for lesser thicknesses. This test shall qualify the welding operator for groove and fillet welds in material of unlimited thickness.

6.35.3 The welding operator making a complete joint penetration procedure qualification test meeting the requirements is thereby qualified for that process and test position for plate of thicknesses equal to or less than the thickness of the test plate. If the test plate is 38 mm (1-1/2 in.) or over in thickness for electroslag or electrogas welding, or 25 mm (1 in.) or over for all other processes, the welding operator will be qualified for all thicknesses.

6.36 Base Metal. The base metal used shall be carbon or low alloy steel or comply with the procedure specification.

6.37 Welding Procedure. The welding operator shall follow the welding procedure specified by the procedure specification.

6.38 Test Specimens – Number, Type and Preparation

6.38.1 For mechanical testing, two side-bend specimens shall be cut from the test joint approximately 102 mm (4 in.) apart, or 203 mm (8 in.) apart for electroslag and electrogas, at the middle of the length of the weld prepared for testing in accordance with Fig. 6.35.2. Radiographic testing of the test joint may be made at the contractor's option in lieu of the guided-bend test.

6.38.2 If radiography is used in lieu of the prescribed bend tests, the weld reinforcement need not be ground or otherwise smoothed for inspection unless its surface irregularities or juncture with the base metal would cause objectionable weld defects to be obscured in the radiograph. If the backing is removed for radiography, the root shall be ground flush with the base metal.

Table 6.24 – Welder qualification – type and position limitations

Qualification test	Type of weld and position of welding qualified*				
	Plate		Pipe		
Weld	Plate or pipe positions**	Groove	Fillet	Groove	Fillet
Plate – groove	1G	F	F, H	F	F
	2G	F, H	F, H	F, H	F, H
	3G	F, H, V	F, H, V		
	4G	F, OH	F, H, OH		
	3G & 4G	All	All		
Plate – fillet	1F		F		F
	2F		F, H		F, H
	3F		F, H, V		
	4F		F, H, OH		
	3F & 4F		All		
Pipe – groove	1G	F	F, H	F	F
	2G	F, H	F, H	F, H	F, H
	5G	F, V, OH	F, V, OH	F, V, OH	F, V, OH
	6G	Note 1	Note 1	Note 1	Note 1
	2G & 5G	Note 1	Note 1	Note 1	Note 1
	6GR	All	All	All	All

*Positions of welding: F = flat, H = horizontal, V = vertical, OH = overhead.

**See Figs. 6.9.1, 6.9.2 and 6.9.3.

Note: Qualifies for all but groove welds for T-, Y-, and K-connections.

6.38.3 Method of Testing Specimens

6.38.3.1 Side-Bend Specimens. Each specimen shall be bent in a jig having the contour shown in Fig. 6.28.1 and otherwise substantially in accordance with that figure. Any convenient means may be used to move the plunger member with relation to the die member. The specimen shall be placed on the die member of the jig with the weld at midspan. Specimens shall be placed with that side showing the greater defects, if any, directed toward the gap.

6.38.3.2 The radiographic procedure and technique shall be in accordance with the requirements of Part A of Section 7.

6.39 Test Results Required

6.39.1 Side-Bend Tests. The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect, exceeding 3 mm (1/8 in.) measured in any direction, is present after the bending shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.

6.39.2 For acceptable qualification, the weld, as revealed by the radiograph, shall conform to the requirements of Part A of Section 7.

6.40 Retests. In case a welding operator fails to meet the requirements of one or more test welds, a retest may be allowed under the following conditions:

6.40.1 An immediate retest may be made consisting of two test welds of each type failed, all of which shall meet all the requirements specified for such welds.

6.40.2 A retest may be made provided there is evidence that the welding operator has had further training or practice. In this case a complete retest shall be made.

6.41 Period of Effectiveness. The welding operator's qualification specified herein shall be considered in effect indefinitely unless (1) the welding operator will not be engaged in the given process of welding for which he is qualified for a period exceeding six months or unless (2) there is some specific reason to question the welding operator's ability.

6.42 Records. Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

Part E Qualification of Tackers

6.43 General. The qualification tests described herein are specially devised tests to determine the tacker's ability to produce sound welds. It is not intended that the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the procedure specification.

6.44 Limitation of Variables. For the qualification of a tacker, these rules shall apply:

6.44.1 A tacker shall be separately qualified for each type of steel to be used.

Table 6.27.1—Number and type of specimens and range of thickness qualified—welder qualification

Type of weld	Thickness (t) of test plate or pipe as welded	Pipe or tube size qualified	Plate, pipe, or tube wall thickness qualified min	Visual inspection max	Bend tests								T-joint break	Macro-etch test	
					Number of specimens										
					All positions except 5G & 6G				5G & 6G positions only						
					Face	Root	Side	Face	Root	Side					
Groove	10				Plate test		19 ³		Yes		1				
Groove	25 or over				Unlimited ³		Yes		2						
Fillet	See Fig. 6.23.1 ¹				Unlimited		Yes		1		1				
Fillet	See Fig. 6.23.2 ²				Unlimited		Yes		2						
Pipe test															
Groove	51 Sch. 80 or 76 Sch. 40 Job size pipe Diam. $\leq$ 102	Through 102	1.6	17.1	Yes	1	1	2	2	2					
Groove	152 Sch. 80 or 203 Sch. 120 Job size pipe Diam. $>$ 102	19 through 102 and over 1/2 diam. or 102 min.*	4.7	Unlimited ³	Yes			2		4					
Groove	See Fig. 6.22	T, K, and Y connections	Unlimited ³		Yes									4	
*Minimum pipe size qualified shall not be less than 102 mm (4 in.) or 1/2 d, whichever is greater, where d is diam. of test pipe.															
Option no. 1															
Option no. 2															
Also qualifies for welding fillet welds on material of unlimited thickness.															
Note: Radiographic examination of the welder or welding operator test plate or test pipe may be made in lieu of the bend test. See 6.3.2.															
All dimensions in millimeters															
			mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	
			1.6	0.063	17.1	6.74	51	2	152	6					
			8.7	0.187	19	3/4	76	3	203	8					
			10	3/8	25	1	102	4							

*Minimum pipe size qualified shall not be less than 102 mm (4 in.) or 1/2 d, whichever is greater, where d is diam. of test pipe.

1. Option no. 1

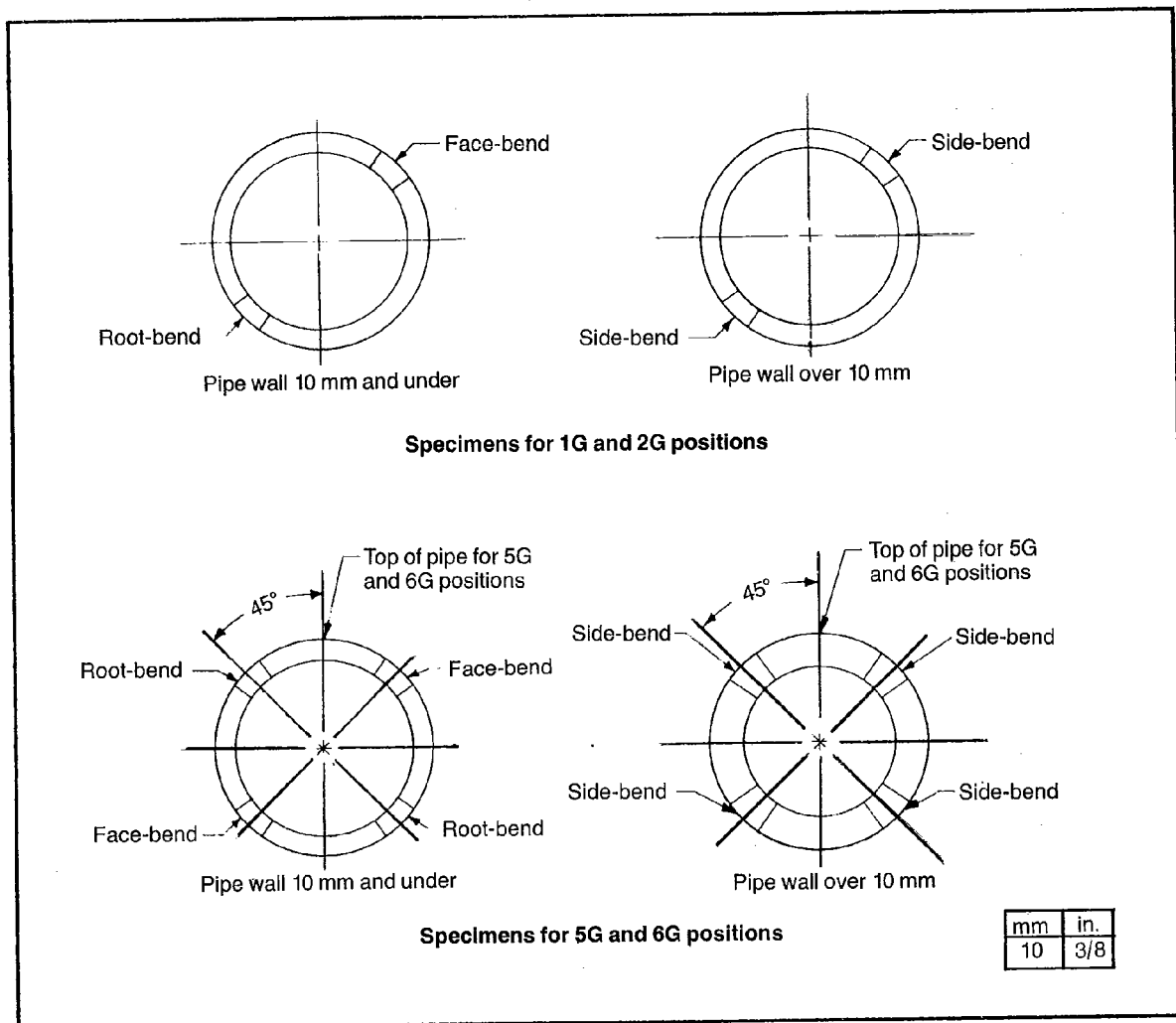
2. Option no. 2

3. Also qualifies for welding fillet welds on material of unlimited thickness.

Note: Radiographic examination of the welder or welding operator test plate or test pipe may be made in lieu of the bend test. See 6.3.2.

mm		in.		mm		in.		mm		in.		mm		in.	
1.6	0.063	17.1	6.74	51	2	152	6								
8.7	0.187	19	3/4	76	3	203	8								
10	3/8	25	1	102	4										

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All dimensions in millimeters except angles

Fig. 6.27.2 – Location of test specimens on welded test pipe – welder qualification

6.44.2 A tacker qualified for manual shielded metal arc welding with an electrode identified in the table below shall be considered qualified to tack weld with any other electrode in the same group designation and with any electrode listed in a numerically lesser group designation:

Group designation	AWS Electrode classification*
F4	EXX15, EXX16, EXX18
F3	EXX10, EXX11
F2	EXX12, EXX13, EXX14
F1	EXX20, EXX24, EXX27, EXX28

*The letters "XX" used in the classification designations in this table represent the various strength levels in ksi (60, 70, 80, 90, 100, 110 and 120) of electrodes.

6.44.3 A tacker qualified with an approved electrode and shielding medium combination shall be considered

qualified to tack with any other approved electrode and shielding medium combination for the process used in the qualification test.

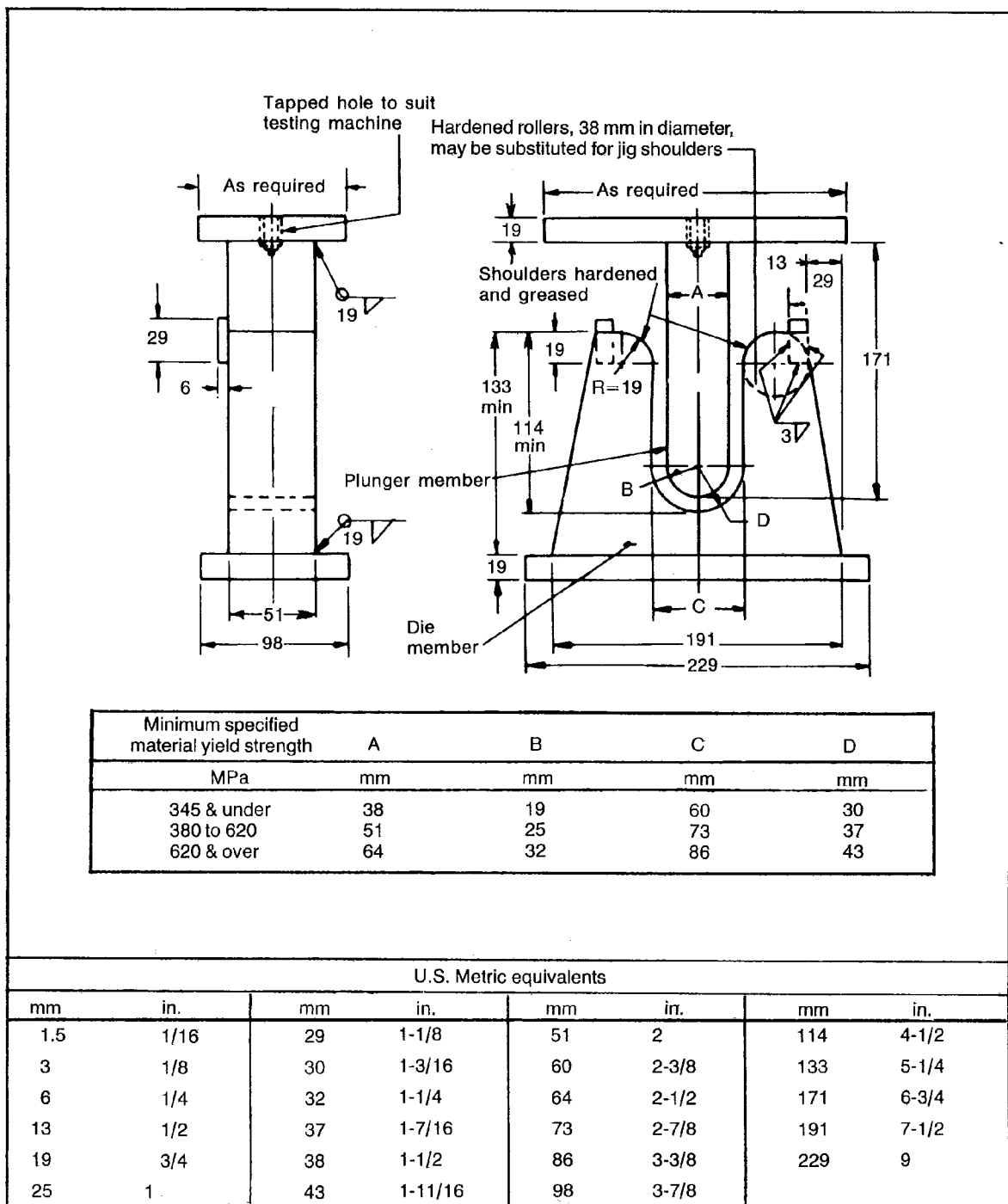
6.44.4 A tacker shall be qualified for each process used.

6.44.5 A change in the position in which tacking is done, as defined in 6.9, shall require requalification.

6.45 Qualification Tests Required. A tacker shall be qualified by one test plate made in each position in which he is to tack.

6.46 Base Metal. The base metal used shall be carbon or low alloy steel or comply with the procedure specification.

6.47 Test Specimens—Number, Type and Preparation. The tacker shall make a 6 mm (1/4 in.) maximum size tack



All dimensions in millimeters

Fig. 6.28.1(A) – Guided-bend test jig

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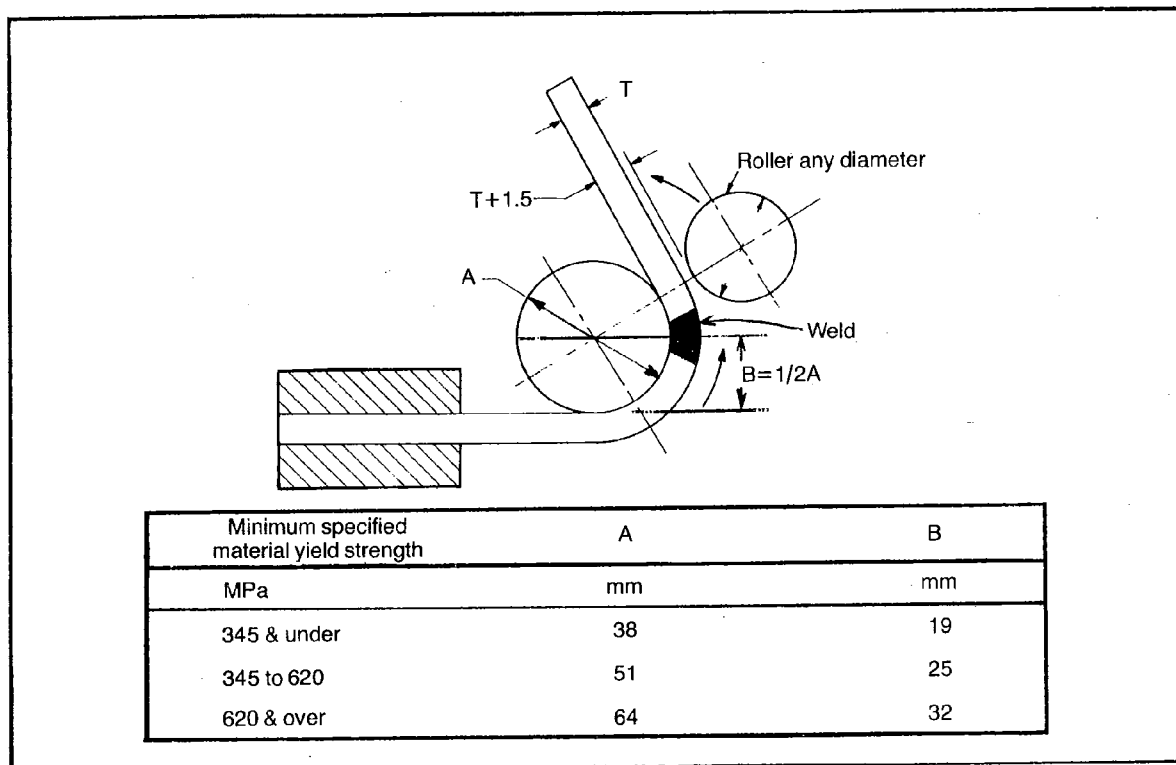


Fig. 6.28.1(B) – Alternative wraparound guided-bend test jig

All dimensions in millimeters

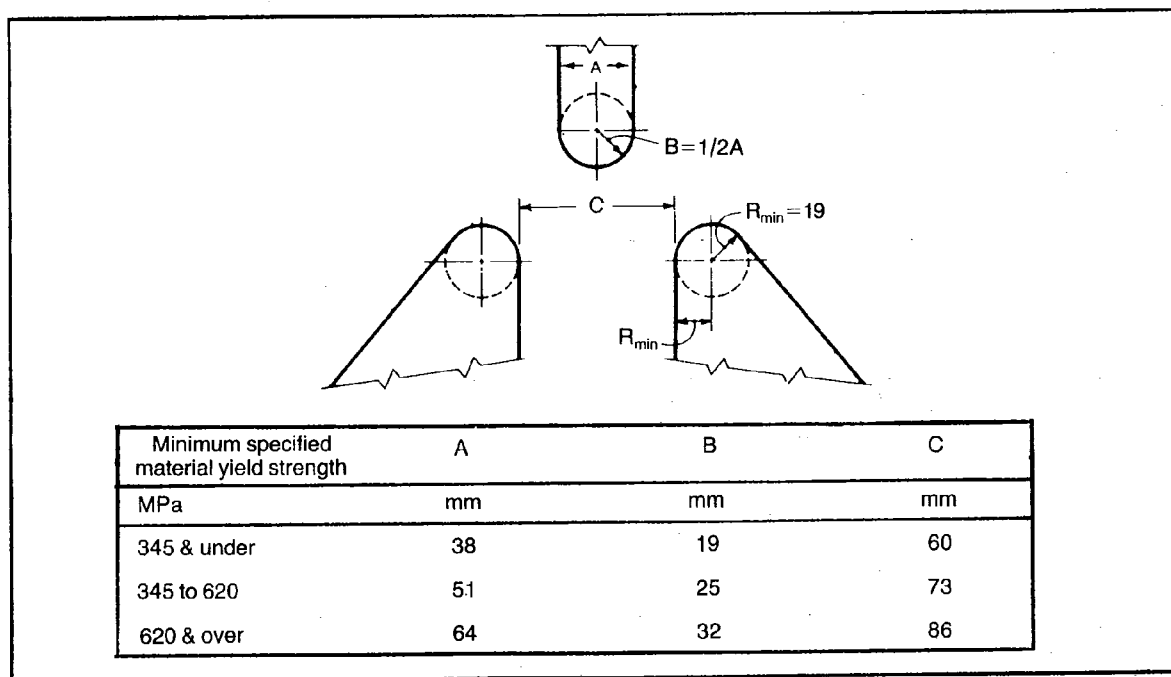
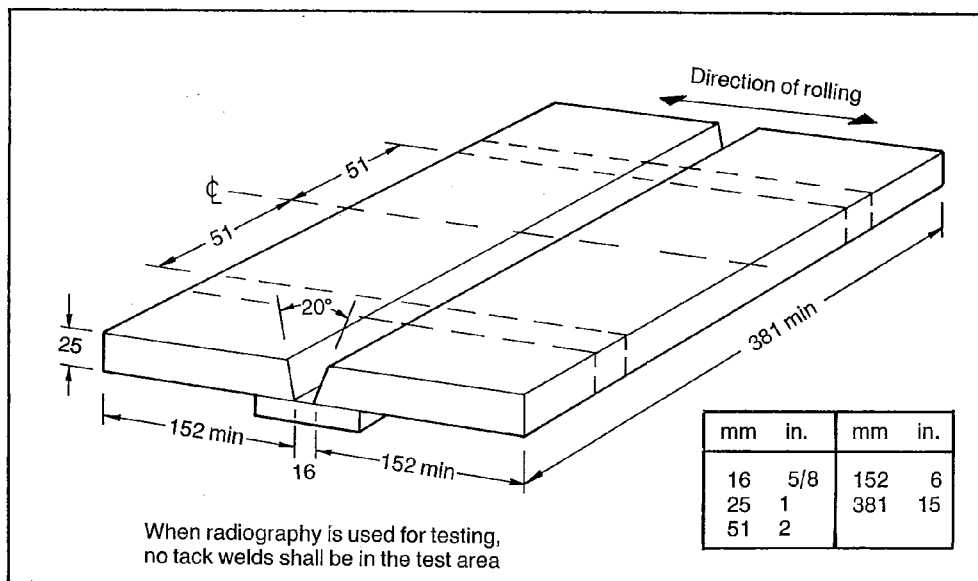
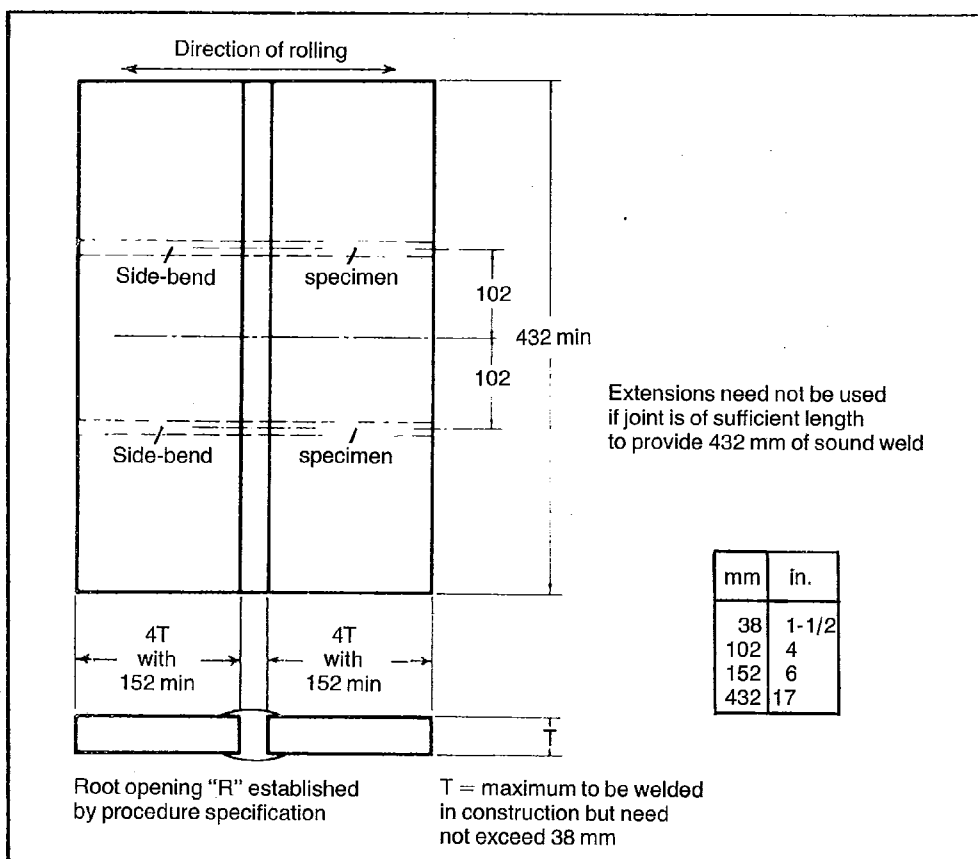


Fig. 6.28.1(C) – Alternative roller-equipped guided-bend test jig for bottom ejection of test specimen

All dimensions in millimeters

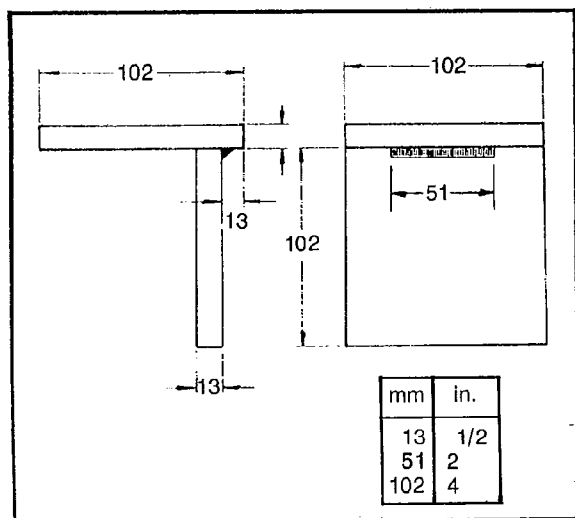


All dimensions in millimeters except angles

Fig. 6.35.1 – Test plate for unlimited thickness – welding operator qualification

All dimensions in millimeters

Fig. 6.35.2 – Butt joint for welding operator qualification – electroslog and electrogas welding



All dimensions in millimeters

Fig. 6.47 – Fillet weld break specimen – tacker qualification

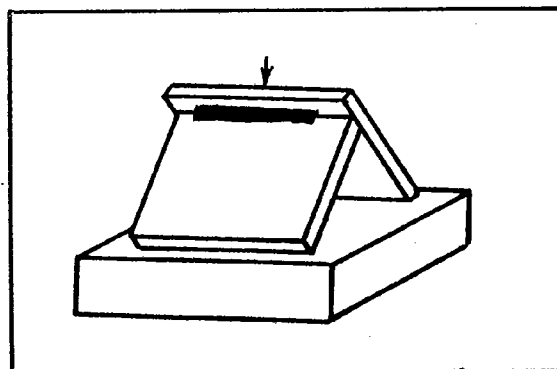
weld approximately 51 mm (2 in.) long on the fillet weld break specimen as shown in Fig. 6.47 using a 4 mm (5/32 in.) diameter electrode.

6.48 Method of Testing Specimens. A force shall be applied to the specimen as shown in Fig. 6.48 until rupture occurs. The force may be applied by any convenient means. The surfaces of the weld and of the fracture shall be examined visually for defects.

6.49 Test Results Required

6.49.1 The tack weld shall present a reasonably uniform appearance and shall be free of overlap, cracks and excessive undercut. There shall be no porosity visible on the surface of the tack weld.

6.49.2 The fractured surface of the tack weld shall show complete penetration into the root of the joint and



6.48 – Method of rupturing fillet weld break specimen – tacker qualification

shall exhibit no incomplete fusion to the base metal nor any inclusion or porosity larger than 2 mm (3/32 in.) in greatest dimension.

6.49.3 A tacker who passes the fillet weld break test shall be eligible to tack weld all types of joints for the process and in the position for which he has been qualified.

6.50 Retests. In case of failure to pass the fillet weld break test, the tacker may make one retest without additional training.

6.51 Period of Effectiveness. A tacker who passes the fillet weld break test shall be considered eligible to perform tack welding indefinitely in the positions and with the processes for which he is qualified unless there is some specific reason to question his ability. In such case, the tacker shall be required to again demonstrate his ability to make sound tack welds by again passing the prescribed tack welding test.

6.52 Records. Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

7. Inspection

Part A Radiographic Inspection

7.1 General. Radiographic examination of welded joints, where required, shall be conducted in accordance with the procedures specified in Part A of this section, which include standards for radiographic acceptance. The procedures and standards set forth in this section are to govern radiographic inspection of butt welded joints when such inspection is required. Personnel qualification and records shall be in accordance with the American Society for Nondestructive Testing SNT-TC-1A, Recommended Practice, Supplement A, Radiography.

7.2 Extent of Inspection

7.2.1 Information furnished to the bidder shall clearly identify the extent of the radiographic inspection to be performed by identifying the joints to be radiographed and by designating whether complete or spot radiographs shall be made.

7.2.2 When complete inspection is specified, the entire length of the weld in each designated joint shall be inspected in accordance with 7.3.1 through 7.3.9.4.

7.2.3 When spot radiography is specified, the inspection and selection of the spots shall be in accordance with 7.4.1 through 7.4.4.

7.3 Radiographic Procedure

7.3.1 All welded joints to be radiographed shall be prepared as follows:

7.3.1.1 The weld ripples or weld surface irregularities, inside and outside, shall be removed, where practical, by any suitable mechanical process to such a degree that the resulting radiographic contrast due to any irregularities cannot mask or be confused with the image of any objectionable defect.

7.3.1.2 The weld surface shall merge smoothly into the joint surface.

7.3.2 The weld shall be radiographed using a technique which will have sufficient sensitivity to indicate the features of the penetrameter as described in 7.3.3.7; the penetrameter will have the specified thickness for the thickness of the weld being examined. The size and shape of the penetrameter shall be as shown on Fig. 7.3.2. These dimensions apply to the penetrameter itself and not to its projected image on the radiograph. The thickness of the penetrameter shall be as shown in Table 7.3.2.

7.3.3 As a check on the radiographic technique employed, the penetrameters described herein shall be used in the following manner to determine whether the requirements are met:

7.3.3.1 The radiographic quality shall be evaluated by the image of a properly located penetrameter.

7.3.3.2 A standard source side penetrameter of the thickness shown in Table 7.3.2 shall be placed on the side

nearest the radiation source. Where it is physically impossible to do this, a film side penetrameter shall be placed on the film side of the joint. Its thickness shall be in accordance with Table 7.3.2 and a lead letter "F;" at least 13 mm (1/2 in.) in height, shall be placed adjacent to the penetrameter.

7.3.3.3 One penetrameter shall be used for each exposure and shall be placed so that the plane of the penetrameter is normal to the radiation beam. Each penetrameter shall represent an area of essentially uniform radiographic density as determined by density comparison strips or a densitometer. If the film density through the weld varies more than minus 15 or plus 30 percent from the density through the penetrameter, then an additional penetrameter will be required for the exceptional area or areas. If the requirements of 7.3.3.8 are met by two penetrameters, one appearing in the lightest area of a film and the other in the darkest, the intervening film shall be considered as having acceptable density. It is not necessary that these additional penetrameters be normal to the radiation at their locations. The density through acceptable weld metal shall be 1.5 minimum for single film viewing or composite viewing of multiple film exposures.

7.3.3.4 The material of the penetrameter shall be radiographically similar to that of the filler metal under examination. Any steel, preferably stainless, may be used for radiographing steel weldments. Aluminum penetrameters should be used for aluminum weldments. If the filler metal is not radiographically similar to the base material, the penetrameter may be placed over the filler metal.

7.3.3.5 The penetrameter shall be placed adjacent to the weld seam except as provided for in 7.3.3.4. If the weld reinforcement or backing strip, or both, are not removed, a shim of a material radiographically similar to the filler metal shall be placed under the penetrameter. The shim thickness shall be selected so that the total thickness being radiographed under the penetrameter is the same as the total weld thickness including backing strip, if used and not removed.

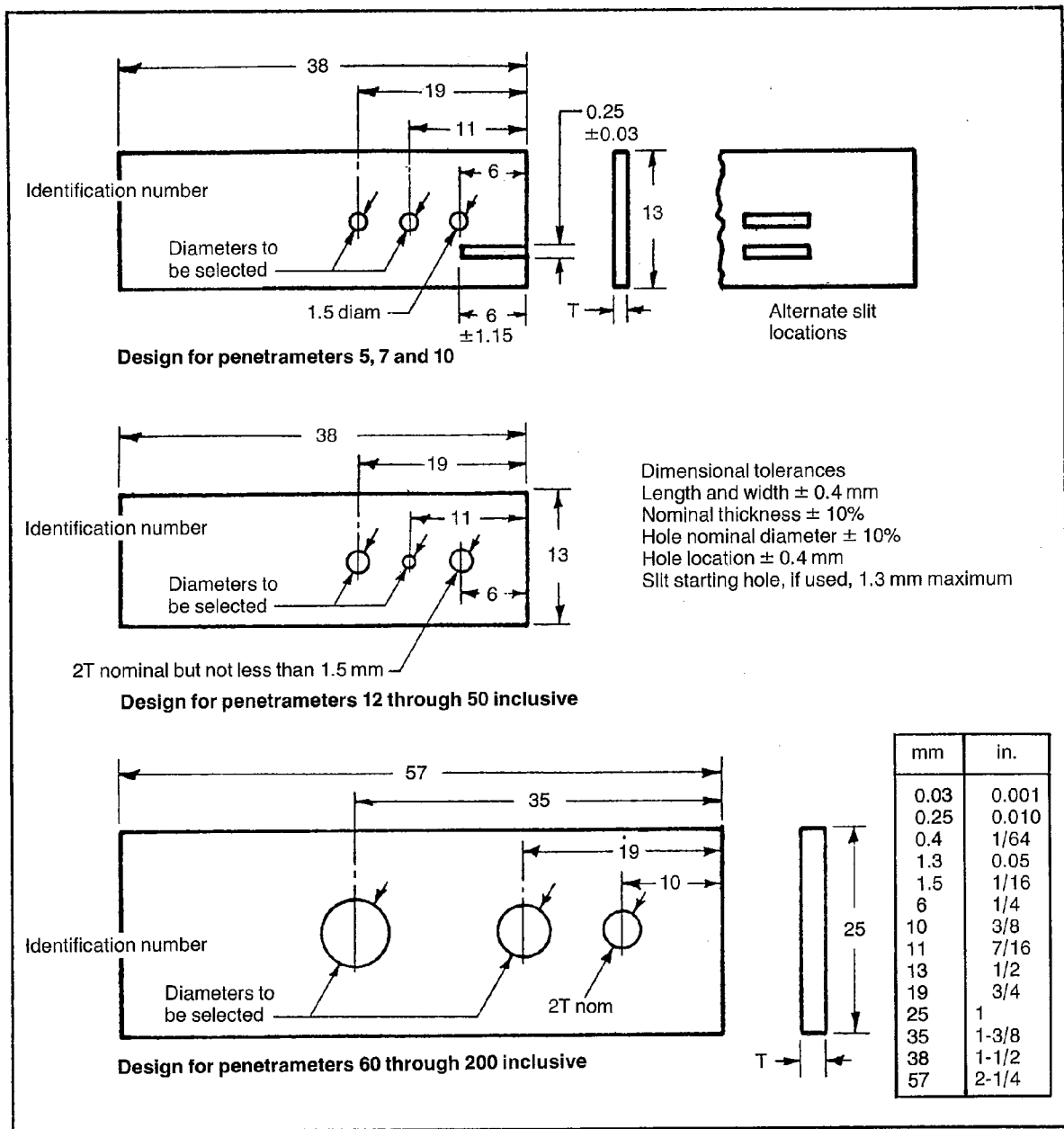
7.3.3.6 In each penetrameter, there shall be three holes; the diameter of one hole shall be equal to twice the nominal penetrameter thickness (2T) but not less than 1.5 mm (1/16 in.). The diameter of the two remaining holes shall be selected by the manufacturer and will ordinarily be equal to three (3T) and four (4T) times the penetrameter thickness; the holes need not be smaller than 1.5 mm (1/16 in.) but smaller holes are permitted.

These holes shall be true and normal to the surface and not chamfered. For weld thickness less than 13 mm (1/2 in.), the penetrameter shall also contain a slit 6 mm (1/4 in.) long by 0.25 mm (0.010 in.) wide. The long dimension of this slit is to be placed parallel to the longitudinal direction of the weld.

7.3.3.7 The holes or slit, as required, shall be delineated on the radiograph as defined in 7.3.3.8.

7.3.3.8 The image of the identifying numbers, of the penetrameter outline, and of the 2T hole are all essential

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All dimensions in millimeters

Fig. 7.3.2—Penetrameter (image quality indicator)

Table 7.3.2 — Standard penetrometer sizes

mm	Weld thickness range*	Thickness of penetrometer on source side		Designation on penetrometer		Thickness of penetrometer on film side		Designation on penetrometer
		mm	in.	mm	in.	mm	in.	
Up to 6	1/4 inc.	0.13	0.005	5	0.005	0.13	0.005	5
Over 6—10	1/4—3/8	0.19	0.0075	7	0.0075	0.19	0.0075	7
Over 10—13	3/8—1/2	0.25	0.010	10	0.010	0.25	0.010	10
Over 13—16	1/2—5/8	0.32	0.0125	12	0.0125	0.25	0.010	10
Over 16—19	5/8—3/4	0.38	0.015	15	0.015	0.30	0.012	12
Over 19—22	3/4—7/8	0.44	0.0175	17	0.0175	0.38	0.015	15
Over 22—25	7/8—1	0.51	0.020	20	0.020	0.43	0.017	17
Over 25—32	1—1-1/4	0.64	0.025	25	0.025	0.51	0.020	20
Over 32—38	1-1/4—1-1/2	0.76	0.030	30	0.030	0.64	0.025	25
Over 38—51	1-1/2—2	0.89	0.035	35	0.035	0.76	0.030	30
Over 51—64	2—2-1/2	1.0	0.040	40	0.040	0.76	0.030	30
Over 64—76	2-1/2—3	1.1	0.045	45	0.045	0.89	0.035	35
Over 76—102	3—4	1.3	0.050	50	0.050	1.0	0.040	40
Over 102—152	4—6	1.5	0.060	60	0.060	1.3	0.050	50
Over 152—203	6—8	2.0	0.080	80	0.080	1.5	0.060	60
Over 203—254	8—10	2.5	0.100	100	0.100	2.0	0.080	80
Over 254—305	10—12	3.0	0.120	120	0.120	2.5	0.100	100
Over 305—408	12—16	4.1	0.160	160	0.160	3.0	0.120	120
Over 408—508	16—20	5.1	0.200	200	0.200	4.1	0.160	160

*Including any weld reinforcement or backing strip thickness, or both, if not removed. In the case of double wall tube radiography, the thickness of the penetrometer shall be based on the thickness of the weld next to the film.

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indexes of image quality on the radiograph and they shall appear clearly on the radiograph. For penetrameters 5, 7 and 10, the slit shall appear clearly and the hole need not appear.

7.3.4 When the source is placed on the axis of the joint and the complete circumference is radiographed with a single exposure, at least three uniformly spaced penetrameters shall be used.

7.3.5 All radiographs shall be free from excessive mechanical, chemical or other processing defects that could interfere with proper interpretation of the radiograph.

7.3.6 Identification markers, whose images appear on the film, shall be placed adjacent to the weld on the part, not on the film; their locations shall be marked on the surface near the weld in such a manner that a defect appearing on a radiograph may be accurately located and that it is evident on the film that complete coverage of the weld has been obtained.

7.3.7 The job identification, weld seam identification and radiographic facility identification shall be indicated on each film.

7.3.8 A complete set of radiographs for each job shall be retained by the manufacturer and kept on file for a period of at least five years.

7.3.9 Sections of the weld shown by radiography to have any of the following types of imperfections shall be judged unacceptable and shall be repaired by an approved weld procedure and the repair radiographed according to this procedure:

7.3.9.1 Any type of crack or zone of incomplete fusion or penetration.

7.3.9.2 Any elongated slag inclusion which has a length greater than 6 mm (1/4 in.) for T to 19 mm (3/4 in.), 1/3 T for T from 19 mm (3/4 in.) to 57 mm (2-1/4 in.), 19 mm (3/4 in.) for T over 57 mm (2-1/4 in.), where T is the thickness of the weld.

7.3.9.3 Any group of slag inclusions in line that have an aggregate length greater than T in a weld length of 12T, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group.

7.3.9.4 Porosity in excess of that specified by Table 7.5(1) and Figs. 7.5(2) through 7.5(6). (ASTM reference radiographs E390 may be used in lieu of these figures.)

7.4 Spot Examination of Welded Joints³

7.4.1 Minimum extent of spot radiography for welds not radiographed their complete length shall be as follows:

7.4.1.1 One spot shall be examined in the first 15 m (50 ft.) of welding and one spot shall be examined for each additional 15 m (50 ft.) of welding or fraction thereof. When identical welds individually less than 15 m (50 ft.) seam length are being fabricated, 15 m (50 ft.) increments of welding may be represented by one spot examination.

3. Spot radiography, in accordance with these rules, will not insure a predetermined quality level throughout the product fabricated. An accepted weld, according to these spot radiography rules, may still contain defects which might be disclosed on further examination.

7.4.1.2 Such additional spots as may be required shall be selected so an examination of the welding of each welding operator or welder is made. Under conditions where two or more welders or welding operators make weld layers in a joint or on the two sides of a double welded butt joint, one spot examination may represent the work of both welders or welding operators.

7.4.1.3 Each spot examination shall be made as soon as practicable after the completion of the increment of the weld that is to be examined. The location of the spots to be examined shall be agreed on by the purchaser and fabricator.

7.4.2 Spot examination by radiography shall be made in accordance with 7.3.1 through 7.3.3.8. The minimum length of spot radiograph shall be 152 mm (6 in.). The acceptability of welds examined by spot radiography shall be judged by the following standards:

7.4.2.1 Welds in which the radiographs show any type of crack or zone of incomplete fusion or penetration shall be acceptable.

7.4.2.2 Welds in which the radiographs show slag inclusions or cavities shall be unacceptable if the length of any such imperfection is greater than $2/3T$ where T is the thickness of the thinner plate welded. If several imperfections within these limitations exist in a line, the welds shall be judged acceptable if the sum of the longest dimensions of all such imperfections is not more than T in a length of 6T and if the longest imperfections considered are separated by at least 3L of acceptable weld metal, where L is the longest imperfection. The maximum length of acceptable imperfection shall be 19 mm (3/4 in.). Any such imperfection shorter than 6 mm (1/4 in.) shall be acceptable for any plate thickness.

7.4.3 Evaluation and Retests

7.4.3.1 Where spot radiography is acceptable, the entire weld length represented by the radiograph is acceptable.

7.4.3.2 If a spot radiographed in accordance with these requirements discloses welding which does not comply with the minimum quality requirements, two additional spots shall be radiographically examined in the same weld at locations away from the original spot.

7.4.3.2.1 If the additional spots examined show the welding meets the minimum quality requirements, the entire weld, represented by the three radiographs, is acceptable. The defective weld found in the first radiograph shall be repaired.

7.4.3.2.2 If either of the two additional spots examined shows welding which does not comply with the minimum quality requirements, the entire unit of weld represented shall be rejected. The entire rejected weld shall be removed and the joint shall be rewelded or, at the fabricator's option, the entire unit of weld represented shall be completely radiographed and defective welding only need be corrected.

7.4.4 Repair welding shall be performed using a qualified weld procedure. The rewelded joint of the repaired areas shall be spot radiographed at one location in accordance with the foregoing requirements.

Porosity Figures

7.5 Acceptance Standards for Radiographically Determined Porosity in Welds

7.5.1 These standards are applicable to ferritic, austenitic and nonferrous materials.

7.5.2 The total area of porosity as determined from the radiographic film shall not exceed $1.52 T \text{ mm}^2$ ($0.060 T \text{ in.}^2$) in any 152 mm (6 in.) length of weld, where T is the thickness of the weld measured in millimeters (inches). If the weld is less than 152 mm (6 in.) long, the total area of porosity will be reduced in proportion.

7.5.2.1 The maximum pore dimension shall be 20 percent of T or 3 mm (1/8 in.), whichever is smaller, except that an isolated pore separated from an adjacent pore by 25 mm (1 in.) or more may be 30 percent of T or 6 mm (1/4 in.), whichever is less.

7.5.2.2 Dark images of a generally circular or oval shape shall be interpreted as porosity for the purposes of this standard.

7.5.2.3 Table 7.5(1) and Figs. 7.5(2) through 7.5(6) illustrate various types of assorted and uniform, randomly dispersed porosity indications. They indicate the maximum acceptable porosity for each thickness and represent full scale 152 mm (6 in.) radiographs. They shall not be enlarged or reduced. The porosity distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the number and size of indications permitted. When porosity indications differ significantly from the porosity charts, the actual numbers and sizes of indications may be counted and Table 7.5(1) used for acceptance.

Part B Ultrasonic Inspection

7.6 General

7.6.1 Ultrasonic examination of welded joints, where required, shall be conducted in accordance with the procedures specified herein, which include standards for ultrasonic acceptance.

7.6.2 This procedure contains the minimum requirements for the ultrasonic inspection of butt-, corner- and certain T-welded joints by the contact method and is applicable to welds in alloy steel and aluminum plates from 13 to 178 mm (1/2 to 7 in.) thick.

7.6.3 Acceptance criteria are given for two classes of acceptance: Class I for complete inspection of the weld where joint performance is equivalent to the base metal under all conditions; Class II for welds when 10 percent of the length of the weld is inspected after magnetic particle or liquid penetrant inspection has been performed.

7.7 Extent of Inspection

7.7.1 Contractual specifications shall designate the class of ultrasonic inspection to be performed by identifying the welded joints to be inspected as Class I or Class II.

7.7.2 When Class I welds are designated, the entire length of the weld shall be inspected.

7.7.3 When Class II welds are specified, the location inspected shall be a 152 mm (6 in.) length of weld. The number of locations shall total 10 percent of the total length of the weld. When an inspected location requires repair, two adjacent locations, one on each side, shall be inspected also. If defects requiring repair are shown in either of these locations, the entire weld in that joint shall be inspected.

7.8 Requirements

7.8.1 Operator Qualifications. The ultrasonic operator shall be thoroughly familiar with the calibration and operation of the equipment used and the inspection requirements of this procedure. He shall have demonstrated his ability to calibrate and operate the equipment in accordance with this procedure. Personnel shall be qualified in accordance with the American Society for Nondestructive Testing SNT-TC-1A, Recommended Practice, Supplement C, Ultrasonic Testing Method. Only individuals qualified for NDT Level I, working under supervision of an individual qualified for NDT Level II, or individuals qualified for NDT Level II may perform ultrasonic weld testing.

7.8.2 Equipment. The ultrasonic inspection equipment shall consist of the inspection instrument, search unit, and accessories and shall have the following capabilities:

7.8.2.1 "A" scan data presentation

7.8.2.2 Sweep length control

7.8.2.3 Sensitivity control

7.8.2.4 Time corrected gain control

7.8.2.5 Search Unit. The maximum dimension of the transducer active element shall not exceed 25 mm (1 in.). The transducer frequency shall be 2.0 MHz or higher. The shear wave transducer shall be fitted with a plastic wedge designed to induce shear waves into the material to be tested at an angle of 45°, 60° or 70° within a maximum tolerance of $\pm 3^\circ$.

7.8.2.6 Calibration Standards. In lieu of this calibration standard, the calibration block listed by IIW or ASTM test standards may be used. Calibration reference standards shall be 32 mm (1-1/4 in.) thick and made from material acoustically similar to the material to be tested. The top surfaces shall be machined to approximately $6.4 \mu\text{m}$ (250 $\mu\text{in.}$) RMS finish as compared with machined surface finish standards. The calibration standards shall be capable of revealing any equipment malfunction that might be detrimental to the test. The calibration standards must also provide reference sensitivity levels for the inspection of the weld mass to permit different instruments to be operated at the same sensitivity level. Example calibration standards are shown in Figs. 7.8.2.6.1, 7.8.2.6.2, and 7.8.2.6.3. The following is a brief description of the calibration blocks:

7.8.2.6.1 The 1.2 mm (3/64 in.) diameter holes are used in setting the test sensitivity level.

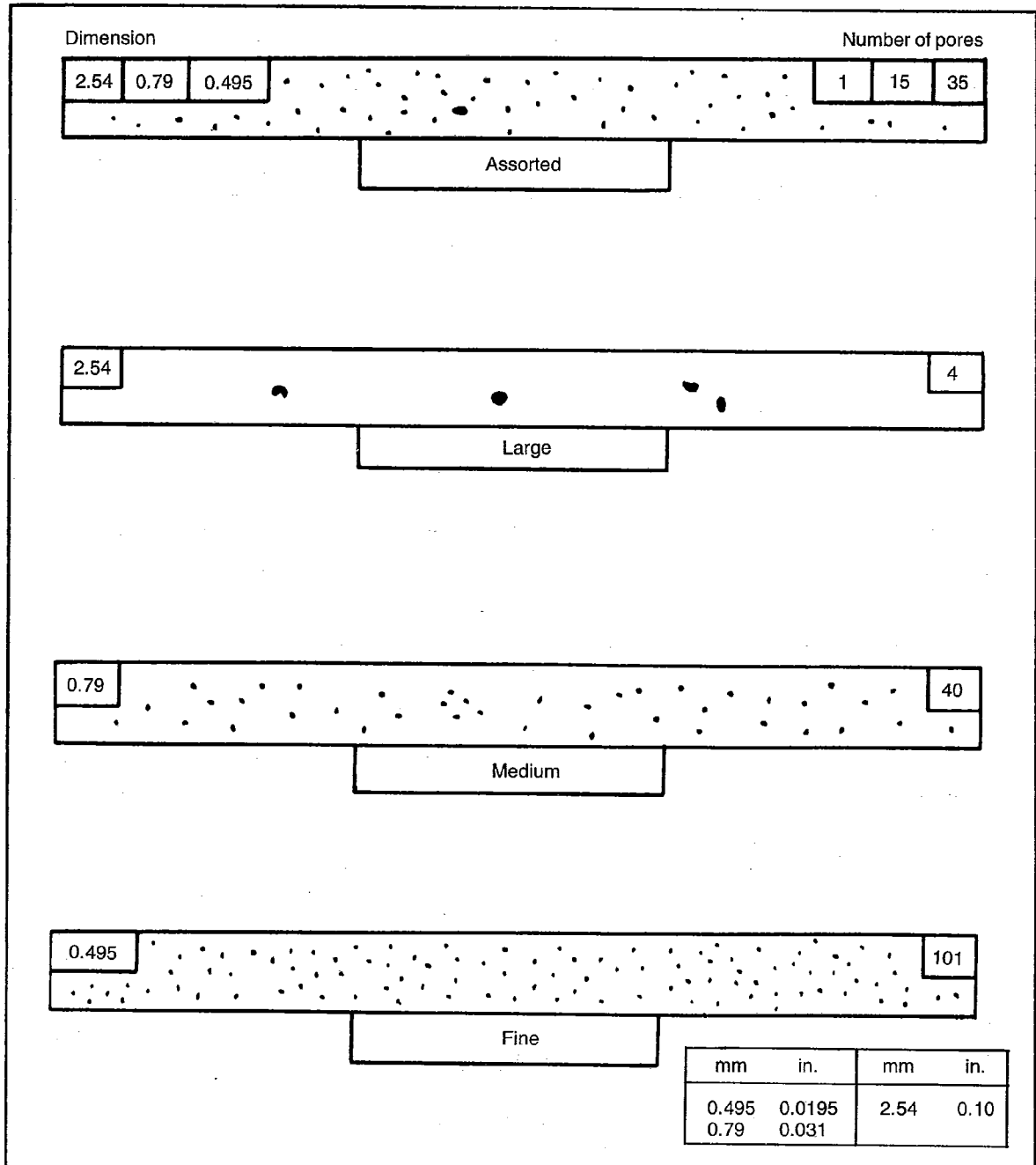
7.8.2.6.2 The 3 mm (1/8 in.) diameter holes are used to check the accuracy of the refracted angle produced by the plastic wedge.

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Table 7.5(1)—Maximum permissible porosity indications in radiographs per 152 mm (6 in.) length of weld

Weld thickness mm	Weld thickness in.	Total area of permitted porosity mm ²	Total area of permitted porosity in. ²	Large pore size			Medium pore size			Fine pore size		
				mm	Approx. fraction	in.	mm	Approx. fraction	in.	mm	Approx. fraction	in.
3	1/8	4.8	0.0075	..			..			0.4	1/64	0.014
6	1/4	9.7	0.015	..			..			0.4	1/64	0.0138
13	1/2	19.4	0.030	2	3/32	0.10	4	1/32	0.031	0.64	3/128	0.0195
19	3/4	29.0	0.045	3	1/8	0.125	4	1/32	0.034	0.64	3/128	0.024
25	1	38.7	0.060	3	1/8	0.125	5	5/128	0.039	0.8	1/32	0.0275
38	1-1/2	58.1	0.090	3	1/8	0.125	7	3/64	0.048	0.8	1/32	0.034
51	2	77.4	0.120	3	1/8	0.125	10	7/128	0.055	1.0	5/128	0.039
64	2-1/2	96.8	0.150	3	1/8	0.125	12	1/16	0.061	1.2	3/64	0.044
76	3	116	0.180	3	1/8	0.125	15	1/16	0.068	1.2	3/64	0.048
89	3-1/2	135	0.210	3	1/8	0.125	17	5/64	0.073	1.4	7/128	0.052
102	4	155	0.240	3	1/8	0.125	20	5/64	0.078	1.4	7/128	0.055

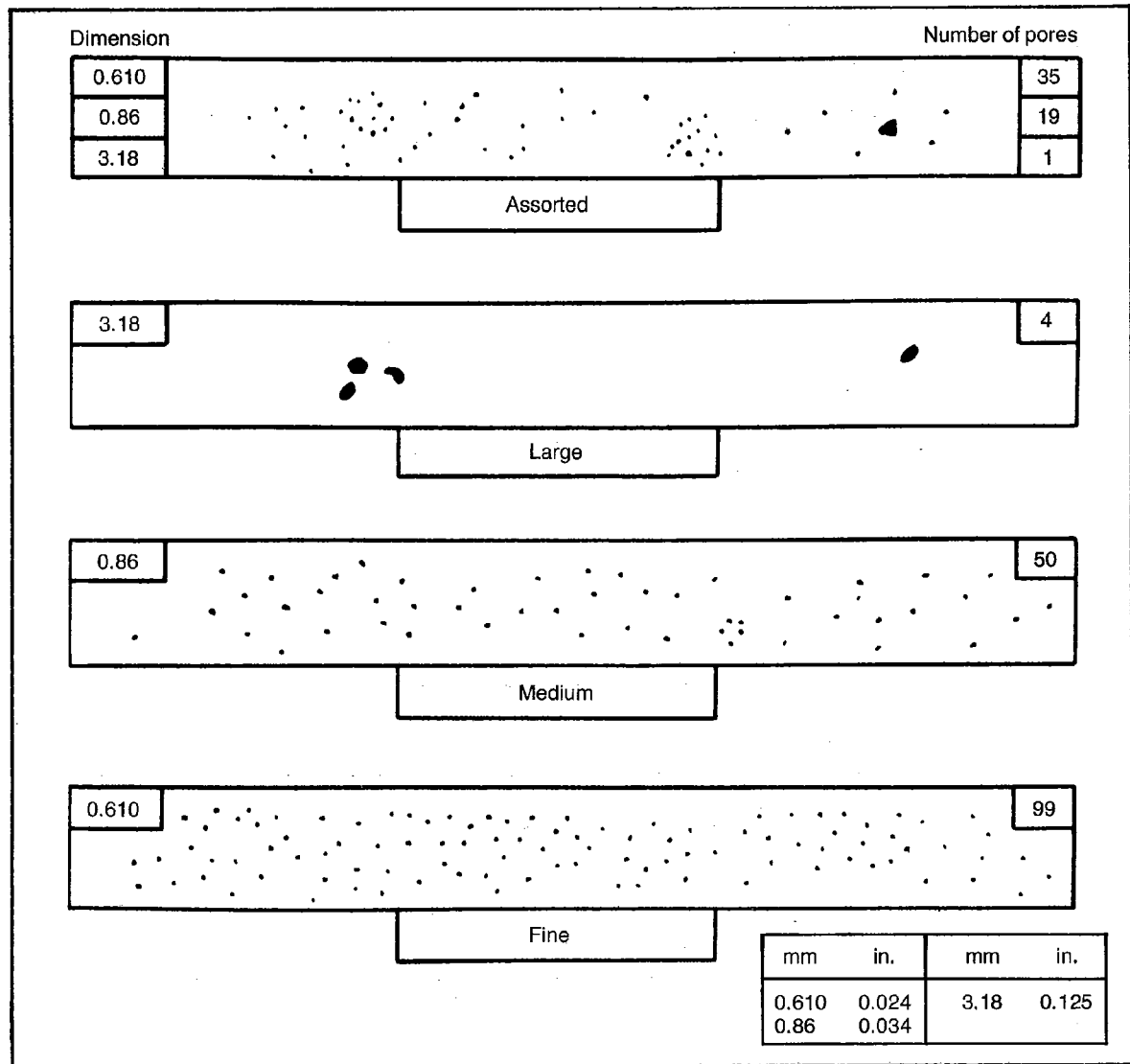
*The decimal values are those values used for calculating total area of permissible porosity.



All dimensions in millimeters

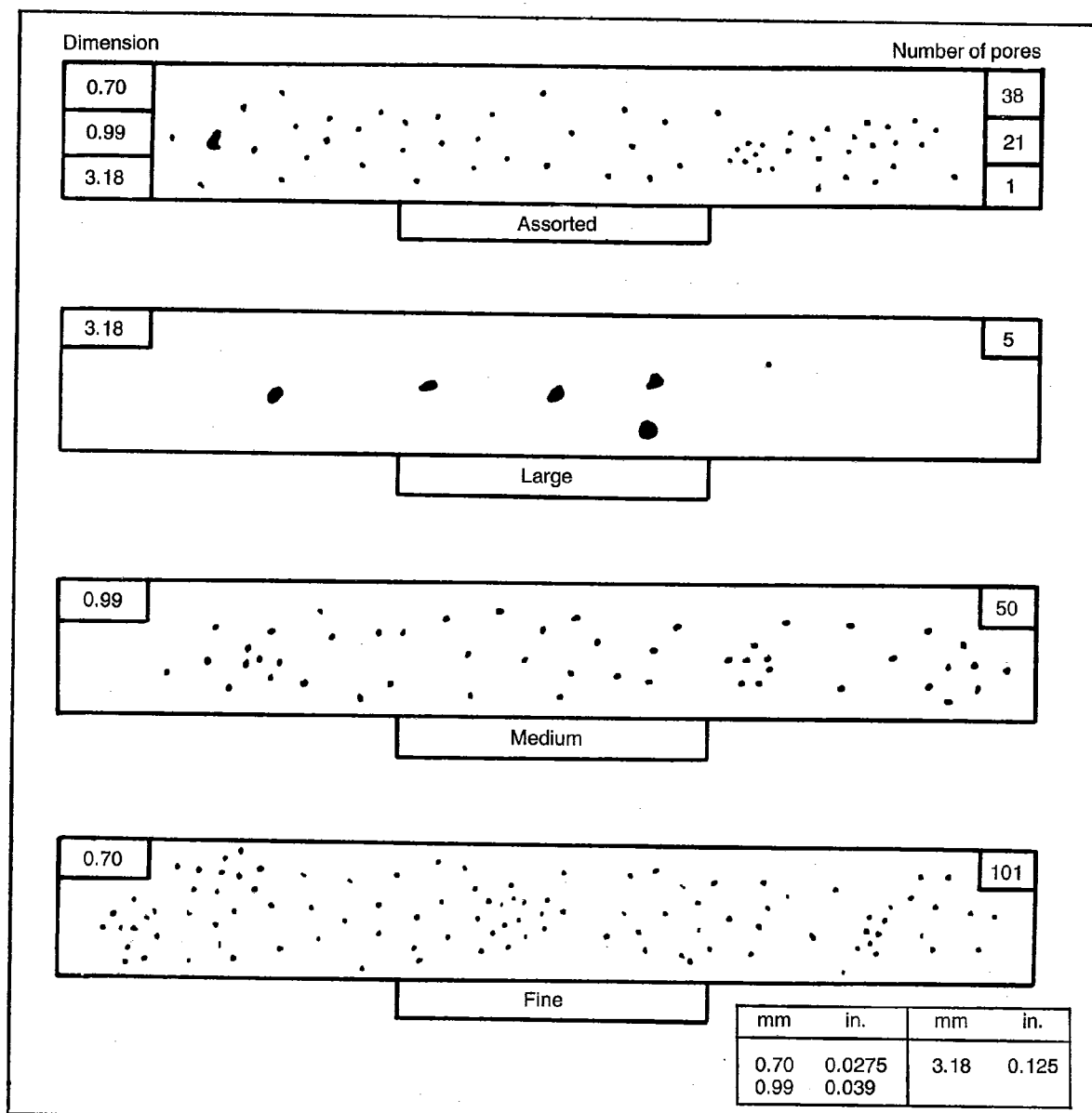
**Fig. 7.5(2) – Typical number and size permitted in any 152 mm (6 in.) length of weld –
13 mm (1/2 in.) weld thickness –
total pore area permitted is 19 mm² (0.030 in.²)**

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All dimensions in millimeters

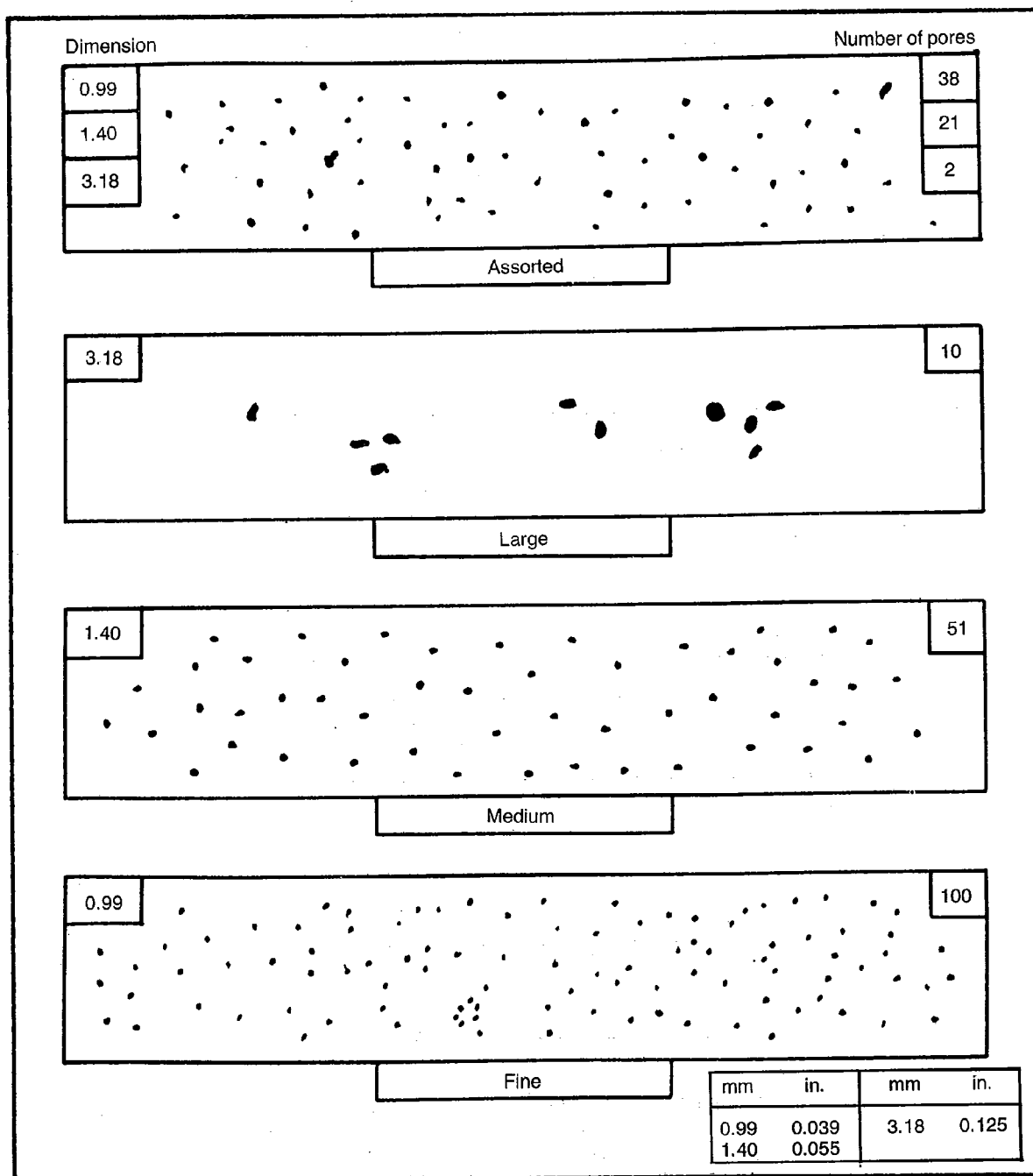
**Fig. 7.5(3) – Typical number and size permitted in any 152 mm (6 in.) length of weld –
19 mm (3/4 in.) weld thickness –
total pore area permitted is 29 mm² (0.045 in.²)**



All dimensions in millimeters

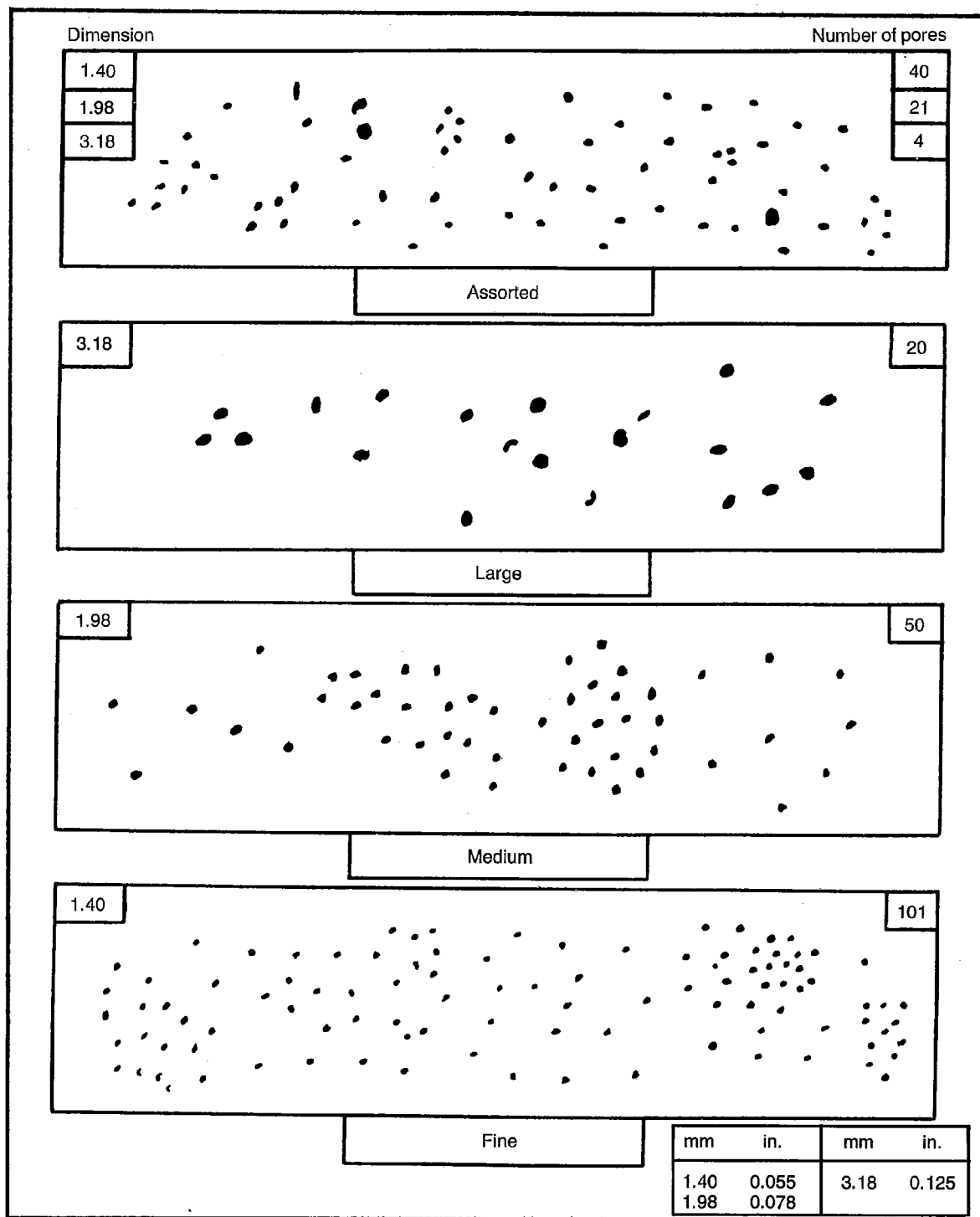
**Fig. 7.5(4) – Typical number and size permitted in any 152 mm (6 in.) length of weld –
25 mm (1 in.) weld thickness –
total pore area permitted is 39 mm² (0.060 in.²)**

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All dimensions in millimeters

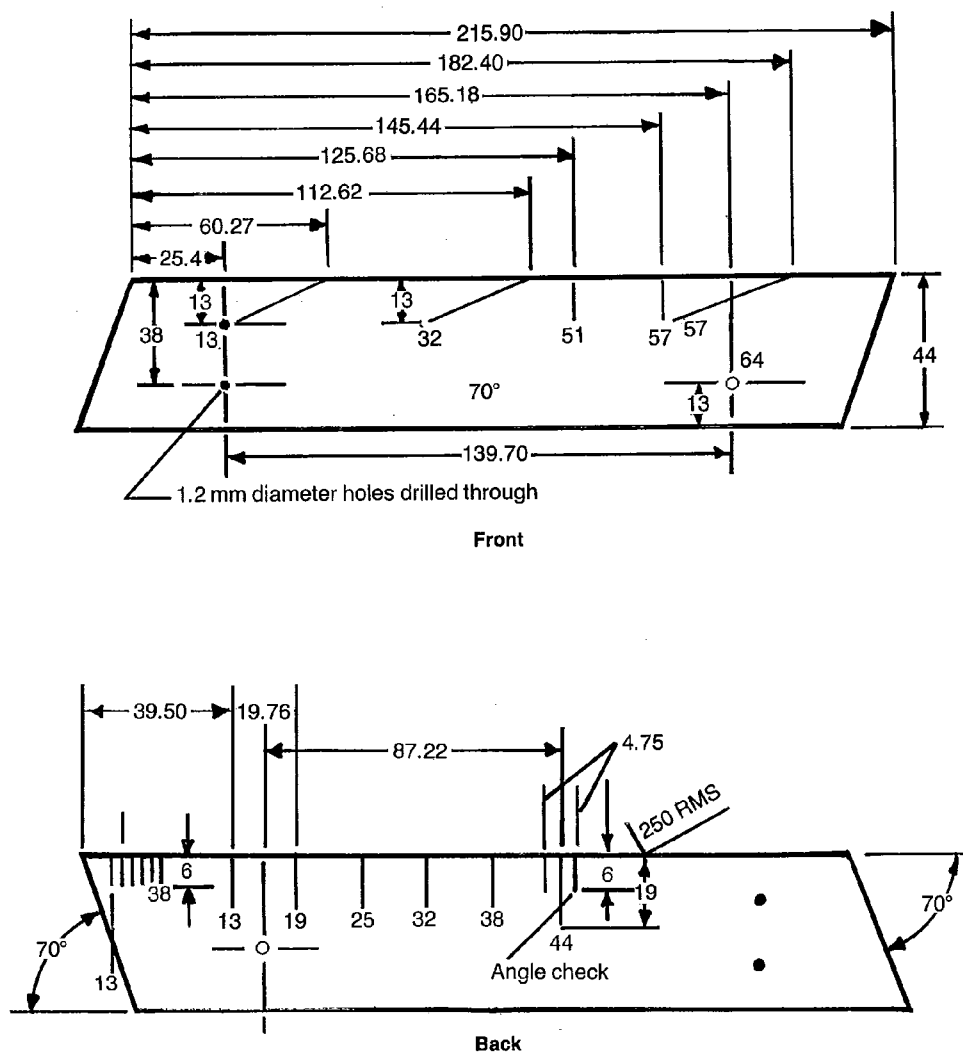
**Fig. 7.5(5) – Typical number and size permitted in any 152 mm (6 in.) length of weld –
51 mm (2 in.) weld thickness –
total pore area permitted is 77 mm² (0.120 in.²)**



All dimensions in millimeters

**Fig. 7.5(6) – Typical number and size permitted in any 152 mm (6 in.) length of weld –
102 mm (4 in.) weld thickness –
total pore area permitted is 155 mm² (0.240 in.²)**

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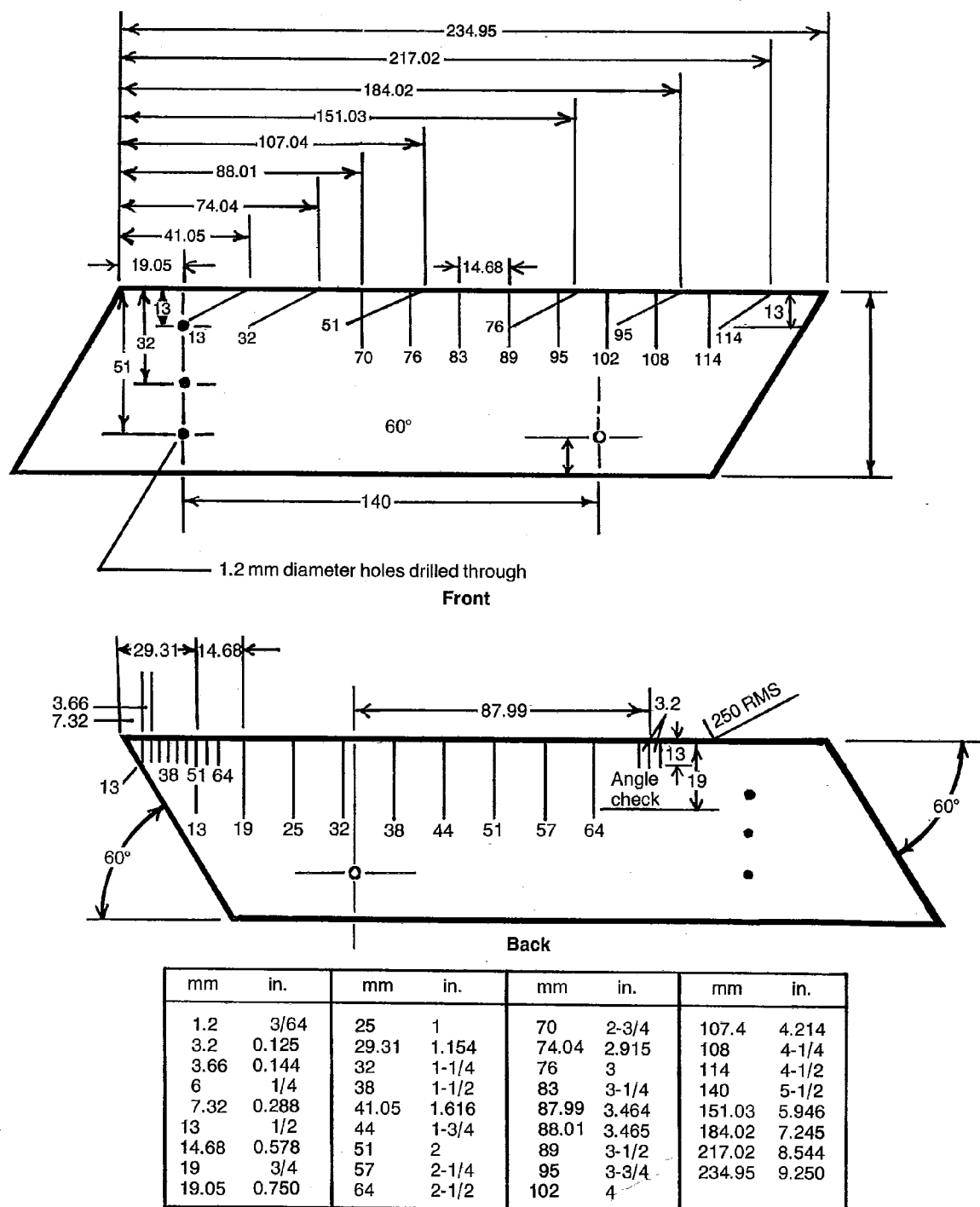
mm	in.	mm	in.	mm	in.	mm	in.
1.2	3/64	19	3/4	39.50	1.555	112.62	4.434
2.31	0.091	19.76	0.778	44	1-3/4	125.68	4.948
4.62	0.182	25	1	51	2	139.70	5.500
4.75	0.187	25.4	1.000	57	2-1/4	145.44	5.726
6	1/4	32	1-1/4	60.27	2.373	165.18	6.503
13	1/2	38	1-1/2	64	2-1/2	182.40	7.181
				87.22	3.434	215.90	8.500

All dimensions in millimeters except angles

Notes:

1. Material is same as material to be tested.
2. Thickness = 32 mm (1-1/4 in.)

Fig. 7.8.2.6.1 - 70° calibration standards



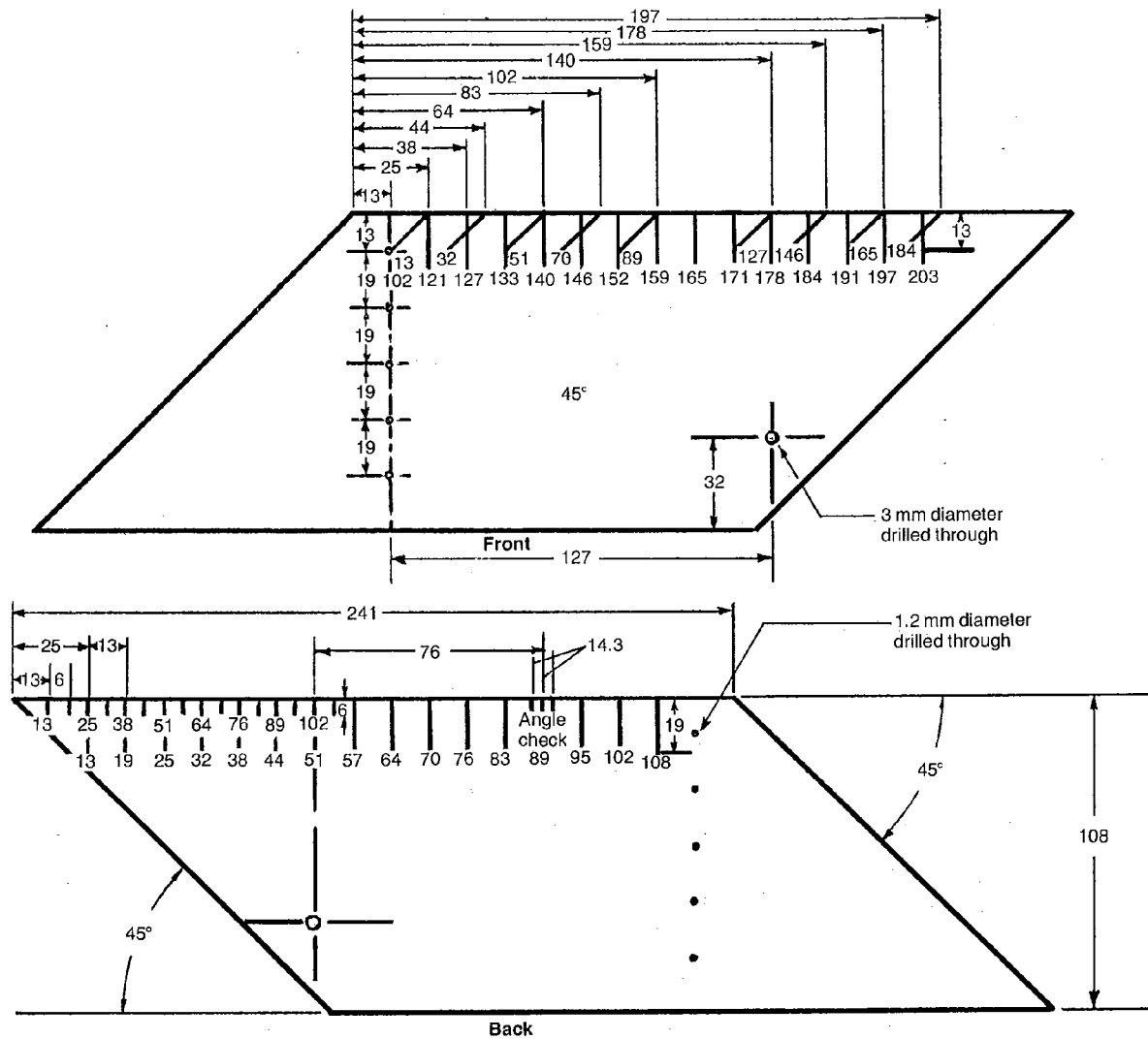
Notes:

1. Material is same as material to be tested.
2. Thickness = 32 mm (1-1/4 in.)

All dimensions in millimeters except angles

Fig. 7.8.2.6.2—60° calibration standards

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mm	in.	mm	in.	mm	in.	mm	in.
1.2	3/64	38	1-1/2	95	3-3/4	152	6
1.57	0.062	44	1-3/4	102	4	159	6-1/4
3	1/8	51	2	108	4-1/4	165	6-1/2
6	1/4	57	2-1/4	114	4-1/2	171	6-3/4
13	1/2	64	2-1/2	121	4-3/4	178	7
14.27	0.562	70	2-3/4	127	5	184	7-1/4
19	3/4	76	3	133	5-1/4	191	7-1/2
25	1	83	3-1/4	140	5-1/2	203	8
32	1-1/4	89	3-1/2	146	5-3/4	241	9-1/2

All dimensions in millimeters except angles

Notes:

1. Material is same as material to be tested.
2. Thickness = 32 mm (1-1/4 in.)

Fig. 7.8.2.6.3—45° calibration standards

7.8.2.6.3 The diagonal lines mark the positions of the transducer to detect the 1.2 mm (3/64 in.) diameter holes.

7.8.2.6.4 The 19 mm (3/4 in.) vertical lines mark the positions of the transducer when calibrating for depth.

7.8.2.6.5 The 6 mm (1/4 in.) vertical lines are used in adjusting the flaw-locating rule.

7.8.2.6.6 The angle check area marks the position of the transducer when checking the accuracy of the refracted angle produced by the plastic wedge.

7.8.3 Procedure

7.8.3.1 Equipment Calibration

7.8.3.1.1 Search unit angles shall be selected as follows:

(1) For plate thicknesses 13 mm (1/2 in.) to, but not including, 38 mm (1-1/2 in.), a wedge angle producing a 60° or 70° shear wave in the material to be tested shall be used.

(2) For plate thicknesses 38 mm (1-1/2 in.) to, but not including, 64 mm (2-1/2 in.), a wedge angle producing a 45° or 60° shear wave in the material to be tested shall be used.

(3) For plate thicknesses 64 mm (2-1/2 in.) and over, a wedge angle producing a 45° shear wave in the material to be tested shall be used.

7.8.3.1.2 Angle Check. With the transducer positioned for maximum signal response from the 3 mm (1/8 in.) diameter hole in the calibration block, the sound emission point of the transducer shall fall on or between the two lines in the angle check area.

7.8.3.1.3 Flaw-Locating Device Adjustment (if used). With the sound emission point of the transducer aligned with the 19 mm (3/4 in.) vertical line on the calibration block representing the thickness of the weld, the flaw device is adjusted so that the line on the rule representing the weld thickness is in alignment with the corresponding 6 mm (1/4 in.) line on the calibration block.

7.8.3.1.4 Depth Calibration. The instrument is calibrated for the range of depth to be inspected using the large signal from the end of the block. When the emission point marked on the transducer is aligned with one of the 19 mm (3/4 in.) vertical lines on the calibration standard, the signal will appear on the screen at the depth for which that line is marked. A "B" (for bottom) is marked on the screen at the depth equal to the weld thickness and a "T" (for top) is placed on the screen at the depth equal to twice the weld thickness. See Fig. 7.8.3.1.4 for typical screen calibration.

7.8.3.1.5 Test Sensitivity Calibration

(1) For Class I welds, the instrument gain and attenuation correction controls shall be adjusted to peak all signals from the 1.2 mm (3/64 in.) diameter holes within the range of test at a minimum of 80 percent and a maximum of 95 percent of full screen. Minor adjustments of depth calibration should be made using the peaked signals from the holes to compensate for slight variations in search unit angles. The screen shall be divided by two horizontal lines at 20 percent (the disregard level or DRL)

and 80 percent (the amplitude rejection level or ARL) or full screen.

(2) For Class II welds, the instrument gain and attenuation correction controls shall be adjusted to peak all signals from the 1.2 mm (3/64 in.) diameter holes within the range of test at a minimum of 80 percent and a maximum of 95 percent of full screen. Minor adjustments of depth calibration should be made using the peaked signals from the holes to compensate for slight variations in search unit angles. The screen shall be divided by two horizontal lines at 40 percent (the DRL) and 80 percent (the ARL) of full screen.

7.8.3.2 Surface Preparation. A scanning area on each side of the weld, wide enough to allow search of the entire weld volume and heat-affected zone, shall be prepared on each side of the weld for the test. The surface of this area shall be free of loose scale, loose paint, weld spatter, grease, dirt and any other foreign matter that might interfere with the scanning procedure. The surface must also have a finish of 6.4 μ m (250 μ in.) RMS or better and be flat enough to allow good coupling between the transducer and the scanning surface.

7.8.3.3 Test Procedure

7.8.3.3.1 Butt Welds

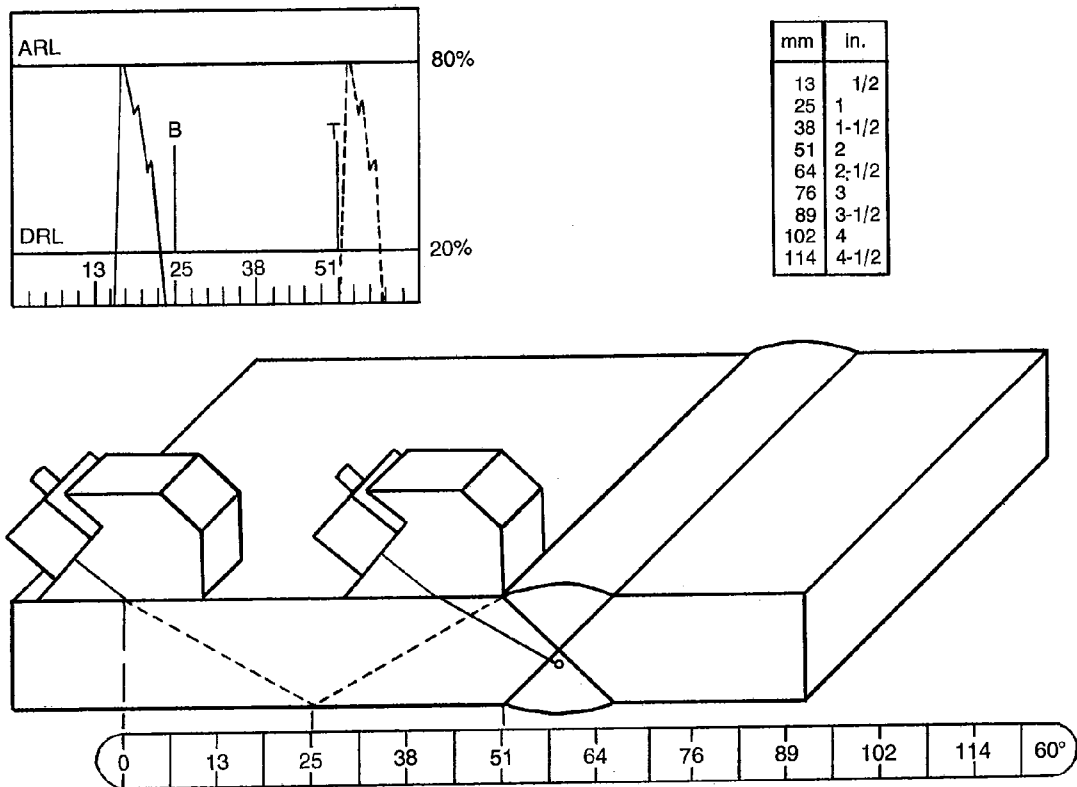
(1) The entire weld volume and heat-affected zone, excluding the weld reinforcement, shall be scanned with shear waves by directing the sound beam toward or across and along the weld axis. See Fig. 7.8.3.3.1(1).

(2) To detect longitudinal discontinuities in welds not ground flush, the search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning perpendicularly to the weld. The lateral movement advancing the search unit along the longitudinal axis of the weld shall not exceed 75 percent of the transducer width. The weld shall be scanned from one surface or effective beam width on two sides or from one side on two surfaces. See Fig. 7.8.3.3.1(2). The scanning area shall begin with the search unit touching the weld reinforcement and shall include an area wide enough to ensure that the entire weld and heat-affected zone is covered by the second half of the first skip distance.

(3) To detect transverse discontinuities in welds not ground flush, the search unit shall be placed on the base metal surface at the edge of the weld. The sound beam shall be directed by angling the search unit toward the weld at approximately 15° to the longitudinal axis of the weld. Scanning shall be performed by moving the search unit along the weld edge from both sides on one surface and from two opposing directions.

(4) To detect longitudinal discontinuities in welds ground flush, the search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning perpendicularly across the weld. The weld shall be scanned from one surface on two sides of the weld when possible. Where this procedure is impossible, the weld may be scanned from one side on two surfaces or from one side on one surface using at least

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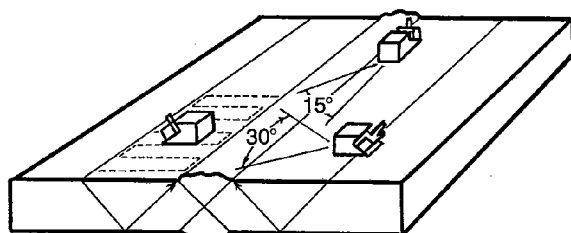


Notes:

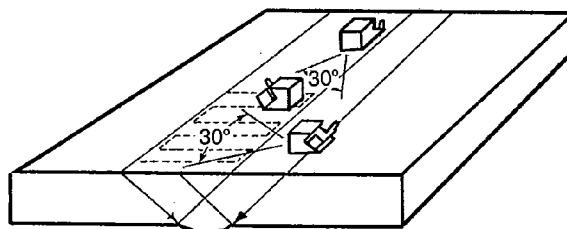
1. Weld thickness = 25 mm (1 in.).
2. Angle is 60°.
3. Depth calibration range is 13 mm to 51 mm (1/2 in. to 2 in.).

All dimensions in millimeters except angles

Fig. 7.8.3.1.4— Typical screen calibration



(A) Scanning procedure for welds not ground flush



(B) Scanning procedure for welds ground flush

Fig. 7.8.3.3.1(1) – Test procedure – butt welds

a full skip distance. See Fig. 7.8.3.3.1(4). The lateral movement advancing the search unit along the longitudinal axis of the weld shall not exceed 75 percent of the transducer width per transverse scan.

(5) To detect transverse discontinuities in welds ground flush, the search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning along the top of the weld from two opposing directions. If the weld width exceeds the width of the transducer, parallel scans shall be performed so that each scan overlaps the previous scan by at least 25 percent of the transducer width. An area wide enough to ensure coverage of the weld and heat-affected zone shall be scanned.

7.8.3.3.2 Corner Welds

(1) The entire weld and heat-affected zone, excluding the weld reinforcement, shall be scanned with shear waves by directing the sound beam toward or across and along the weld axis.

(2) To detect longitudinal discontinuities, the search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning perpendicularly to the weld. The lateral movement advancing the search unit along the longitudinal axis of the weld shall not exceed 75 percent of the transducer width per transverse scan. The weld shall be tested using the first full skip distance from surface "A" as shown in Fig. 7.8.3.3.2(2).

(3) To detect transverse discontinuities, the search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning along the top of the weld from two opposing directions. If the weld width exceeds the width of the transducer, parallel scans shall be made so that each scan overlaps the previous scan by at least 25 percent of the transducer width. An area wide enough to ensure complete coverage of the weld and heat-affected zone shall be scanned.

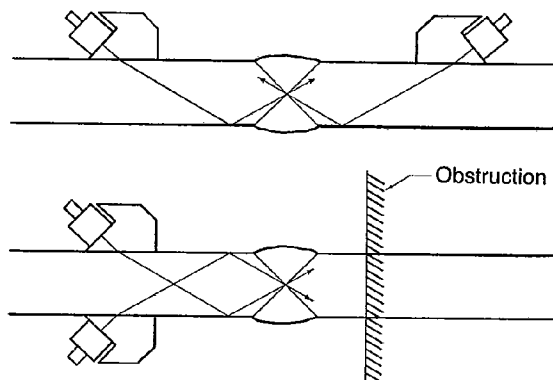


Fig. 7.8.3.3.1(2) – Method for detecting longitudinal discontinuities in butt welds not ground flush

7.8.3.3.3 T-Joint Welds. The entire weld and heat-affected zone excluding the weld reinforcement shall be scanned with shear waves. The search unit shall be oscillated to the left and right with an included angle of approximately 30° while continuously scanning perpendicularly to the weld. The lateral movement advancing the search unit along the longitudinal axis of the weld shall not exceed 75 percent of the transducer width per transverse scan. The weld shall be tested from surfaces "A" and "B" as shown in Fig. 7.8.3.3.3A, using the first full skip distance, or from surface "C" as shown in Fig. 7.8.3.3.3B, using the first half skip distance.

7.8.3.3.4 Discontinuities. If discontinuities are detected, the sound beam shall be directed to maximize the signal amplitude. If the signal amplitude equals or

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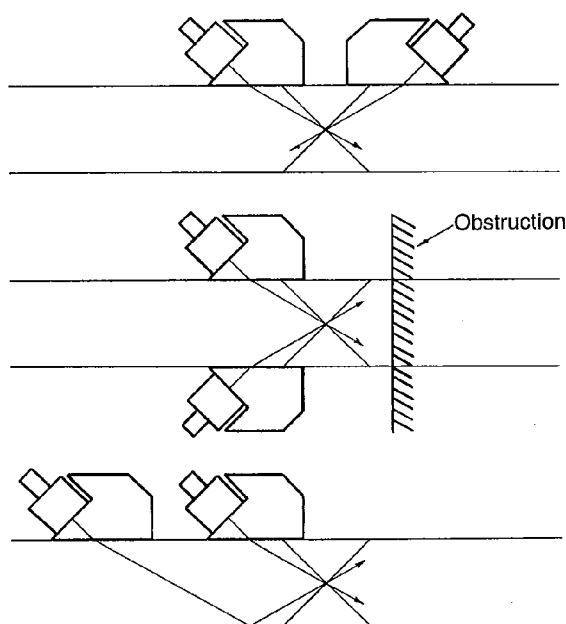


Fig. 7.8.3.3.1(4) – Method for detecting longitudinal discontinuities in butt welds ground flush

exceeds the DRL, the maximum amplitude, location, length, depth and zone location shall be determined.

(1) To determine the length of a discontinuity, the transducer shall be positioned for maximum signal response and moved parallel to the discontinuity axis until the signal drops rapidly to the base line. The transducer is then returned to the position where the indication began to drop rapidly to the base line. The plate is marked at the center of the transducer. This mark shall be defined as one extremity of the discontinuity and the procedure shall be repeated in the opposite direction to determine the other extremity.

(2) The depth of a discontinuity from the scanning surface shall be determined by the position of the signal on the viewing screen when the signal is maximized.

(3) The zone location of a discontinuity shall be determined by observing the depth of the signal on the screen and marking the weld at the corresponding depth on the flaw-locating rule.

7.8.3.3.5 Lamination Test

(1) Before the shear wave test is conducted on welds in carbon and low alloy steel plates, a compressional wave test shall be performed to determine if any laminar discontinuities are present that might interfere, unless a test for laminations has been previously conducted on the plate material.

(2) The test shall be performed using a 25 mm (1 in.) diameter 2.25 MHz compressional wave transducer.

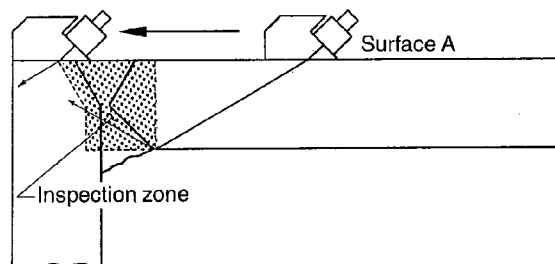


Fig. 7.8.3.3.2(2) – Method for detecting longitudinal discontinuities in corner welds not ground flush

With the first back reflection from the plate adjusted to 80 percent of full screen height, the full width of the area to be scanned by the shear wave test shall be scanned. If a discontinuity is noted that causes a complete loss or transposition of the first back reflection, the discontinuity shall be noted on the weld inspection report. The weld in the area of the discontinuity cannot be reliably tested with shear waves from the side containing the discontinuity.

7.8.3.4 Acceptance Standards

7.8.3.4.1 Class I Welds

7.8.3.4.1.1 Any discontinuity whose reflection exceeds 80 percent of full screen height shall be rejected.

7.8.3.4.1.2 Discontinuities whose reflections equal 20 percent or greater up to and including 80 percent of full screen height shall be evaluated as follows:

(1) If the discontinuity length exceeds $T/2$ (where T = thickness of the thinner member), it shall be rejected. In no case shall any single discontinuity length exceed 38 mm (1-1/2 in.).

(2) Any two discontinuities separated by less than $2L$ of sound metal (where L = length of the longest discontinuity), shall be considered a single discontinuity. The maximum distance between the outer extremities of any two such discontinuities or the sum of their lengths, whichever is greater, shall not exceed the length specified in 7.8.3.4.1.2(1).

(3) If the total accumulative lengths of discontinuities in any 305 mm (12 in.) of weld length exceeds $1T$, that weld length shall be rejected. When less than 305 mm (12 in.) of weld is inspected, the $1T$ criterion applies to that length.

7.8.3.4.2 Class II Welds

7.8.3.4.2.1 Any discontinuity whose reflection exceeds 80 percent of full screen height and whose length exceeds 6 mm (1/4 in.) shall be rejected. Adjacent discontinuities whose reflections exceed 80 percent of full screen, separated by less than $2L$ of sound metal (where L = length of longest discontinuity), shall be considered a single discontinuity.

7.8.3.4.2.2 Discontinuities whose reflections equal 40 percent of full screen height, up to and including 80 percent, shall be evaluated as follows:

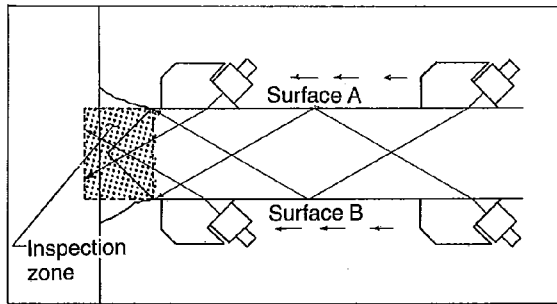


Fig. 7.8.3.3(A) – Procedure for testing T-welds

(1) If the discontinuity length exceeds $1T$ (where T = thickness of the thinner member), it shall be rejected. In no case shall any single discontinuity length exceed 51 mm (2 in.).

(2) Any two discontinuities separated by less than $2L$ of sound metal (where L = length of longest discontinuity) shall be considered as a single discontinuity. The maximum distance between the outer extremities of any two such adjacent discontinuities or the sum of their lengths, whichever is greater, shall not exceed the length specified in 7.8.3.4.2.2(1).

(3) If the cumulative length of discontinuities in any 305 mm (12 in.) of weld exceeds $2T$, that weld length shall be rejected. When less than 305 mm (12 in.) of weld is inspected, the $2T$ criterion applies to that length.

7.8.3.5 Test Results

7.8.3.5.1 Recording and Reporting Discontinuities

7.8.3.5.1.1 The location, length, depth, maximum amplitude and zone location of discontinuities having a signal amplitude that equals or exceeds the DRL shall be recorded and reported.

7.8.3.5.1.2 Indications less than the DRL shall be disregarded.

7.8.3.5.2 Record Data and Report Sheets. The ultrasonic test data and report sheets for inspection results of welds shall contain, as a minimum, the following information:

- (1) Weld identification
- (2) Location
- (3) Type of weld
- (4) Type of material
- (5) Thickness of material
- (6) Joint identification
- (7) Segment number
- (8) Length of weld inspected
- (9) Operational procedure identification
- (10) Equipment used for inspection and its record of calibration. See 7.8.3.6.5.
- (11) Reference block identification
- (12) Inspection results
- (13) Acceptance or rejection
- (14) Signature of inspection personnel
- (15) Date of test

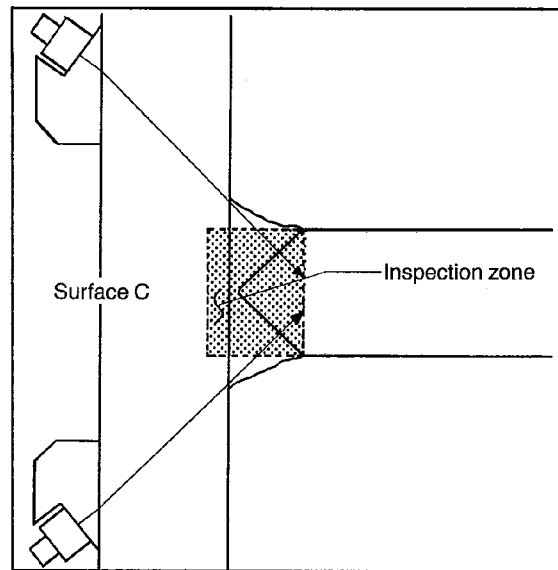


Fig. 7.8.3.3.3(B) – Method of using procedure for testing T-welds

7.8.3.6 Special Notes

7.8.3.6.1 Supplemental ultrasonic inspection techniques that contribute to the final inspection result shall be recorded, if used.

7.8.3.6.2 All repaired areas, plus an additional 76 mm (3 in.) beyond each end of repair, shall be retested as original welds and the test results shall be recorded in accordance with 7.8.3.5.1 and 7.8.3.5.2.

7.8.3.6.3 Welds requiring preheat or postweld heat treatment shall have final inspection after all postweld treatment and required cool-down or other waiting periods, as described in 7.8.3.6.4.

7.8.3.6.4 Final inspection shall not be performed less than eight hours after cool-down to ambient temperature or as required by applicable specifications.

7.8.3.6.5 The instrument shall be allowed to warm up before calibration is attempted. The equipment shall be calibrated with the reference calibration standard each time it is used and shall be recalibrated at least once every four hours during continuous use, whenever the electric power to the instrument has been interrupted or whenever the calibration of the equipment is suspected of being in error.

Part C

Magnetic Particle Inspection

7.9 General. Magnetic particle inspection of welded joints, where required, shall be conducted in accordance with the procedures specified herein, which include standards for acceptance.

The procedures and standards set forth in this section are to govern magnetic particle inspection of welds when such inspection is required by this standard. This proce-

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ture is for inspection of fillet and butt welded joints. Personnel qualification and records shall be in accordance with the American Society for Nondestructive Testing SNT-TC-1A, Recommended Practice, Supplement B, Magnetic Particle.

7.10 Extent of Inspection

7.10.1 Information furnished to the buyer shall clearly identify the extent of the magnetic particle inspection to be performed.

7.10.2 Drawings with symbols in accordance with AWS A2.4, Symbols for Welding and Nondestructive Testing, shall be used where practicable.

7.10.3 Equipment

7.10.3.1 Source of Magnetic Fields. The following magnetizing equipment shall be capable of inducing a magnetic flux of suitable intensity in the desired direction:

7.10.3.1.1 Prod Method

(1) Portable prod type electrical contacts shall be spaced 76 to 203 mm (3 to 8 in.) apart using direct current at 100 to 125 amperes per 25 mm (1 in.) of spacing.

(2) At least two separate examinations shall be carried out using the dry particle medium. Prods shall be placed so that the magnetizing flux during one examination is perpendicular to the other examination direction.

7.10.3.1.2 Coil Method

(1) Multiple coil shall be looped around the part and shall be capable of producing a magnetic field strength of 3000 to 10 000 ampere turns using direct current.

(2) At least two separate examinations shall be carried out using dry or wet particle medium. The second examination shall be with magnetic flux at right angles to the first examination or a different magnetic source may be used.

7.10.3.1.3 Yoke Method

(1) Either alternating current or permanent yokes shall be used, equivalent to a prod method of 25 to 30 amperes per 25 mm (1 in.) of prod spacing.

(2) At least two separate examinations shall be done using dry or wet particle medium. The second examination shall be with the magnetic flux at right angles to the first examination.

7.10.3.2 Examination Medium. The magnetic particles used for detection of defects shall be as follows:

7.10.3.2.1 Dry Particles. Dry particles used shall be of high permeability and low retentivity and of such size and shape as will produce suitable indications. It is desirable that the color be such as to provide adequate contrast with the background of the surface being examined.

7.10.3.2.2 Wet Particles. Wet particles used shall be red or black or, alternatively, may be fluorescent when viewed under ultraviolet illumination. The particles shall be suspended in a suitable liquid medium in the concentration recommended by the manufacturer of the particles. Amplified details on the use of wet particles are given in ASTM-E-138, Wet Magnetic Particle Inspection.

7.10.3.3 Particle Application and Removal

7.10.3.3.1 Dry Particles. Dry particles may be applied by means of mechanical shakers, bulb blowers or mechanical blowers. Excess particles shall be removed by means of a dry air current of sufficient force to remove the excess particles which are not indicative of discontinuities.

7.10.3.3.2 Wet Particles. Wet particles may be applied by means of spraying or dipping (see ASTM-E-138, Wet Magnetic Particle Inspection).

7.10.3.4 Lighting. The weld areas shall be adequately illuminated for proper evaluation of the indications revealed on the weld surface.

7.10.4 Surface Preparation

7.10.4.1 Surface Finish – Completed Surfaces. As-welded surfaces shall be considered suitable for inspection without any grinding, provided the following conditions are met:

7.10.4.1.1 There shall be no roll-over or undercutting and the deposited metal must be fused smoothly and uniformly into the plate surfaces.

7.10.4.1.2 The finished weld shall be reasonably smooth and free from irregularities, grooves or depressions.

7.10.4.2 Precleaning. The materials or parts to be examined shall be dry and free of oil or other foreign matter which might interfere with the formation or interpretation of magnetic particle patterns or indications. Oil or grease shall be removed with petroleum distillate or alcohol.

7.10.4.3 Application of Magnetic Field

7.10.4.3.1 Direction. The magnetic field shall be induced in more than one direction to insure detection of discontinuities having axes in any direction.

7.10.4.3.2 Direct Magnetization. When using direct magnetization, direct or half-wave rectified, alternating current shall be passed through the part being tested for a minimum of 1/5 second.

7.10.4.3.3 Indirect Magnetization. Indirect magnetization shall be accomplished by passing magnetizing current through an auxiliary conductor for a minimum of 1/5 second.

7.10.4.3.4 Precaution. Care shall be taken to prevent local overheating, arcing or burning the surface being inspected. The magnetizing current shall not be turned on until after prods have been properly positioned in contact with the surface and current shall be turned off before the prods are removed.

7.10.5 Acceptance Standard

7.10.5.1 Examination of welds by the magnetic particle method shall be made over an area including the weld and base metal and extending for at least 13 mm (1/2 in.) on each side of the weld.

7.10.5.2 Surfaces examined by the magnetic particle method shall be free of laps, fissures, cracks or other defects: In-line porosity which appears as a linear accumulation of magnetic powder shall also be removed.

7.10.5.3 Only such defects need be removed as to render the surface acceptable to the requirements of this standard. Areas containing defects shall be ground out to remove the defects. The ground out areas shall be reinspected to verify the complete removal of the defect. Minor cavities resulting from the removal of shallow discontinuities shall be blended into the surrounding area. They need not be repair welded if they do not reduce wall thickness or drawing requirements or affect machined or gasket fits. Other defects may be repair welded by means of the original or an approved repair welding process. Completed repairs shall be reinspected by the method originally used.

7.10.6 Defect Removal and Repair. Unacceptable imperfections shall be removed and reexamination made to assure complete removal. Whenever a defect is removed and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. Where welding is required after removal of a defect, the area shall be cleaned and welding performed in accordance with a qualified welding procedure. Completed repairs shall be reexamined by the method originally used for detection of the defect.

Part D

Liquid Penetrant Inspection

7.11 General. Liquid penetrant inspection of welded joints, where required, shall be conducted in accordance with the procedures specified herein, which include standards for acceptance.

The procedures and standards set forth in this section govern liquid penetrant inspection of welds when such inspection is required by this standard. This procedure is for inspection of fillet and butt weld joints using visible or fluorescent methods. Personnel qualification and records shall be in accordance with the American Society for Nondestructive Testing SNT-TC-1A, Recommended Practice, Supplement D, Liquid Penetrant.

7.12 Extent of Inspection

7.12.1 Information furnished to the buyer shall clearly identify the extent of the liquid penetrant inspection to be performed.

7.12.2 Drawings with symbols in accordance with AWS A2.4, Symbols for Welding and Nondestructive Testing, shall be used where practicable.

7.13 Equipment

7.13.1 Penetrant Equipment. Aerosol cans, air or CO₂ powdered spray guns, paint brushes, spraying or dipping may be used to apply the liquids.

7.13.2 Drying Equipment. Paper towels, lint-free cloths, or vacuum equipment may be used for drying.

7.13.3 Lighting. The test area shall be adequately illuminated for proper evaluation of the visual indications revealed on the test surface.

7.13.4 Fluorescent Penetrants. A darkened area for black light use is necessary. The black light intensity should be 970 to 1100 lx (90 to 100 foot candles) in 3650 Angstrom wave length band.

7.14 Procedure

7.14.1 Temperature. The temperature of the penetrant on the part to be inspected shall be 4 to 52° C (40 to 125° F) before application of the penetrant. When inspection is necessary under conditions where the temperature of the penetrant and the inspection surface is outside the 4 to 52° C (40 to 125° F) range, the temperatures shall be adjusted to bring them within this range.

7.14.2 Surface Finish — Completed Surfaces. As-welded surfaces shall be considered suitable for inspection without any grinding, provided the following conditions are met:

7.14.2.1 There shall be no roll-over or undercutting, valleys or grooves along the axis of, or within, the weld.

7.14.2.2 The deposited metal must be fused smoothly and uniformly into the plate surfaces.

7.14.2.3 The finished weld shall be reasonably smooth and free from irregularities, grooves or depressions.

7.14.3 Precleaning

7.14.3.1 Rust, scale, slag, weld pimples or other hard tenacious materials shall be removed by wire brushing, grinding or machining.

7.14.3.2 All types of grinding wheels are permitted on carbon steel. All other materials shall be ground with rubber or resin-bonded aluminum oxide or silicon carbide wheels.

7.14.3.3 All oil and grease shall be removed with petroleum distillate or alcohol using paper towels or lint-free cloth.

7.14.4 Application of Penetrant. The surface shall be thoroughly dry before application of the liquid penetrant. The penetrant may be applied by spraying, brushing or immersion. The area to be inspected shall be completely covered. The surface shall be kept wet for a minimum of six minutes and during this period additional penetrant should be added, if necessary, to prevent drying. Precautions should be taken to prevent inspection materials from entering inaccessible areas. It is permissible to remove excess penetrant prior to application of the emulsifier by wiping with paper towels or lint-free cloth.

7.14.5 Application of Remover. The remover shall be applied by spraying, immersing or brushing.

7.14.6 Removal of Excess Penetrant

7.14.6.1 Wet Removal (Water Washable). After an emulsification time to exceed two minutes, the penetrant-emulsified film shall be removed by a water

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spray. The water pressure shall not exceed 345 kPa (50 psi) and the water temperature shall not be less than 4° C (40° F) or more than 43° C (110° F). The spray shall be applied at a distance of 250 to 381 mm (10 to 15 in.) from the surface. Washing should be continued until all traces of surface penetrant have disappeared. Where restricted areas prevent the use of a water spray, the penetrant-emulsified film may be removed by repeated applications of dry or water-soaked paper towels or lint-free cloths.

7.14.6.2 Dry Removal (Solvent)

7.14.6.2.1 As much penetrant as possible shall be removed by first wiping the surface thoroughly with a clean dry cloth or absorbent paper.

7.14.6.2.2 The remaining excess penetrant shall be removed by wiping the surface with a clean cloth or absorbent paper dampened with remover. Flushing of the surface with any liquid, following application of the penetrant and prior to developing, is prohibited.

7.14.6.3 Postemulsifying Removal. With post-emulsifying penetrants, an additional step is required. This step is the application of a liquid emulsifier prior to the rinsing operation. The emulsifier may be applied by brushing, spraying or dipping. Emulsifying times of ten seconds to five minutes can be used, depending upon prevailing conditions, such as surface roughness, or the type of defect sought. The emulsifying time is critical. Once the emulsifying time has been set for a particular test, it should not vary more than ± 10 percent. After emulsification, the mixture is removed by a water spray, using the same procedure as for water-washable liquid penetrants.

7.14.7 Application of Developer

7.14.7.1 Dry. After the surface has been thoroughly dried, the developer shall be applied by dipping, spraying or brushing. Application of the developer by spraying is preferable. The surface shall be completely covered with developer. It is suggested that the aerosol can or sprayer be held 250 mm (10 in.) from the work and be applied in short dusting strokes. The application of excessive developer should be avoided, such as pools in cavities, since it is possible for a thick coating of developer to mask indications.

7.14.7.2 Liquid. The liquid developer is a suspension of powder in water or a volatile solvent. It is applied by dipping, spraying or brushing. In any case, a film of powder is left on the surface when the developer dries. Where a water suspension developer is used, drying time may be decreased by the use of warm air.

7.14.8 Examination. Visual examination of the surface being inspected shall be made after a minimum of seven minutes and a maximum of thirty minutes after developer has dried. Interpretation and acceptance shall be made according to 7.15.

7.14.9 Final Cleaning. When the inspection is concluded, the penetrant materials shall be removed as soon as possible by means of brushing or wiping with paper towels or lint-free cloth.

7.15 Acceptance Standards. All surfaces examined shall

be free of linear defects (cracks, laps, fissures, etc.). These surfaces may have four or fewer, but not more, rounded imperfections in a line, edge to edge, separated by 1.5 mm (1/16 in.) except where the specification for the material establishes different requirements for acceptance so far as defects are concerned.

7.15.1 Linear indications are those indications in which the length is more than twice the width.

7.15.2 Rounded indications are indications which are circular or elliptical with the length less than twice the width.

7.16 Defect Removal and Repair. Unacceptable imperfections shall be removed and reexamination made to assure complete removal. Whenever a defect is removed and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. Where welding is required after removal of a defect, the area shall be cleaned and welding performed in accordance with a qualified welding procedure. Completed repairs shall be reexamined by the method originally used for detection of the defect.

Part E**Visual and Dimensional Inspection**

7.17 General. Standards for visual and dimensional inspection of welded joints are included in this section.

7.17.1 Visual and Dimensional Defects. Weldment discontinuities and defects subject to visual examination and dimensional inspection are defined as follows:

7.17.1.1 Structural Discontinuities in Welds

- (1) Cracks
- (2) Undercut
- (3) Inadequate joint penetration
- (4) Surface holes
- (5) Weld bead irregularities

7.17.1.2 Dimensions Defects

- (1) Incorrect joint preparation
- (2) Incorrect weld size
- (3) Incorrect weld profile
- (4) Incorrect final dimensions

7.17.2 Extent of Inspection Required

7.17.2.1 All welds conforming to Class I through Class VI of this standard shall be visually inspected in their entirety for structural discontinuities given in 7.17.1.1.

7.17.2.2 All weldments containing Class I through Class IV welds shall be visually inspected in their entirety for dimensional defects given in 7.17.1.2.

7.17.2.3 Visual inspection for cracks in welds and base metal and other defects should be aided by a strong light, magnifiers or other such devices as may be found helpful.

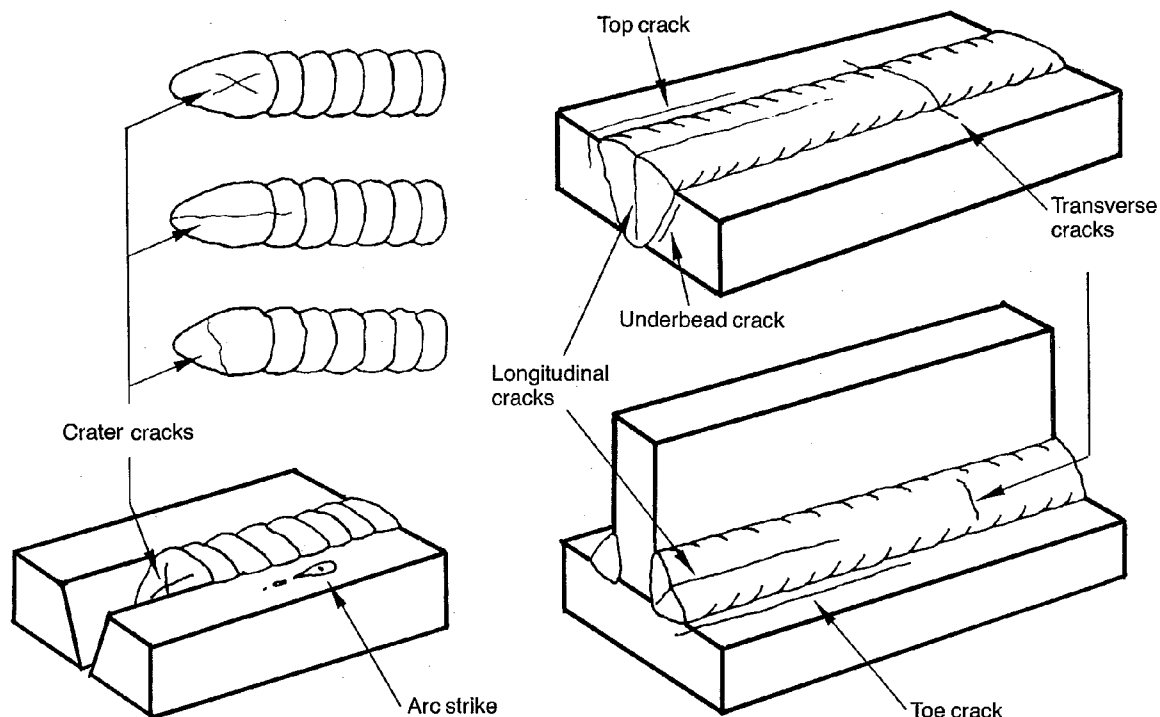


Fig. 7.17.3.1.3—Cracks in welded joints

7.17.3 Definition of Structural Discontinuities

7.17.3.1 Cracks

7.17.3.1.1 Weld metal cracks subject to visual inspection include longitudinal and transverse cracks and crater cracks.

7.17.3.1.2 Base metal cracks subject to visual inspection include toe cracks adjacent to weld edges and transverse cracks extending from the weld metal into the base metal. Subsurface (underbead) cracks are not revealed by visual inspection.

7.17.3.1.3 Weld metal and base metal cracks subject to visual inspection are illustrated in Fig. 7.17.3.1.3.

7.17.3.2 Undercut. Undercut associated with T-, corner- and lap-joint fillet welds and butt welded joints is illustrated in Fig. 7.17.3.2.

7.17.3.3 Inadequate Joint Penetration. Inadequate joint penetration subject to visual inspection includes areas of less than complete penetration at the root of butt, T- and corner welds made from one side only, without the use of permanent backing material.

7.17.3.4 Surface Holes. Surface holes subject to visual inspection include piping porosity, gas pockets, pockmarks or other similar generally globular type voids on the surface of welds.

7.17.3.5 Weld Bead Irregularities

7.17.3.5.1 Weld bead irregularities and conditions of poor appearance subject to visual inspection include variations in surface layer width, variations in height of weld reinforcement, nonuniformity of weld ripple and excessive weld metal spatter.

7.17.3.5.2 Mechanical conditioning of weld surfaces by machining, grinding, etc. to reduce stress concentrations and improve fatigue properties shall be required for Class I and Class II welds subject to dynamic loading. Weld ripples and irregularities shall be removed to produce a smooth, uniform weld profile blending with the base metal without notches, depressions or sharp edges.

7.17.4 Allowable Structural Discontinuities. All welds conforming to Class I through Class VI of this standard shall meet the visual inspection requirements of Table 7.17.4.

7.17.5 Definition of Dimensional Defects

7.17.5.1 Incorrect Joint Preparation

7.17.5.1.1 Incorrect joint preparation subject to visual inspection, generally before welding is started, includes out-of-tolerance welding level or groove dimensions, base metal misalignment and undesirable weld joint

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fit-up conditions. In the absence of the specific weld joint preparation tolerances, any condition of the joint preparation which can reasonably be expected to produce unacceptable structural discontinuities shall be considered incorrect joint preparation.

7.17.5.1.2 Included in the requirements for weld joint preparation shall be inspection for removal of scale, paint, oil, etc. from the weld joint to assure the quality level of the class of weld to be made.

7.17.5.2 Incorrect Weld Size

7.17.5.2.1 Incorrect weld size subject to visual inspection includes undersized fillet weld leg dimensions and insufficient butt weld throat dimension as defined in Fig. 7.17.3.2. Fillet weld size shall be determined by means of a fillet weld gage.

7.17.5.2.2 Partial penetration on weld joint preparations shall be visually inspected prior to welding to assure proper weld throat dimension.

7.17.5.3 Incorrect Weld Profile

7.17.5.3.1 Incorrect fillet weld profiles include conditions of insufficient throat, excessive convexity, excessive undercut, overlap and insufficient leg size as defined in Figs. 7.17.3.2(A) through (D).

7.17.5.3.2 Incorrect butt weld profiles include conditions of insufficient throat, excessive convexity, excessive undercut and overlap as defined in Figs. 7.17.3.2(E) and (F).

7.17.5.4 Incorrect Final Dimensions

7.17.5.4.1 Incorrect final dimensions subject to visual inspection include all conditions of dimensional inaccuracies, distortion and lack of conformity to drawing requirements.

7.17.5.4.2 Acceptability of specific dimensional conditions of the completed weldment depends upon appearance requirements and the accuracies required for subsequent machining, assembly, installation or end use of the product.

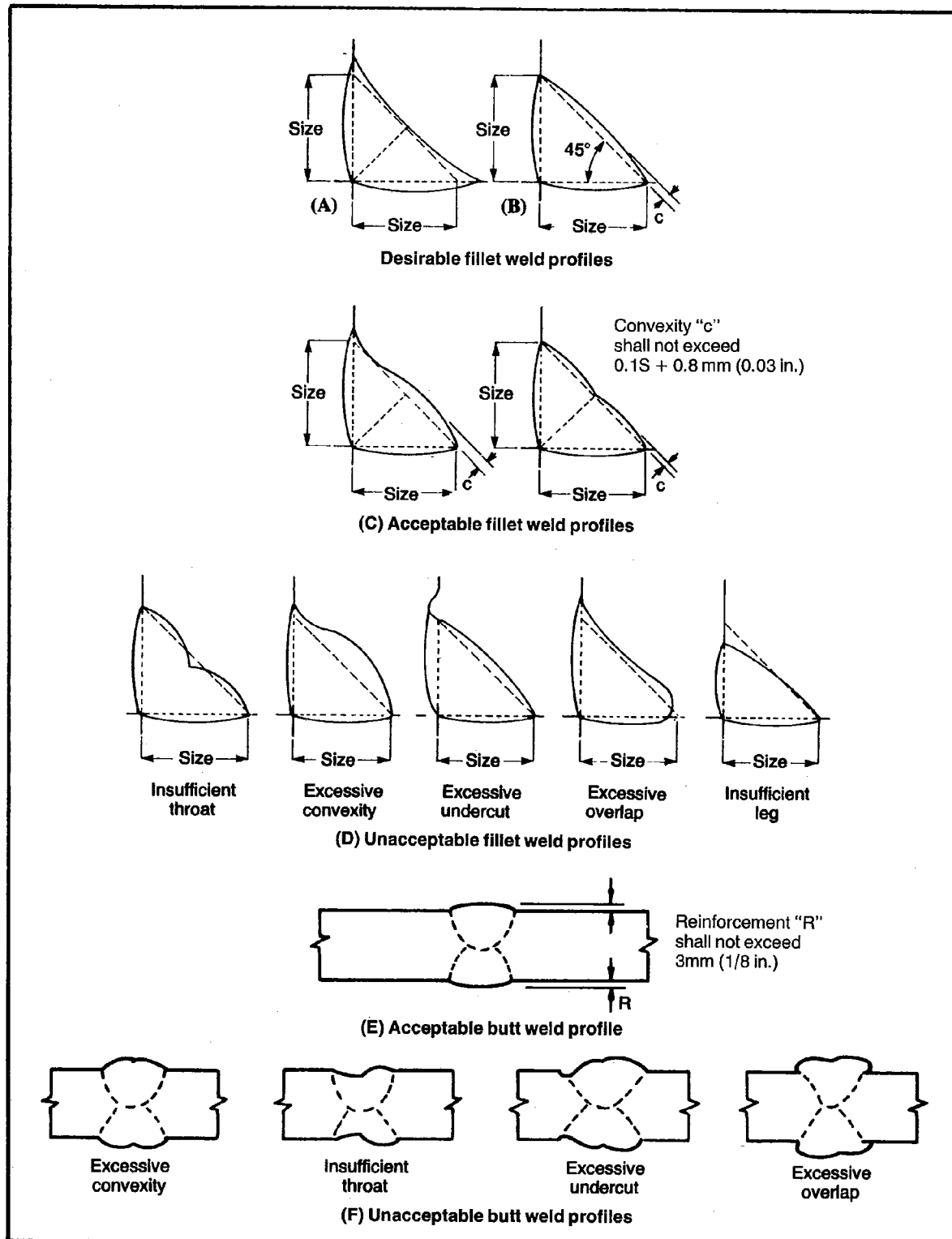


Fig. 7.17.3.2— Acceptable and unacceptable weld profiles

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Table 7.17.4 – Allowable structural discontinuities

Class of weld quality	Extent of visual weld defects allowed				
	Cracks	Undercut	Inadequate joint penetration	Surface holes	Weld bead irregularities
Class I	None	Visually free from undercut in direction transverse to primary stress. 0.25 mm (0.01 in.) maximum depth smoothly contoured undercut parallel to direction of primary stress.	Visually free from all evidence of inadequate joint penetration or other types of fusion defects at root of weld.	Sum of 0.8 mm (1/32 in.) maximum diameter scattered or randomly distributed surface holes not to exceed 3 mm per 645 mm ² (1/8 in. per sq. in.) or 6 mm per 305 mm length (1/4 in. per 12 in. length). Linear orientation of holes not allowed.	Surface of weld to be ground or machined to produce smooth, uniform profile blending with base metal without notches, depressions or sharp edges.
Class II	None				
Class III	None	Undercut 0.25 mm (0.01 in.) maximum depth when direction transverse to primary stress. 0.8 mm (1/32 in.) maximum depth when direction parallel to primary stress.	1/3 T or 13 mm (1/2 in.) maximum length inadequate penetration. Sum of all defects not to exceed 25 mm (1 in.) in 305 mm (12 in.).	Sum of 1.5 mm (1/16 in.) maximum diameter surface holes not to exceed 6 mm per 645 mm ² (1/4 in. per sq. in.) or 13 mm (1/2 in.) per 305 mm length.	Rough, irregular welds and excess reinforcement to be ground smooth.
Class IV	None		2/3 T or 19 mm (3/4 in.) maximum length inadequate penetration. Sum of all defects not to exceed 25 mm (1 in.) in 152 mm (6 in.).	Sum of 2 mm (3/32 in.) maximum diameter surface holes not to exceed 10 mm per 645 mm ² (3/8 in. per sq. in.) or 19 mm in 305 mm length (3/4 in. in 12 in. length).	X
Class V	None	Undercut 0.8 mm (1/32 in.) maximum depth when direction transverse to primary stress. 1/4 T or 1.5 mm (1/16 in.) maximum depth when direction parallel to primary stress.	T or 25 mm (1 in.) maximum length inadequate penetration. Sum of all defects not to exceed 25 mm (1 in.) in 152 mm (6 in.).	X	X
Class VI	None		X	X	X