SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS-STD-1595A

Issued 1998-03
Cancelled SEP 2002
Superseded by AWS D17.1
Superseding AMS-STD-1595

Qualification of Aircraft, Missile and Aerospace Fusion Welders

CANCELLATION NOTICE

This specification has been "CANCELLED" by the Aerospace Materials Division, SAE, as of September, 2002, and has been superseded by AWS D17.1, Specification for Fusion Welding for Aerospace Applications. The requirements of the latest issue of AWS D17.1 shall be fulfilled whenever reference is made to the cancelled AMS-STD-1595. By this action, this document will remain listed in the Numerical Section of the Index of Aerospace Material Specifications, noting that it is superseded by AWS D17.1.

Cancelled specifications are available from SAE. Copies of AWS D17.1 are available from AWS, 550 NW LeJeune Road, Miami, FL 33126, or URL www.aws.org.

TO PLACE A DOCUMENT ORDER:
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NOTICE

This document has been taken directly from U.S. Military Specification MIL-STD-1595A and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace MIL-STD-1595A. Any part numbers established by the original specification remain unchanged.

The original Military Specification was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Any material relating to qualified product lists has not been adopted by SAE. This material was part of the original military specification and is reprinted here for historic reference only.

CONTENTS

CONTENTS - continued

CONTENTS - continued

CONTENTS - continued

TABLES

CONTENTS - continued

FIGURES

1. SCOPE:

1.1 Purpose:

This standard establishes the procedure for qualification of welders and welding operators engaged in the welding of aircraft, missiles, other aerospace equipment, and their parts and accessories by fusion welding processes. This standard is applicable to aircraft, missile, and aerospace ground support equipment or other welding, when included in the contracting documents or when invoked in the absence of a specified welder qualification document.

1.2 Welder and welding operator assignments:

1.2.1 Welder: Welders may weld all joints by manual and semi-automatic welding for which they are qualified by producing acceptable test welds, as defined in Sections 4 and 5. In addition, welders may weld all joints by machine and automatic welding within the same limitations as for the acquired welder qualification.

1.2.2 Welding operator: Welding operators may weld all joints by machine and automatic welding for which they are qualified by producing acceptable test welds, as defined in Sections 4 and 5.

2. APPLICABLE DOCUMENTS:

The following publications, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification
MIL-STD-453 Inspection, Radiographic

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

ASTM DS-56 Unified Numbering System for Metals and Alloys (Same as SAE HS1086)

2.3 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS1086 Unified Numbering System for Metals and Alloys (Same as ASTM DS-56)

2.4 AWS Publications:

Available from American Welding Society, 550 N.W. LaJeune Road, Miami, FL 33126.

AWS A3.0	Welding Terms and Definitions
AWS B3.0	Welding Procedure and Performance Qualification
AWS D1.1	Structural Welding Code
AWS D10.9	Qualification of Welding Procedures and Welders for Piping and Tubing

3. DEFINITIONS:

3.1 Welding terminology:

The welding terminology of "Welding Terms and Definitions" AWS A3.0, shall be used in the interpretation of this standard. Some of these items and additional terms are defined below.

3.1.1 As-welded: The condition of weld metal, welded joints, and weldments after welding but prior to any subsequent thermal, mechanical, or chemical treatments.

3.1.2 Automatic welding: Welding with equipment which performs the welding operation without adjustment of the controls of a welding operator. The equipment may or may not perform the loading and unloading of the work.

3.1.3 Backing: A material (base metal, weld metal, carbon, or granular material) placed at the root of a weld joint for the purpose of supporting molten weld metal.

3.1.4 Base metal: The metal to be welded, soldered, or cut.

3.1.5 Blank: Part of a test weld removed for the preparation of a bend test specimen or a metallographic specimen.

3.1.6 Butt joint: A joint between two members aligned approximately in the same plane.

3.1.7 Complete fusion: Fusion that has occurred over the entire base metal surfaces intended for welding and between all layers and weld beads.

3.1.8 Complete joint penetration: Joint penetration in which the weld metal completely fills the groove and is fused to the base metal throughout its total thickness.

3.1.9 Defect: A discontinuity or discontinuities which by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designated rejectability.

3.1.10 Depth of fusion: The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

3.1.11 Discontinuity: An interruption of the typical structure of a weldment, such as a lack of homogeneity in the mechanical, metallurgical, or physical characteristics of the material or weldment. A

discontinuity is not necessarily a defect.

3.1.12 Filler metal: The metal to be added in making a welded, brazed, or soldered joint.

3.1.13 Fusion zone: The areas of base metal melted as determined on the cross section of a weld.

3.1.14 Heat-affected zone: That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or cutting.

3.1.15 Joint: The junction of members or the edges of members which are to be joined or have been joined.

3.1.16 Machine welding: Welding with equipment which performs the welding operation under the constant observation and control of a welding operator. The equipment may or may not perform the loading and unloading of the work.

3.1.17 Manual welding: A welding operation performed and controlled completely by hand.

3.1.18 Semiautomatic arc welding: Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

3.1.19 Test weld: A joint made by a welder for purposes of welder qualification.

3.1.20 Welder: One who performs a manual or semiautomatic welding operation.

3.1.21 Welder certification: Certification in writing that a welder has produced welds meeting prescribed standards.

3.1.22 Welding machine: Equipment used to perform the welding operation. For example, spot welding machine, arc welding machine, seam welding machine, etc.

3.1.23 Welding operator: One who operates machine or automatic welding equipment.

3.2 Symbols and terms:

a. Sheet refers to both sheet and plate, where appropriate.

b. Tube refers to both tube and pipe, where appropriate.

c. The lower case letter, t, indicates base metal thickness for either sheet or tube wall.

d. Mathematical symbols used before numbers mean:

< less than
> more than
≤ equal to or less than
≥ equal to or more than.

4. GENERAL REQUIREMENTS:

4.1 Qualification requirements:

To achieve qualified status, welders and welding operators shall demonstrate their skill by producing acceptable test welds in accordance with 4.1.1. No test welds are required for those welds which will not be required in production welding.

4.1.1 Welders: The correlation between test welds and production welds shall be based on the following factors.

a. Welding process (see 5.1).
b. Base metal composition (see 5.2).
c. Base metal thickness (see 5.3).
d. Welding position (see 5.4).
e. Base metal form, sheet or tube (see 5.5).
f. Type of weld, groove or fillet (see 5.5).
g. Other welding conditions (see 5.6).

4.1.2 Welding operators: The correlation between test welds and production welds shall be based on only the first three factors given in 4.1.1.

4.2. Minimum requirements:

The requirements of this standard are minimum. Other requirements may be added by the contractor, but may not be substituted for the requirements of this standard.

4.3 Physical requirements:

The contractor shall establish reasonable and appropriate physical requirements for welders and welding operators. It will be accepted that those whose corrected vision in each eye for long distance is better than 20/30 and for 16 inches distance permits reading of Joeger No. 2 type will ordinarily satisfy vision needs for welding.

4.4 Identification:

The contractor shall assign a unique number or other identification to each welder or welding operator upon qualification.

4.5 Test records:

The contractor shall complete a test record containing the essential information required as evidence of the welder or welding operator qualification. These records shall be retained for the period of time specified in the contract or, if no retention time is specified, the period of record retention shall be for the duration of qualification.

4.5.1 Test record forms: Suggested test record forms are given in Figure 1 and in the following documents.

a. Structural Welding Code, AWS D1.1
b. Qualification of Welding Procedures and Welders for Piping and Tubing, AWS D10.9.

4.6 Requalification: A welder or welding operator shall be requalified every five years to the same requirements as an original qualification. Requalification is also required when either of the following two conditions are present.

4.6.1 A welder or welding operator has not welded with a given welding process for a period of three months; except that this period shall be extended to six months if the welder has welded with another process of Table I.

4.6.2 There is a specific reason to question the ability of a welder or welding operator to meet the requirements for qualification in a given welding process.

4.7 Alternate requalification: As an alternate to the requirements of 4.6.1, requalification to the same requirements as an original qualification may be accomplished at two year intervals, in lieu of the three month and six month restrictions.

5. DETAILED REQUIREMENTS:

5.1 Welding process: For welders and welding operators, a test weld made with a given welding process of Table I qualifies only that welding process. This standard does not apply to welding processes not included in Table I.

5.2 Base metals: For welders and welding operators, a test weld made in a base metal included in one of the ten base metal groups of Table II qualifies only that base metal group, except as modified by 5.2.1 and 5.2.2 and as illustrated in Table III. The specific base metals included in each of the base metal groups of Table II, are given in the Appendix of this standard. Since the base metal groups are intended only for the purpose of qualification, some of the base metal groups contain base metals whose composition does not conform to the nominal description of the base metal group.

QUALIFICATION TEST RECORD

Name_____ Id._____ SS No._____

Joint welding procedure_____ Welder [ ] Welding operator [ ]

TEST WELD

Base metal description_____ Group No._____

Welding process_____ Single weld [ ] Double weld [ ]

Current AC [ ] DC [ ] Backing Yes [ ] No [ ]

Vertical Down [ ] Up [ ] Penetration Complete [ ] Partial [ ]

	Position				Dimension, inch	
Sheet groove	1G [ ]	2G [ ]	3G [ ]	4G [ ]		t_____
Tube groove	1G [ ]	2G [ ]	5G [ ]		O. D._____	t_____
Sheet fillet	1F [ ]	2F [ ]	3F [ ]	4F [ ]		t_____
Tube fillet	1F [ ]	2F [ ]	4F [ ]	5F [ ]	O. D._____	t_____

TEST RESULTS

Visual		Pass [ ]	Fail [ ]
Radiographic	NA [ ]	Pass [ ]	Fail [ ]
Bend	NA [ ]	Pass [ ]	Fail [ ]
Metallographic	NA [ ]	Pass [ ]	Fail [ ]

QUALIFIED

Base Metal Group No._____ Single weld [ ] Double weld [ ]

Current AC [ ] DC [ ] Backing With [ ] Without [ ]

Vertical Down [ ] Up [ ] Penetration Complete [ ] Partial [ ]

	Position				t, inch		O. D., inch	
					Min.	Max.	Min.	Max.
Sheet groove	1G [ ]	2G [ ]	3G [ ]	4G [ ]				
Tube groove	1G [ ]	2G [ ]	5G [ ]					
Sheet fillet	1F [ ]	2F [ ]	3F [ ]	4F [ ]				
Tube fillet	1F [ ]	2F [ ]	4F [ ]	5F [ ]				

The above named individual is qualified in accordance with MIL-STD-1595A within the above limits for the welding process used for this test weld.

Date of test weld_____ Signed by_____

Qualifier

FIGURE 1. Suggested test record form.

TABLE I. Fusion welding processes.

Oxyfuel welding (OFW)
Shielded metal arc welding (SMAW)
Submerged arc welding (SAW)
Gas tungsten arc welding (GTAW)
Gas metal arc welding (GMAW)
Flux cored arc welding (FCAW)
Plasma arc welding (PAW)
Electron beam welding (EBW)

TABLE II. Base metal groups.

Group	Nominal description
Ia	Carbon and low alloy steels
Ib	Alloy steels
IIa	Stainless steels
IIb	Precipitation hardening stainless steels
IIIa	Nickel and nickel-base alloys
IIIb	Precipitation hardening nickel-base alloys
IV	Aluminum and aluminum-base alloys
V	Magnesium-base alloys
VI	Titanium and titanium-base alloys
VII	Cobalt-base alloys

5.2.1 Qualification in a base metal group with a “b” designator also qualifies for base metal numbers with the same roman numeral designator and an “a” designator. See Table III.

TABLE III. Base metal groups qualified by test weld.

Test weld	Qualified
Ia	Ia
Ib	Ia, Ib
IIa	IIa
IIb	IIa, IIb
IIIa	IIIa
IIIb	IIIa, IIIb
IV	IV
V	V
VI	VI
VII	VII

5.2.2 For welders and welding operators, a separate qualification is required for each base metal not included in the Appendix, except as modified in 5.2.2.1.

5.2.2.1 Exception: A base metal not included in the Appendix, with welding characteristics similar to a given base metal group of the Appendix, may be qualified with any base metal of the given base metal group. The preparing activity shall be notified by the organization qualifying a welder or welding operator under the provisions of this paragraph, with DD Form 1426 or a letter, of the two base metals involved and the chemical composition of the base metal not included in the Appendix.

5.3 Base metal thickness: The qualification limits, with regard to base metal thickness (sheet thickness or tube wall thickness), are given below for welders and welding operators. These limits apply to both groove welds and fillet welds.

5.3.1 A test weld with a base metal thickness of t shall qualify welds with a thickness range of 0.67t to 4t; except that, when the test weld thickness is equal to or greater than 1 inch, the qualification range is 0.67t to unlimited.

5.3.2 Two test welds, each with members of equal thickness, shall qualify welds with all intermediate thicknesses, in addition to the thickness qualifications of 5.3.1.

5.4 Welding position:

5.4.1 Welders: The welding positions qualified by a given test weld position, to be found at the left of Table IV, are denoted by an X in the table. The welding positions are illustrated in Figures 2 through 5.

5.4.2 Welding operators: A test weld made in any welding position qualifies for all welding positions.

5.5 Base metal form and weld type:

5.5.1 Welders: The base metal forms and weld types qualified by a given test weld, to be found at the left of Table IV, are denoted by an X in the table, with the exceptions given below.

5.5.1.1 Qualification for fillet welds in base metal equal to or less than 0.063 inch in thickness requires a fillet test weld. Groove test welds do not qualify for fillet welds in this thickness range.

5.5.1.2 A tube test weld shall qualify only for tubes of an outside diameter equal to or greater than the outside diameter of the test weld.

5.5.2 Welding operators: A test weld of any base metal form and of any weld type shall qualify for all base metal forms and all weld types. A tube test weld of any outside diameter shall qualify for tubes of any outside diameter.

5.6 Other welding conditions: In addition to the welding process, base metal composition, base metal thickness, welding position, base metal form and type of weld; other welding conditions which require a correlation between the test weld and the production welds are given in Table V.

5.6.1 Welders: The welding conditions qualified by the given test weld conditions, to be found at the left of Table V, are denoted by an X in the table. The current type restrictions apply only to the GTAW process. For all other processes, a test weld made with either ac or dc current qualifies for welds made with either current type.

5.6.2 Welding operators: The welding condition restrictions of Table V do not apply to the qualification of welding operators.

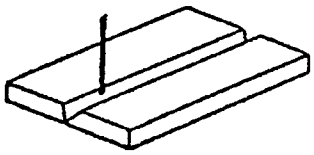
5.7 Test welds: One test weld shall be required for each combination of welding conditions, given in 4.1.1 and 4.1.2, being qualified. Test welds shall be made in accordance with a written joint welding procedure.

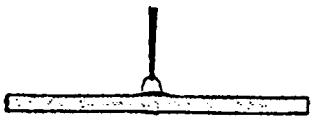
5.7.1 Groove test weld in sheet: The test weld is a butt joint in sheet as described in Figure 6.

TABLE IV. Welding position, base metal form, and weld type qualified by test weld

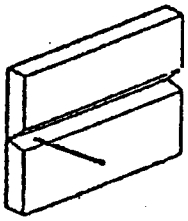
Test Weld			Qualified position			
			Sheet		Tube	
			Groove	Fillet 1/	Groove	Fillet 1/
Form	Weld type	Position	1G 2G 3G 4G	1F 2F 3F 4F	1G 2G 5G 6G	1F 2F 4F 5F
Sheet	Groove	1G	X	X X	X	X
		2G	X X	X X	X X	X
		3G	X X	X X X	X	X
		4G	X X	X X X	X	X
Sheet	Fillet	1F		X		X
		2F		X X		X X
		3F		X X X		X
		4F		X X X		X X X
Tube	Groove	1G	X	X X	X	X X
		2G	X X	X X	X X	X X
		5G	X X X	X X X	X X	X X X
		6G	X X X X	X X X X	X X X X	X X X X
Tube	Fillet	1F		X		X
		2F		X X		X X
		4F		X X X		X X X
		5F		X X X X		X X X X

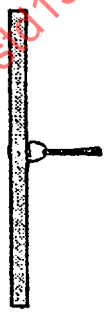
1/ A groove test weld does not qualify for fillet welds in base metal equal to or less than 0.063 inch in thickness (see 5.5.1.1).



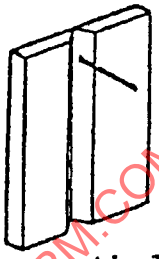


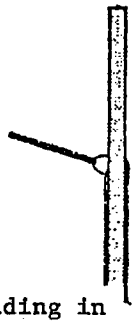
1G flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal



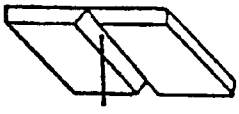


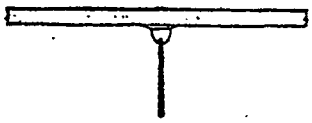
2G horizontal position. The position of welding in which the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane.





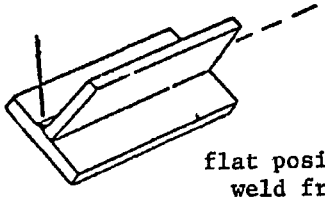
3G vertical position. The position of welding in which the axis of the weld is approximately vertical.





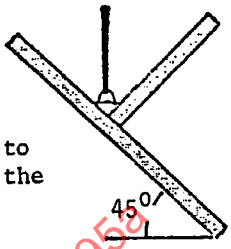
4G overhead position. The position in which welding is performed from the underside of the joint.

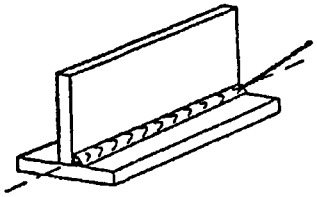
FIGURE 2. Groove weld in sheet: positions 1G, 2G, 3G, and 4G.

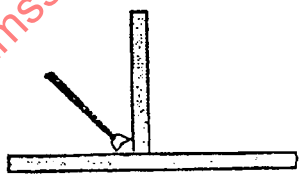


1F

flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal.

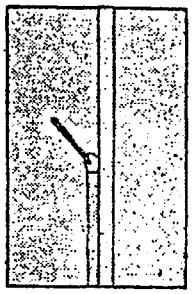


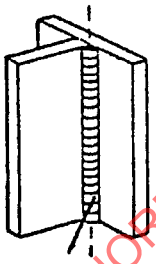




2F

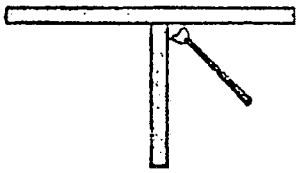
horizontal position. The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.

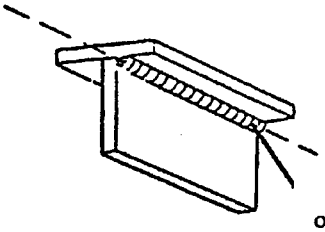




3F

vertical position. The position of welding in which the axis of the weld is approximately vertical.



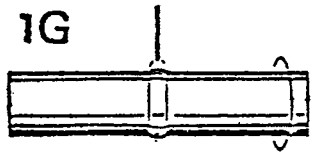


4F

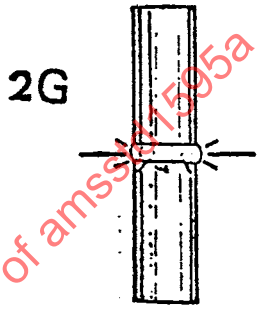
overhead position. The position in which welding is performed from the underside of the joint.

FIGURE 3. Fillet weld in sheet: positions 1F, 2F, 3F, and 4F.

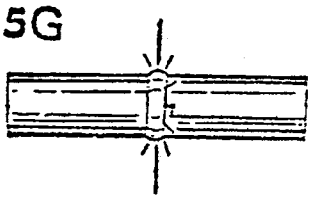
horizontal rolled position. The position of a pipe joint in which the axis of the pipe is approximately horizontal, and welding is performed in the flat position by rotating the pipe.



vertical position. The position of a pipe joint in which welding is performed in the horizontal position and the pipe is not rotated during welding.



horizontal fixed position. The position of a pipe joint in which the axis of the pipe is approximately horizontal and the pipe is not rotated during welding.



inclined position. The position of a pipe joint in which the axis of the pipe is approximately at an angle of 45° to the horizontal and the pipe is not rotated during welding.

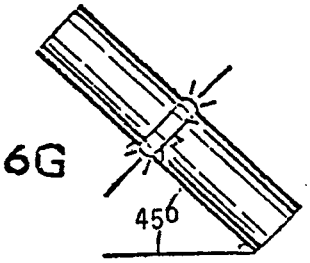
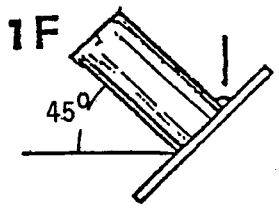
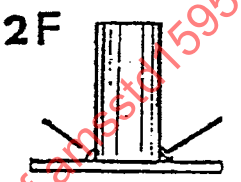


FIGURE 4. Groove weld in tube: positions 1G, 2G, 5G, and 6G.

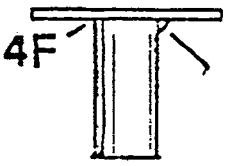
flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal and the pipe is rotated during welding.



horizontal position. The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface and the pipe is not rotated during welding.



overhead position. The position in which welding is performed from the underside of the joint and the pipe is not rotated during welding.



multiple position. The position in which the axis of the pipe is approximately horizontal and the pipe is not rotated during welding.

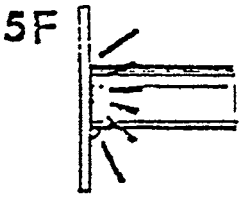
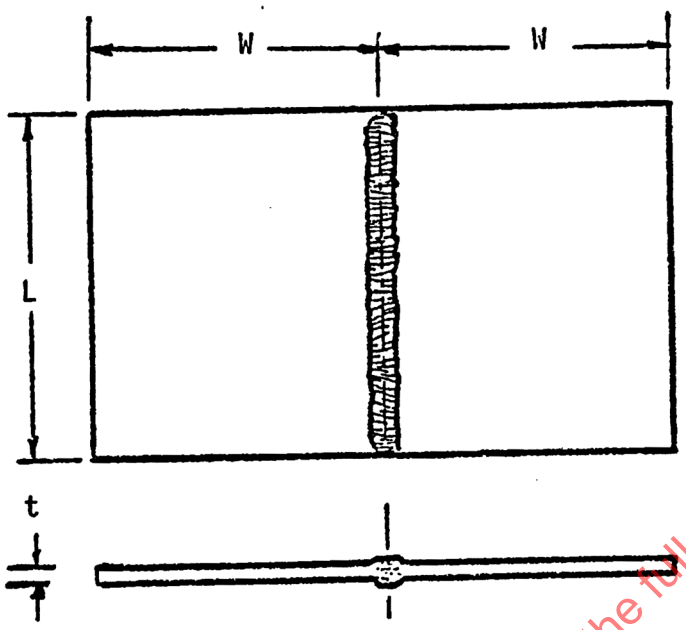


FIGURE 5. Fillet weld in tube: positions 1F, 2F, 4F, and 5F.

TABLE V. Welding conditions qualified by test weld.

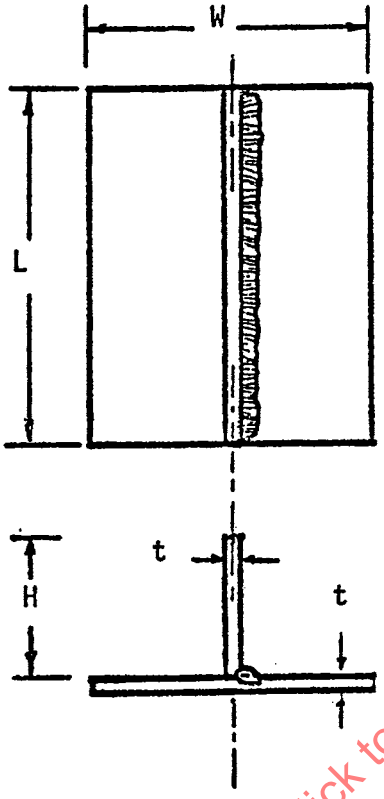
	Qualified							
	Backing		Groove weld				Current type 1/	
Test weld	With	Without	Single	Double	Complete penetration	Partial penetration	ac	dc
With backing	X							
Without backing	X	X						
Single welded groove weld			X	X				
Double welded groove weld				X				
Complete penetration weld					X	X		
Partial penetration weld						X		
ac welding							X	
dc welding								X

1/ Applicable only to GTAW process (see 5.6.1).



BASE METAL THICKNESS	MINIMUM DIMENSIONS	
t	W	L
	INCHES	
≤0.063	2	5
>0.063	3	8

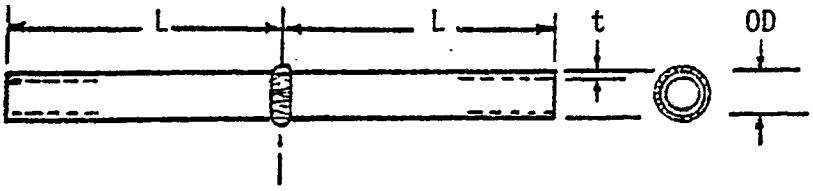
FIGURE 6. Groove test weld in sheet.



BASE METAL THICKNESS	MINIMUM DIMENSIONS		
t	W	L	H
	INCHES		
≤ 0.063	4	5	2
>0.063	4	8	3

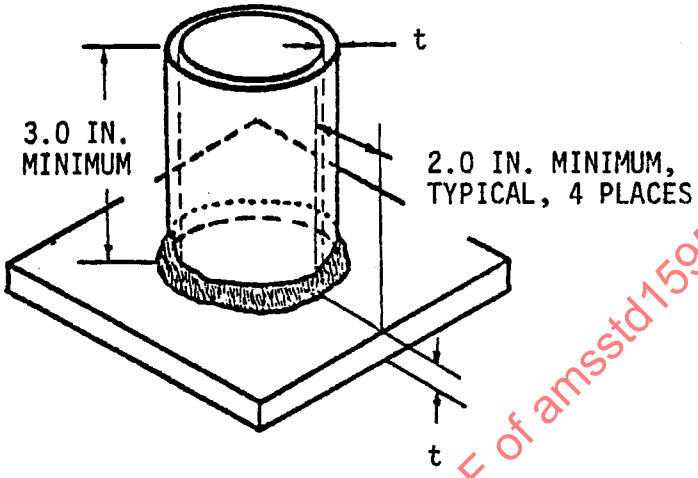
NOTE: Where the members differ in thickness more than 10 percent of the thicker, the cap sheet shall be the thicker.

FIGURE 7. Fillet test weld in sheet.



BASE METAL WALL THICKNESS t	MINIMUM DIMENSIONS L
INCHES	
≤0.063	2
>0.063	3

FIGURE 8. Groove test weld in tube.



NOTE: Where the members differ in thickness equal to or more than 10 percent of the thicker member, the sheet shall be the thicker member.

FIGURE 9. Fillet test weld in tube.

5.7.2 Fillet test weld in sheet: The test weld is a T-joint in sheet as described in Figure 7.

5.7.3 Groove test weld in tube: The test weld is a butt joint in tube as described in Figure 8.

5.7.4 Fillet test weld in tube: The test weld is a tube to sheet joint as described in Figure 9.

5.7.5 Special applications: When none of the test welds described above are applicable to a given production weld, a more limited welder or welding operator qualification may be achieved with a test weld consisting of the given production weld or a test weld representative of the given production weld.

5.7.5.1 Qualification limitations: The qualification is limited to the welding conditions of the test weld with regard to welding process, base metal composition, base metal thickness, welding position, base metal form, type of weld and the other welding conditions of 5.6.

5.7.5.2 Acceptance criteria: The required inspection, examination, bend testing, and acceptance criteria shall be consistent with 5.9 through 5.14.

5.8 Inspection, examination, and bend testing requirements:

5.8.1 Visual inspection: Visual inspection is required for all test welds and shall be completed with the test weld in the as-welded condition.

5.8.2 Radiographic inspection: Radiographic inspection is required for all groove welds, except that bend testing may be used as an alternate under the following conditions.

a. The base metal is not included in Table VI.
b. The base metal is included in the Appendix.
c. The members of the test weld differ in thickness by less than 10 percent of the thicker member.
d. For tube welds, the outside diameter is equal to or more than 2 inches or the wall thickness is equal to or more than 0.250 inch.

5.8.3 Bend testing: Bend testing is required for all fillet welds with a base metal thickness of more than 0.063 inch, except that metallographic examination may be used as an alternate to bend testing. Bend testing of groove welds may be used as an alternate to radiographic inspection as described in 5.8.2.

TABLE VI. Base metals for which bend testing is not applicable.

Base metal group	Unified number	Common description
Ia	NA	9Ni-4Co steel
	K92810	18Ni maraging steel
Ib	All	
IIa	K63198	19-9 DL
	K63199	19-9 DX
	R30155	N155
	R30590	S590
	S15500	15-5PH stainless steel
	S17400	17-4PH stainless steel
	S35000	AM350 PH stainless steel
	S35500	AM355 PH stainless steel
	S41800	Greek Ascoloy
	S42000	420
	S42200	422
	S45000	Custom 450
	S45500	Custom 455
IIb	All	
IIIb	All	
IV	A03560	356
	A92014	2014
	A92219	2219
V	All	
VI	R54620	Ti-6Al-2Sn-4Zr-2Mo
	R56210	Ti-6Al-2Cb-1Ta-1Mo
	R56260	Ti-6Al-2Sn-4Zr-6Mo
	R56620	Ti-6Al-6V-2Sn
	R58640	Ti-3Al-8V-6Cr-4Mo-4Zr
	NA	Ti-6Al-2Sn-2Zr-2Cr-2Mo
	NA	Ti-15V-3Cr-3Mo-3Sn
VII	All	

5.8.4 Metallographic examination: Metallographic examination is required for all fillet welds with a base metal thickness of equal to or less than 0.063 inch. Metallographic examination may be used as an alternate to bend testing for fillet welds with a base metal thickness of more than 0.063 inch.

5.8.5 Summary: The required inspection, examination, and bend testing of test welds are summarized in Table VII.

5.9 Visual inspection procedure: Visual inspection shall be completed with the test weld in the as-welded condition.

5.9.1 Weld length: The center 4-inch length of welds in sheet of equal to or less than 0.063 inch thickness, the center 6-inch length of welds in sheet of more than 0.063 inch thickness, and the entire weld in tubes shall be inspected.

5.9.2 Magnification: Inspection shall be performed at a magnification of 3X for welds in base metal with a thickness of equal to or less than 0.063 inch and without magnification for more than 0.063 inch.

5.10 Radiographic inspection procedure: Radiographic inspection shall be completed with the test weld in the as-welded condition, except as modified by MIL-STD-453.

5.10.1 Weld length: The same length of weld as given in 5.9.1 shall be inspected.

5.10.2 Radiography standard: Radiography shall be performed in accordance with MIL-STD-453.

5.10.3 Radiographer qualification: Radiographers shall be qualified in accordance with MIL-STD-410.

5.11 Preparation of bend specimens: Blanks for bend specimens may be removed from the test weld by any means of cutting, provided that any crack or heat affected zone caused by cutting is removed by mechanical means.

5.11.1 Groove welds in sheet:

a. Blanks for bend specimens shall be removed from test welds at the locations shown in Figure 10.
b. The bend specimen type and dimensions for sheet are given in Table VIII. Each specimen type identified in Column 3 of Table VIII is illustrated in Figure 11.

TABLE VII. Required inspection, examination, and bend testing of test welds.

Weld type	Base metal		Visual	Radiographic	Bend			Metallographic			
	Form	Thickness t, inch			Applicability	Figure reference	Specimens required	Applicability	Figure reference	Specimens required	Cross sections required
1	2	3	4	5	6	7	8	9	10	11	12
Groove	Sheet	≤ 0.063	All	All 1/	All 1/	10 & 11	1	None			
		> 0.063	All	All 1/	1/	10 & 11	2	None			
Groove	Tube	≤ 0.063	All	All	None			None			
		> 0.063	All	All 1/	1/	12 & 13	2	None			
Fillet	Sheet	≤ 0.063	All	None	None			All	19	4	8
		> 0.063	All	None	All 2/	14	1	2/	19	4	8
Fillet	Tube	≤ 0.063	All	None	None			All	20	4	8
		> 0.063	All	None	All 2/	15	2	2/	20	4	8

1/ Bend testing may be used as an alternate to radiographic inspection as described in 5.8.2.
2/ Metallographic examination may be used as an alternate to bend testing.

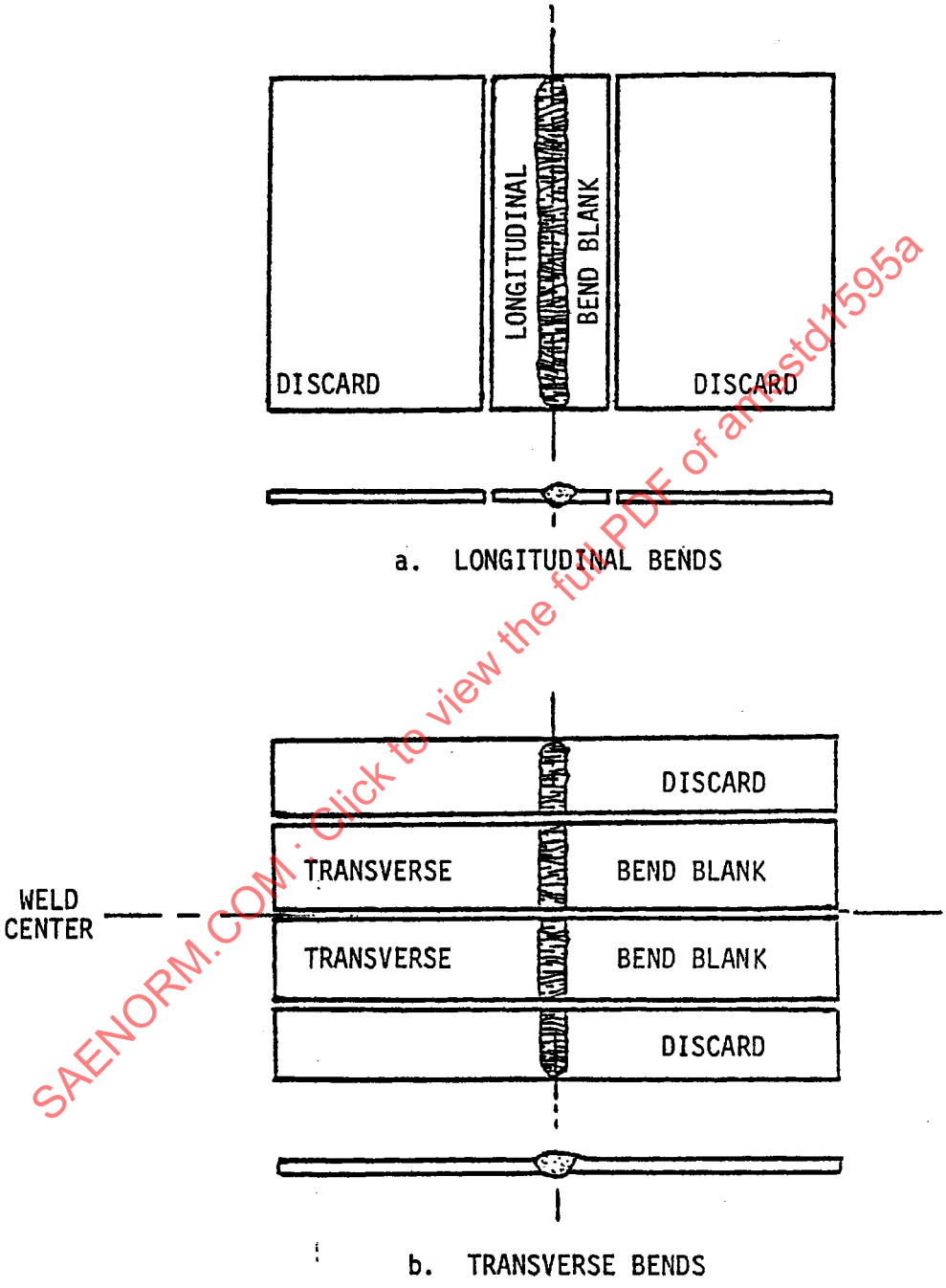
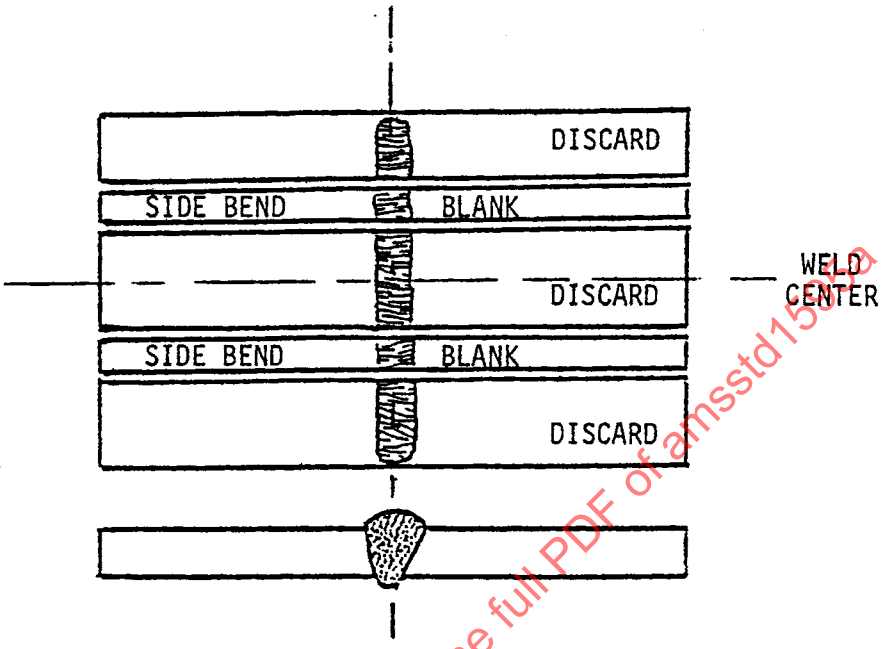


FIGURE 10. Blank locations for bend specimens in groove-welded sheet.



c. SIDE BENDS

NOTE: Discard pieces from b to be of equal width.
Discard pieces from c to be of equal width.

FIGURE 10. Blank locations for bend specimens in groove-welded sheet. Continued.

TABLE VIII. Bend specimens for groove welds in sheet.

Base metal		Bend test specimen					
			Dimensions, inch				
			t_1			W	
Thickness t inch	No.	Type shown in Fig.11	Min.	Max.	L Min.	Min.	Max.
1	2	3	4	5	6	7	8
≤ 0.063	All	LB-a	t	1/	5	1.00	1.05
> 0.063-0.125	All	TB-b & TB-c	0.9t	t	6	1.50	1.55
> 0.125-0.375	2/	TB-b & TB-c	0.115	0.135	6	1.50	1.55
	Others	TB-b & TB-c	0.9t	t	6	1.50	1.55
> 0.375-0.750	2/	TB-b & TB-c or SB-d	0.115	0.135	6	1.50	1.55
			0.115	0.135	6	t	t
	Others	TB-b & TB-c or SB-d	0.350	0.400	6	1.50	1.55
			0.350	0.400	6	t	t
> 0.750	2/	SB-d	0.115	0.135	6	3/	t
	Others	SB-d	0.350	0.400	6	3/	t

1/ The weld face and root surfaces shall be dressed to produce smooth surfaces with a maximum weld metal thickness variation of 10 percent.
2/ A96061 and A96063 of Base Metal Group IV.
3/ For base metal thicknesses of > 0.750 to 1.50 inch, W is equal to t. For base metal thicknesses of > 1.50 inch specimens may be cut into approximately equal strips between 0.75 and 1.50 inch wide for testing, or the specimens may be bent at full width.

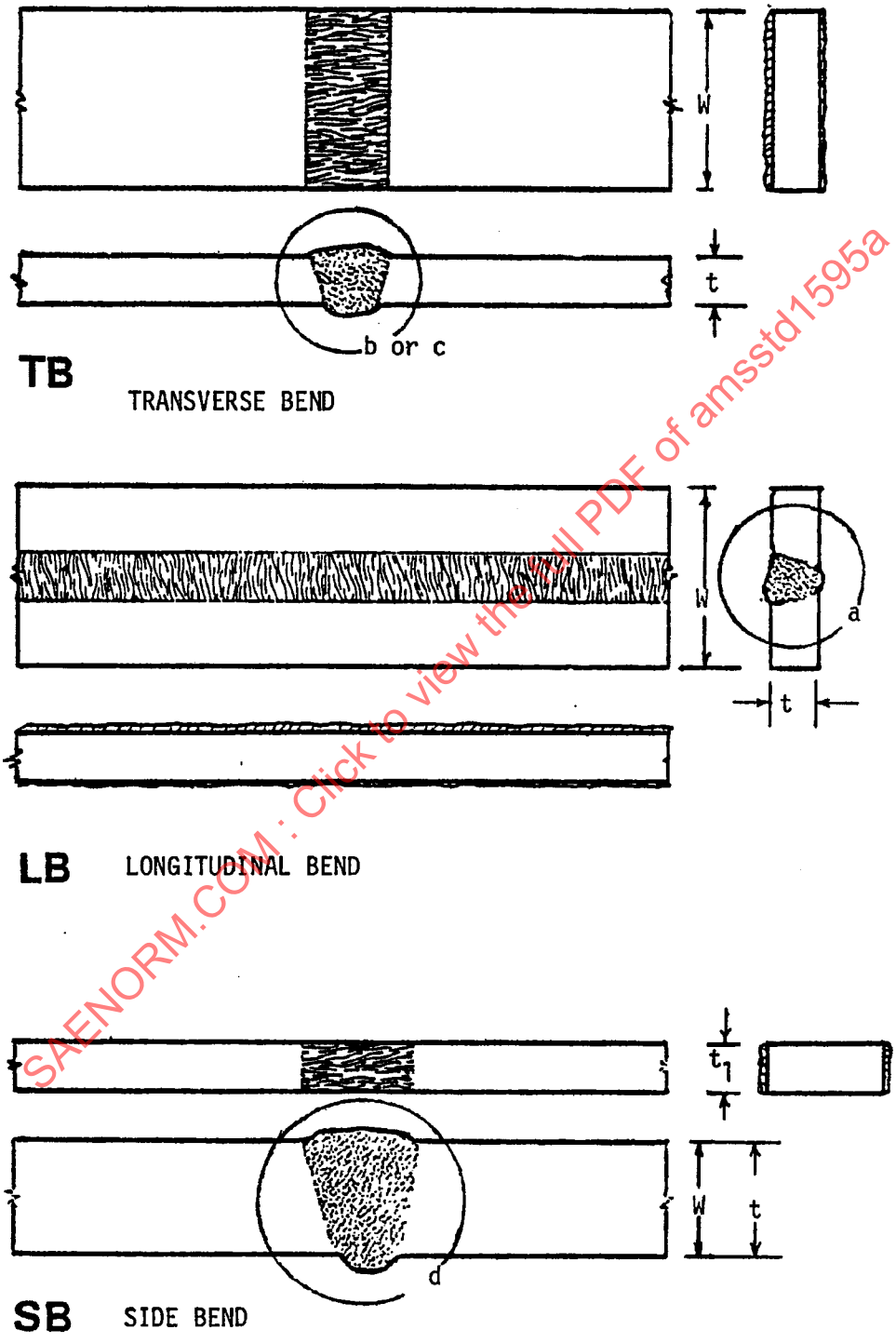


FIGURE 11. Bend specimens in groove-welded sheet.

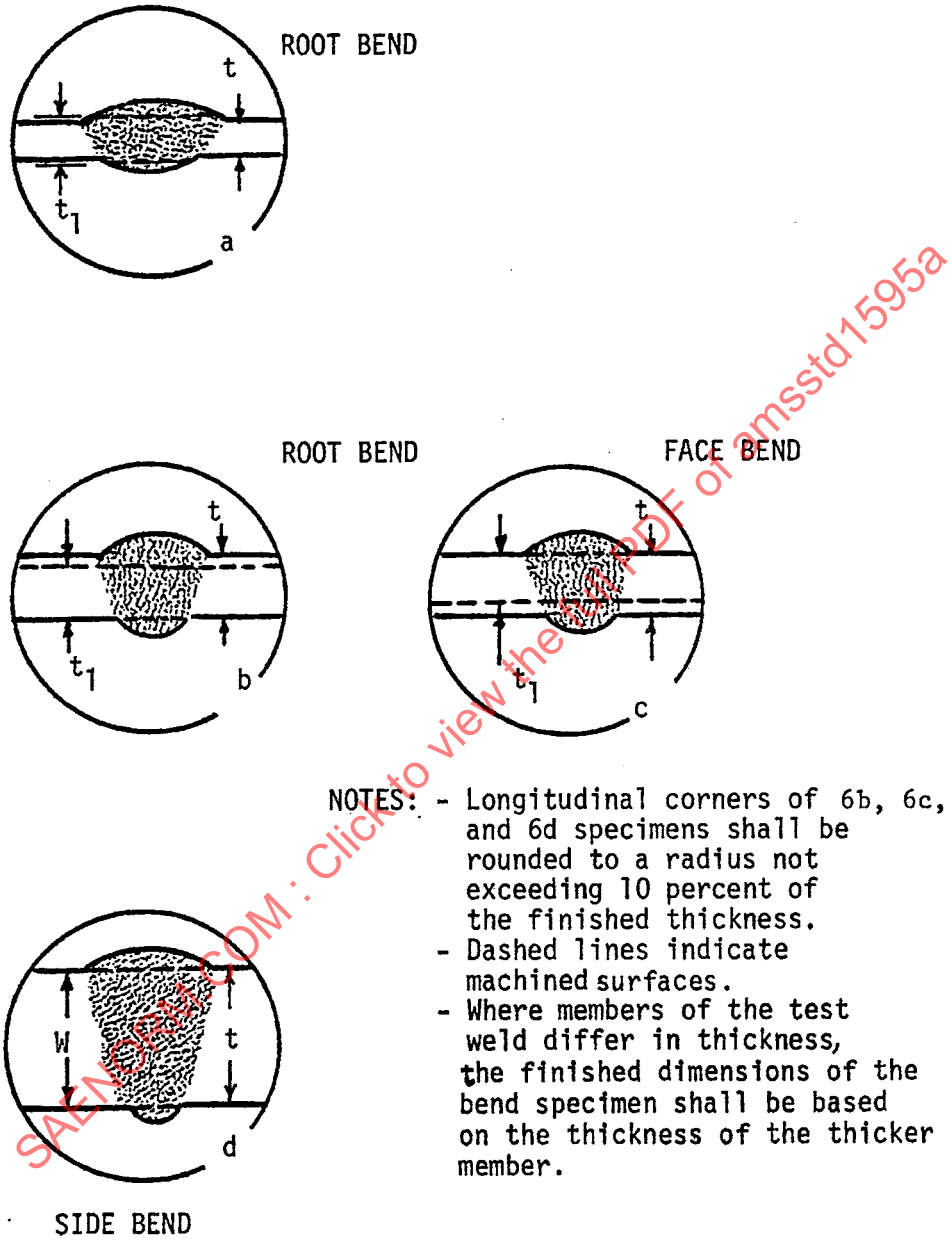


FIGURE 11. Bend specimens in groove-welded sheet. Continued.

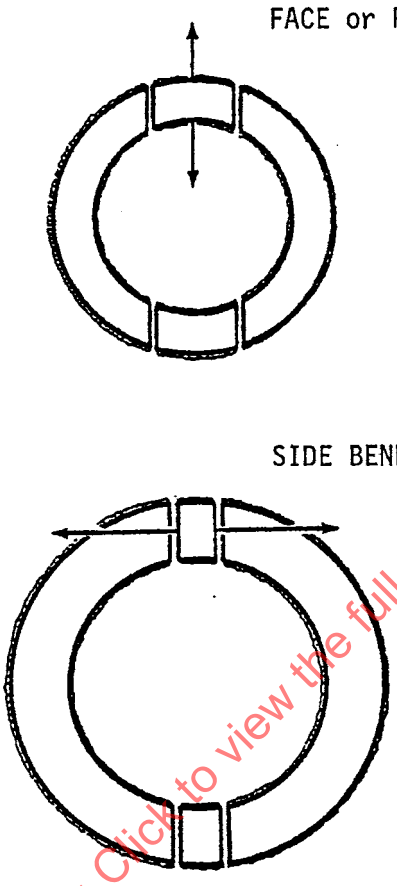


FIGURE 12. Blank locations for bend specimens in groove-welded tube.

5.11.2 Groove welds in tube:

a. Blanks for bend specimens shall be removed from test welds at the locations shown in Figure 12.
b. The bend specimen type and dimensions for tube are given in Table IX. Each specimen type identified in Column 4 of Table IX is illustrated in Figure 13.

5.11.3 Fillet welds in sheet: Blanks for bend specimens shall be removed from the test weld at the location shown in Figure 14.

5.11.4 Fillet welds in tube: Blanks for bend specimens shall be removed from the test weld at the locations shown in Figure 15.

5.12 Bend testing procedure: Testing may be performed with the bend specimen either in the as-welded or any heat-treated condition.

5.12.1 Groove welds:

5.12.1.1 Base metal thickness of more than 0.063 inch: Bend specimens shall be bent in the wrap-around bend test fixture illustrated in Figure 16. After clamping the bend specimen firmly in place, the roller (planetary cylinder) shall be advanced slowly through an arc of 180 degrees from its starting location directly below the fixed mandrel (cylinder with radius A). Root bend specimens shall be placed with the weld root out toward the roller and face bend specimens shall be placed with the weld face out toward the roller.

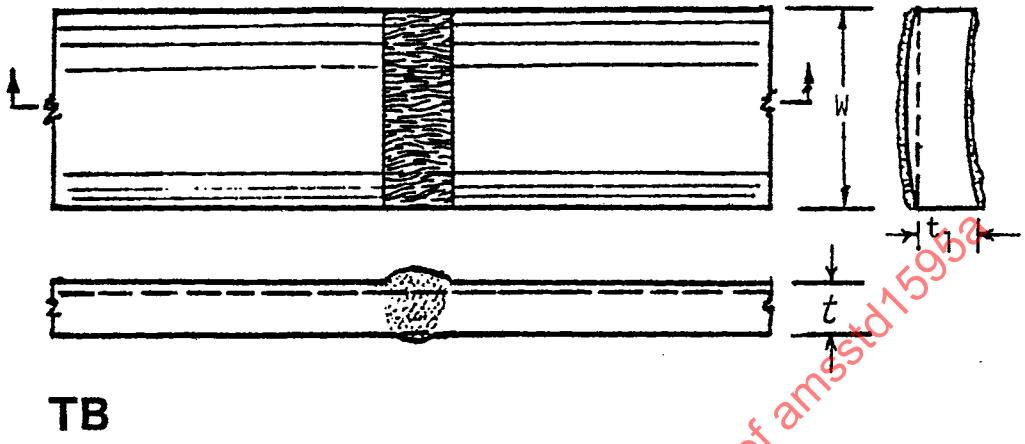
5.12.1.2 Alternate method for base metal thickness of more than 0.063 inch: Bend specimens shall be bent in the ram-and-die bend test fixture illustrated in Figure 17. After placing the bend specimen across the die shoulders, with the center of the weld at the center of the die opening for transverse bend and side bend specimens, the specimen shall be forced into the die cavity by applying a load to the ram until the curvature of the specimen will now allow a wire of 0.12 inch diameter to be inserted between the specimen and the die cavity. Root bend specimens shall be placed with the weld face against the ram and face bend specimens shall be placed with the weld root against the ram.

5.12.1.3 Base metal thickness of equal to or less than 0.063 inch: Bend specimens with a base metal thickness of equal to or less than 0.063 inch shall be tested in a manner similar to that described in 5.12.1.1, except that the roller is not used. The free end of the bend specimen is gripped with pliers and slowly wrapped around the fixed mandrel. Specimens shall be placed with the weld face against the fixed mandrel.

TABLE IX. Bend specimens for groove welds in tube.

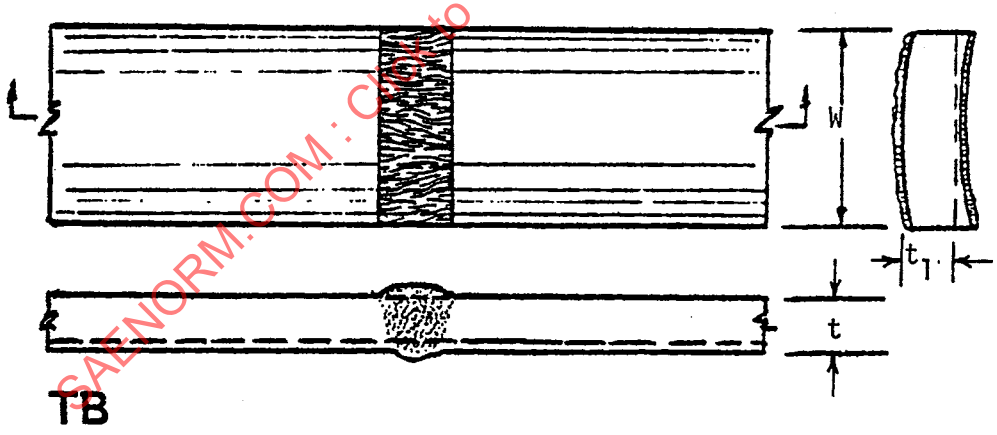
Tube			Bend test specimen				
Outside diameter inch	Wall thickness t, inch	Base metal number	Type shown in Fig.13	Dimensions, inch			
				t_1		W	
				Min.	Max.	Min.	Max.
1	2	3	4	5	6	7	8
< 2	All		Radiographic inspection				
2-5	<0.250		Radiographic inspection				
	≥0.250-0.375	1/	TB-e & TB-f	0.115	0.135	0.750	0.800
		Others	TB-e & TB-f	2/	2/	0.750	0.800
	<0.375-0.750	1/	TB-e & TB-f or SB-g	0.115	0.135	0.750	0.800
				0.115	0.135	t	t
		Others	TB-e & TB-f or SB-g	3/	3/	0.750	0.800
				0.350	0.400	t	t
	>0.750	1/	SB-g	0.115	0.135	t	t
		Others	SB-g	0.350	0.400	t	t
> 5	<0.250		Radiographic inspection				
	≥0.250-0.375	1/	TB-e & TB-f	0.115	0.135	1.50	1.55
		Others	TB-e & TB-f	2/	2/	1.50	1.55
	>0.375-0.750	1/	TB-e & TB-f or SB-g	0.115	0.135	1.50	1.55
				0.115	0.135	t	t
		Others	TB-e & TB-f or SB-g	3/	3/	1.50	1.55
				0.350	0.400	t	t
	>0.750	1/	SB-g	0.115	0.135	4/	t
		Others	SB-g	0.350	0.400	4/	t

1/ A96061 and A96063 of Base Metal Group IV.
2/ The maximum t_1 is the thickness resulting from dressing of the curved surface to a plane. The minimum t_1 is 0.9 times the maximum.
3/ The maximum t_1 is the thickness resulting from dressing the curved surface to a plane, or 0.400 in., whichever is the lesser. In the first case, the minimum t_1 is 0.9 times the maximum. In the second case, the minimum t_1 is 0.350 in.
4/ For wall thicknesses of > 0.750 to 1.50 in., W is equal to t. For wall thicknesses of >1.50 in., specimens may be cut into approximately equal strips between 0.75 and 1.50 in. wide for testing, or the specimens may be bent at full width.



NOTE: The thickness of the transverse root bend specimen is measured at the specimen edge.

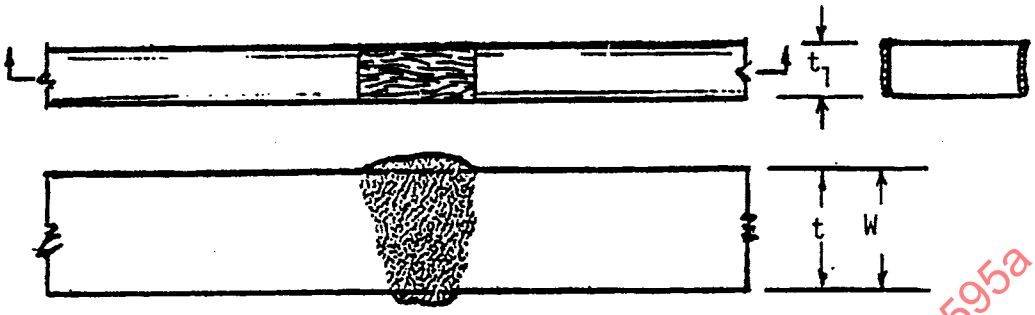
a. TRANSVERSE ROOT BEND



NOTE: The thickness of the transverse root bend specimen is measured at the specimen center.

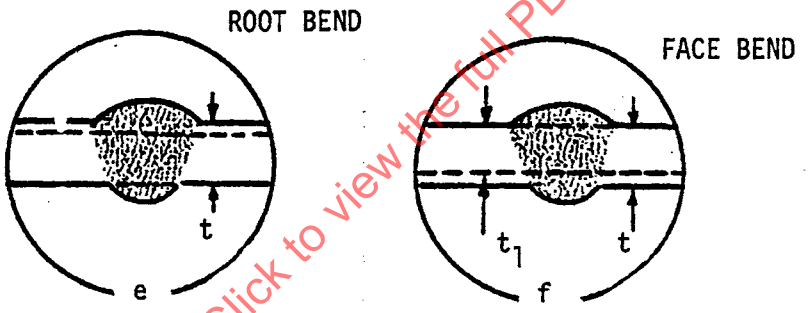
b. TRANSVERSE FACE BEND

FIGURE 13. Bend specimens in groove-welded tube.

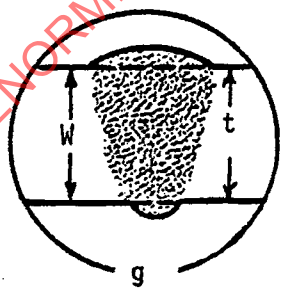


SB

c. SIDE BEND



NOTES:
- Longitudinal corners of all specimens shall be rounded to a radius not to exceed 10 percent of the finished thickness.
- Dashed lines indicate machined surfaces.
- Where the members of the test weld differ in wall thickness, the finished dimensions of the bend specimen shall be based on the thickness of the thicker member.



SIDE BEND

d. BEND SPECIMEN SECTION DETAILS

FIGURE 13. Bend specimens in groove-welded tube. Continued.

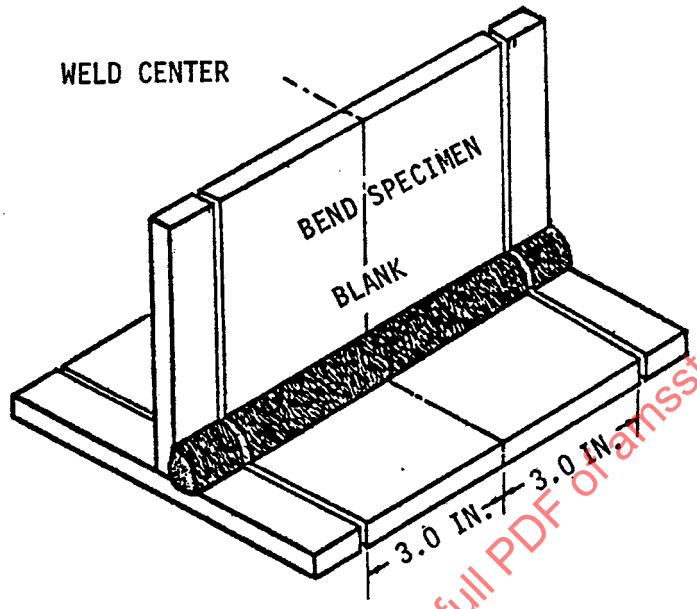
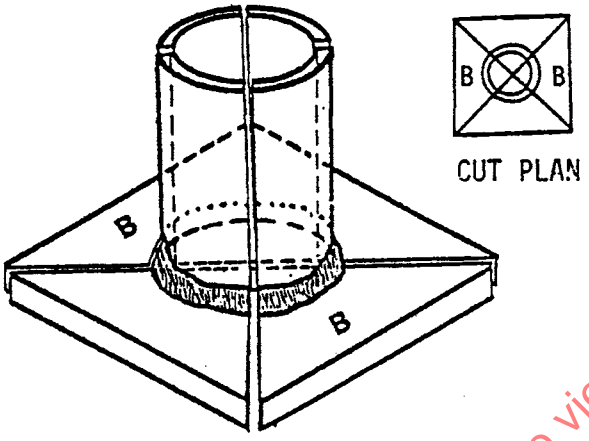
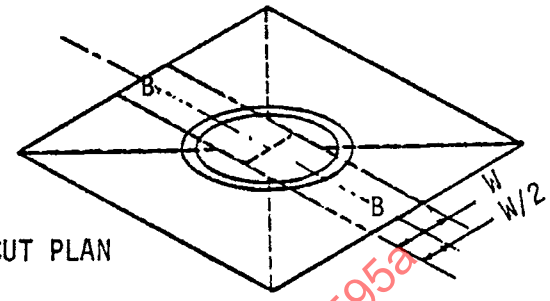


FIGURE 14. Blank location for bend specimens in fillet-welded sheet.

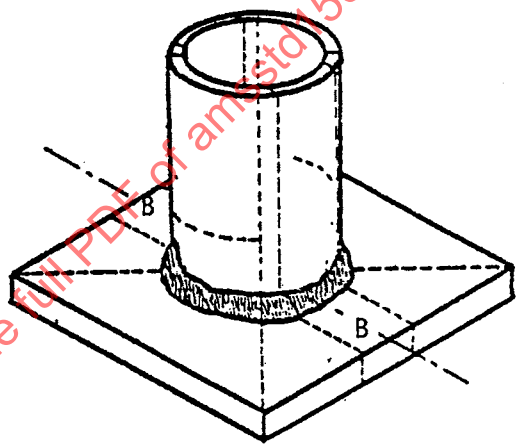
B = BEND SPECIMEN BLANK



CUT PLAN



CUT PLAN

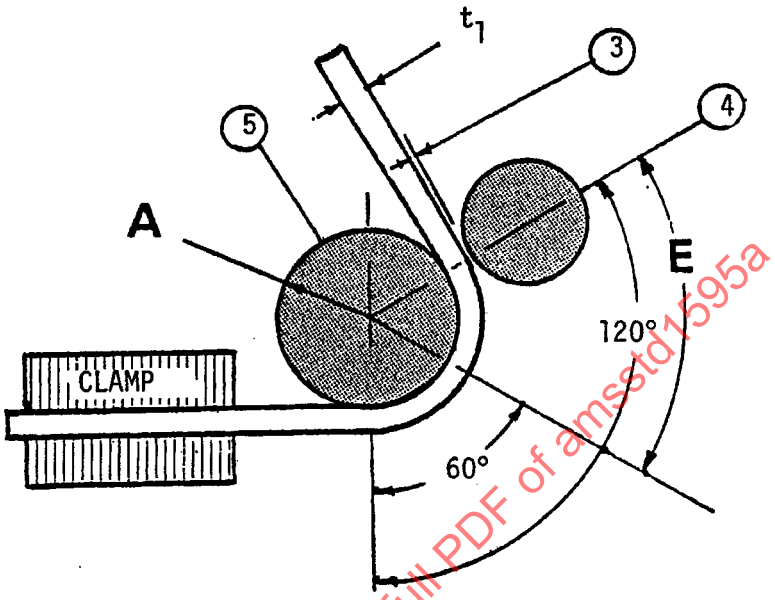


a. For tubes <1.5 in. in outside diameter, OD

b. For tubes ≧1.5 in. in outside diameter, OD

OD	W
INCHES	
1.5 to 3.0	0.75
> 3.0	1.50

FIGURE 15. Blank location for bend specimens in fillet-welded tube.

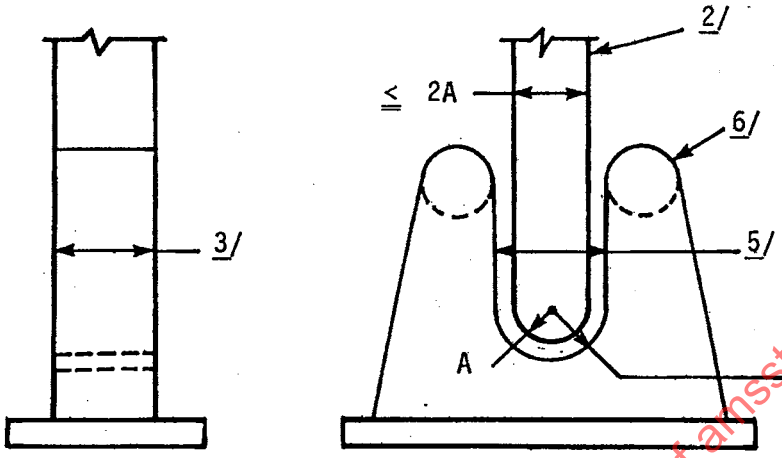


$A = Ft_1$, where A is the bend radius
F is the bend factor
t_1 is the bend specimen thickness

NOTES:

1. Dimensions not shown are the option of the designer. An essential consideration is to have adequate rigidity for the applied loads.
2. For transverse weld bend specimens, the center of the weld shall be located within angle E.
3. This clearance dimension shall be a maximum of 0.06 inch plus 0.1 t_1.
4. This roller shall be free to rotate about its cylindrical axis and shall have a minimum diameter of 0.75 inch. The minimum roller width shall be W plus 0.25 inch.
5. This fixed mandrel may or may not be free to rotate about its cylindrical axis and shall have a minimum width of W plus 0.25 inch.

FIGURE 16. Wrap-around bend test fixture.



$A = Ft_1$, where A is the bend radius
F is the bend factor
t_1 is the bend specimen thickness

NOTES:

1/ Dimensions not shown are the option of the designer. An essential consideration is to have adequate rigidity for the applied loads.

2/ The length of the ram shall be sufficient to reach the bottom of the die cavity. The ram shall be fitted with an appropriate base and provision shall be made for attachment to the testing machine.

3/ The minimum width of the die cavity and the ram shall be equal to W plus 0.25 in.

4/ The maximum radius of the die cavity shall be equal to A plus $1.1t_1$ plus 0.06 in. The minimum depth shall be 2 in. The die shall be fitted with an appropriate base and provision shall be made for maintaining the ram centered in the die cavity.

5/ This dimension shall be twice the radius of the die cavity.

6/ Either hardened and greased shoulders or hardened rollers, free to rotate, shall be used. The minimum radius shall be $5t_1$ or 0.75 in., whichever is less.

FIGURE 17. Ram-and-die bend test fixture.

5.12.1.4 Bend radius: The bend radius (A) to be used with a given bend specimen thickness and a given base metal may be found in Table X. Other ranges of bend specimen thickness and bend radius may be used, provided that the bend factor does not exceed the range of F to 1.1F. (See equation of Figure 16.)

5.12.2 Fillet welds:

5.12.2.1 Loading: The stem of the bend specimen shall be loaded parallel to the cap sheet, so that the root of the weld is in tension. The load shall be slowly increased until the specimen fractures in the weld.

5.12.2.2 Weld fracture: Where it is necessary to ensure fracture in the weld, the weld face shall be grooved as shown in Figure 18. For fillet welds in tube, the groove shall be cut before the bend specimen blanks are removed from the test weld.

5.13 Metallographic examination: Blanks for metallographic specimens shall be removed from test welds in accordance with Figures 19 and 20.

5.13.1 Cutting: Removal from the test weld may be by any means of cutting, provided that any crack or heat affected zone caused by cutting is removed by mechanical means.

5.13.2 Trimming: Extraneous metal may be trimmed from the blanks, either before or after removal from the test weld, to obtain a metallographic specimen of convenient size, provided that the entire weld and heat affected zone at the designated cross section remains in the metallographic specimen.

5.13.3 Cross sections: Each of the cut weld cross sections, designated in Figures 19 and 20, of the metallographic specimens shall be smoothed by fine abrasive or file and etched with a suitable reagent to clearly reveal the weld macrostructure for examination at a magnification of 5X.

5.14 Acceptance criteria:

5.14.1 Visual inspection:

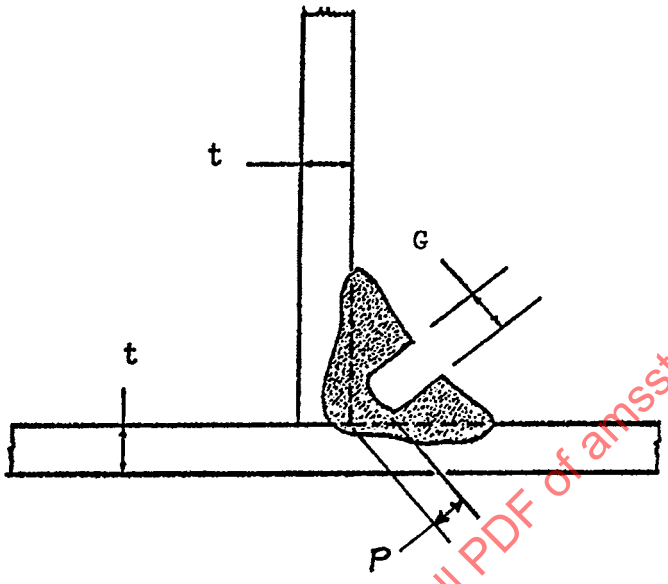
5.14.1.1 Groove welds: Groove welds in sheet or tube which have any of the following defects are unacceptable:

a. Any type of crack.
b. Incomplete joint penetration.
c. Underfill.

TABLE X. Bend specimen thickness and bend radius.

Bend Radius A Inch[2]	Bend specimen thickness[1] — Unified number: R54520 R54810 R56320 R56400 — F = 12 [3]		A96061 A96063 — F = 8		R50400 R50550 R52400 — F = 5		R50250 — F = 4		A95083 A95086 A95456 — F = 3		Others — F = 2	
	≥	<	≥	<	≥	<	≥	<	≥	<	≥	<
0.070											0.031	0.035
0.079											0.035	0.039
0.088											0.039	0.044
0.099									0.029	0.033	0.044	0.050
0.111									0.033	0.037	0.050	0.056
0.125									0.037	0.042	0.056	0.062
0.140							0.031	0.035	0.042	0.047	0.062	0.070
0.157							0.035	0.039	0.047	0.052	0.070	0.078
0.176					0.031	0.035	0.039	0.044	0.052	0.059	0.078	0.088
0.198					0.035	0.040	0.044	0.049	0.059	0.066	0.088	0.099
0.222					0.040	0.044	0.049	0.055	0.066	0.074	0.099	0.111
0.249					0.044	0.050	0.055	0.062	0.074	0.083	0.111	0.124
0.279			0.031	0.035	0.050	0.056	0.062	0.070	0.083	0.093	0.124	0.140
0.313			0.035	0.039	0.056	0.063	0.070	0.078	0.093	0.104	0.140	0.157
0.351			0.039	0.044	0.063	0.070	0.078	0.088	0.104	0.117	0.157	0.176
0.394	0.029	0.033	0.044	0.049	0.070	0.079	0.088	0.099	0.117	0.131	0.176	0.197
0.442	0.033	0.037	0.049	0.055	0.079	0.088	0.099	0.111	0.131	0.147	0.197	0.221
0.496	0.037	0.041	0.055	0.062	0.088	0.099	0.111	0.124	0.147	0.165	0.221	0.248
0.557	0.041	0.046	0.062	0.070	0.099	0.111	0.124	0.139	0.165	0.186	0.248	0.279
0.625	0.046	0.052	0.070	0.078	0.111	0.125	0.139	0.156	0.186	0.208	0.279	0.312
0.701	0.052	0.058	0.078	0.088	0.125	0.140	0.156	0.175	0.208	0.234	0.312	0.351
0.787	0.058	0.066	0.088	0.098	0.140	0.157	0.175	0.197	0.234	0.262	0.351	0.393
0.883	0.066	0.074	0.098	0.110	0.157	0.177	0.197	0.221	0.262	0.294		
0.991	0.074	0.083	0.110	0.124	0.177	0.198	0.221	0.248	0.294	0.330		
1.111	0.083	0.093	0.124	0.139	0.198	0.222	0.248	0.278	0.330	0.370		
1.247	0.093	0.104	0.139	0.156	0.222	0.249	0.278	0.312	0.370	0.416		
1.399	0.104	0.117	0.156	0.175	0.249	0.280	0.312	0.350				
1.570	0.117	0.131	0.175	0.196	0.280	0.314	0.350	0.392				
1.761	0.131	0.147	0.196	0.220	0.314	0.352						
1.976	0.147	0.165	0.220	0.247	0.352	0.395						
2.218	0.165	0.185	0.247	0.277								
2.488	0.185	0.207	0.277	0.311								
2.782	0.207	0.233	0.311	0.349								
3.132	0.233	0.261	0.349	0.392								
3.515	0.261	0.293										
3.943	0.293	0.329										
4.425	0.329	0.369										
4.965	0.369	0.414										

1/ The body of the table contains the bend specimen thickness (t_1) in inches.
2/ The tolerance on bend radius A is ±0.001 in. or ±1%, whichever is the larger.
3/ F = Bend factor



NOTES: G shall be a maximum of 0.5 t or 0.25 inch, whichever is less.

P shall be no less than 0.5 t.

FIGURE 18. Slotted fillet weld.

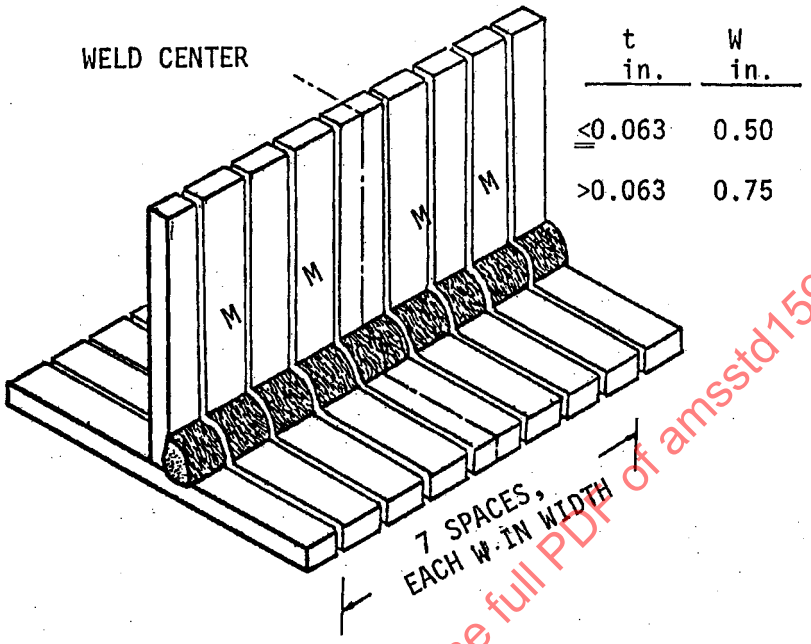


FIGURE 19. Blank locations for metallographic specimens in fillet-welded sheet.

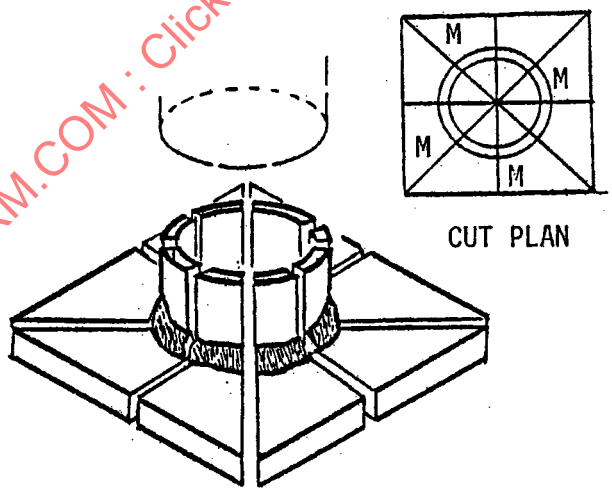


FIGURE 20. Blank locations for metallographic specimens in fillet-welded tube.

5.14.1.1 (Continued):

d. Overlap.
e. For test welds with a base metal thickness of more than 0.063 inch, undercut at any location in excess of 0.05 t or 0.032 inch, whichever is the lesser.
f. Mismatch at any location in excess of 10 percent of the base metal thickness or 0.12 inch, whichever is the lesser, except that a mismatch up to 25 percent is allowed for a base metal thickness of equal to or less than 0.063 inch.
g. Reinforcement of the weld face or the weld root in excess of that shown in Table XI.

5.14.1.2 Fillet welds: Fillet welds in sheet or tube which have either of the following defects are unacceptable:

a. Any type of crack.
b. Overlap.

5.14.1.3 Base metal thickness of more than 0.063 inch: Fillet welds in sheet or tube with a base metal thickness of more than 0.063 inch, which have any of the following defects, are unacceptable:

a. Undercut at any location in excess of 0.1 t or 0.063 inch, whichever is the lesser.
b. Fusion evident at any sheet or tube surface opposite the weld bead.
c. For base metal thickness equal to or less than 1 inch, a leg size less than t. For a base metal thickness of more than 1 inch, the minimum leg size shall be 1 inch. Where the members of the test weld differ in thickness, the minimum leg size shall be based on the thinner member.
d. For base metal thickness equal to or less than 1 inch, a leg size in excess of 3 t, or t plus 0.25 inch, whichever is the lesser. For a base metal thickness more than 1 inch, the maximum leg size shall be 1.25 inch. Where the members of the test weld differ in thickness, the maximum leg size shall be based on the thinner member.
e. A ratio of the leg of larger size to the leg of smaller size greater than 1.5 at any location.
f. For a convex weld, at any location a convexity in excess of 0.1 times the average leg size at that location.
g. For a concave weld, a theoretical throat size of less than 0.5 t at any location. Where the members of the test weld differ in thickness, the minimum theoretical throat size shall be based on the thinner member.

TABLE XI. Maximum allowable weld reinforcement.

Base metal thickness t, in.	Maximum allowable weld reinforcement 1/			
	Face		Root	
	Base metal group	Any location	Base metal group	Any location
≤ 0.063	All	0.020 inch + t or 0.050 inch	IV and V	0.030 inch + t or 0.070 inch
			Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	0.020 inch + t or 0.050 inch
> 0.063	All	0.8 t or 0.25 inch	IV and V	t or 0.25 inch
			Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	0.8 t or 0.25 inch

1/ The applicable maximum is the smaller of the two values given in the body of the table.

5.14.2 Radiographic inspection:

5.14.2.1 Interpretation of indications:

a. A linear indication is defined as one whose maximum dimension is more than three times its minimum dimension.
b. Non-linear indications with major and minor dimensions shall be evaluated as an equivalent circle with estimated average diameter. This estimated diameter shall be the size used in determining the acceptability of the indication, and the area corresponding to this estimated diameter shall be used in calculating the area of an indication.
c. Tungsten inclusions shall be counted as porosity.
d. In a test weld with a base metal thickness of equal to or less than 0.063 inch, a disregard all indications of less than 0.002 inch size. In a test weld with a base metal thickness of more than 0.063 inch, disregard all indications of less than 0.005 inch or 0.02 t size, whichever is greater.

5.14.2.2 Unacceptable indications: Test welds, whose radiograph of the inspected length shows any of the following indications, are unacceptable:

a. Any type of crack.
b. Incomplete joint penetration, except as indicated in 5.14.2.2c.
c. Internal linear indications in excess of those shown in Table XII.
d. Porosity in excess of that shown in Table XIII. Examples of the allowable maximum total porosity area and the maximum pore size are shown in Figure 21.

TABLE XII. Maximum linear indications.

Linear indication	Indication length 1/	
	Base metal thickness, inch	
	≤ 0.063	> 0.063
Length of any indication	2 t	t or 0.38 inch 2/
Accumulated length in any 1 inch weld length	2 t	t or 0.38 inch 2/
Average length	t	0.5 t or 0.18 inch 2/

1/ Where the members of the test weld differ in thickness, t is the thickness of the thicker member.
2/ The applicable maximum is the smaller of the two values.