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SUPERSEDING  
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MILITARY STANDARD

QUALIFICATION OF AIRCRAFT, MISSILE  
AND AEROSPACE FUSION WELDERS



NO DELIVERABLE DATA REQUIRED BY THIS DOCUMENT.

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MIL-STD-1595A

DEPARTMENT OF DEFENSE  
Washington, DC 20360

Qualification of Aircraft, Missile and Aerospace Fusion Welders.

MIL-STD-1595A

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.
2. Beneficial comments (recommendations, additions, and deletions) and any pertinent data of which may be of use in improving this document should be addressed to Materials Laboratory, AFWAL/MLSA, Wright-Patterson AFB, OH 45433.

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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.

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2. REFERENCED DOCUMENTS

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

STANDARDS

MILITARY

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

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific acquisition functions should be obtained from the acquisition activity or as directed by the contracting officer.)

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

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

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

(Copies may be obtained from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

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

(Copies may be obtained from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

AMERICAN WELDING SOCIETY (AWS)

- AWS A3.0 - Welding Terms and Definitions
- AWS B3.0 - Welding Procedure and Performance Qualification

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AWS D1.1  
AWS D10.9

- Structural Welding Code
- Qualification of Welding Procedures  
and Welders for Piping and Tubing

(Copies may be obtained from American Welding Society, 2501 N.W.  
7th Street, Miami, FL 33125.)

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

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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 designates 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.

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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.

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- 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
  - $\leq$  equal to or less than
  - $\geq$  equal to or more than.

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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.

### 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	
	1G	2G	3G	4G	t	O. D.
Sheet groove	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Tube groove	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Sheet fillet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____
Tube fillet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____

#### TEST RESULTS

Visual Pass  Fail   
 Radiographic NA  Pass  Fail   
 Bend NA  Pass  Fail   
 Metallographic NA  Pass  Fail

#### QUALIFIED

	Position				t, inch		O. D., inch	
	1G	2G	3G	4G	Min.	Max.	Min.	Max.
	_____	_____	_____	_____	_____	_____	_____	_____
Sheet groove	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	_____	_____
Tube groove	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	_____	_____
Sheet fillet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	_____	_____
Tube fillet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	_____	_____	_____

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.

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- 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.

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)

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.

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

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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.

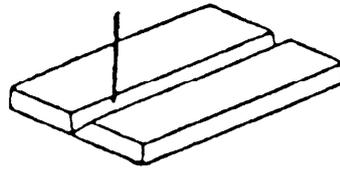
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TABLE IV. Welding position, base metal form, and weld type qualified by test weld.

Test Weld		Position	Qualified position															
Form	Weld type		Sheet								Tube							
			Groove				Fillet <sup>1/</sup>				Groove		Fillet <sup>1/</sup>					
		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	

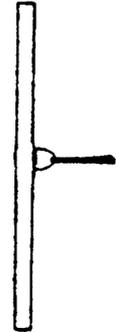
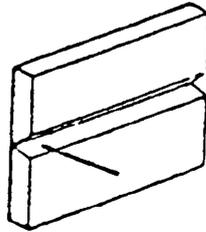
<sup>1/</sup> A groove test weld does not qualify for fillet welds in base metal equal to or less than 0.063 inch in thickness (see 5.5.1.1).

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



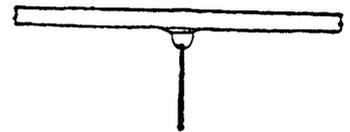
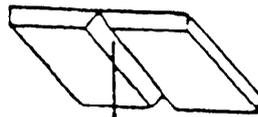
horizontal position. The position of welding in which the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane.

3G



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

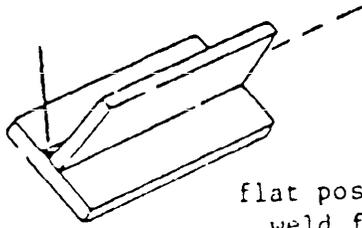
4G



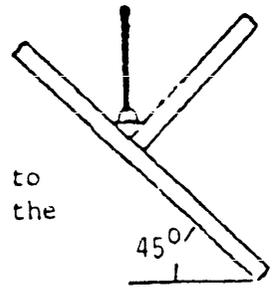
overhead position. The position in which welding is performed from the underside of the joint.

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

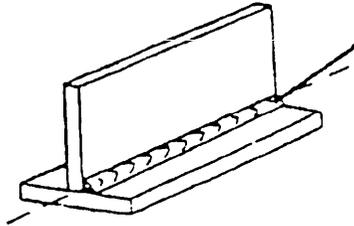
1F



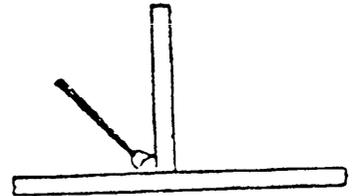
flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal.



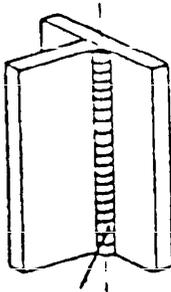
2F



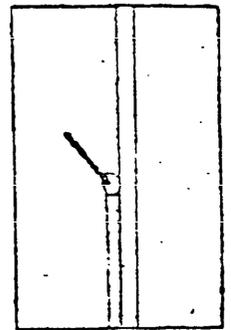
horizontal position. The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.



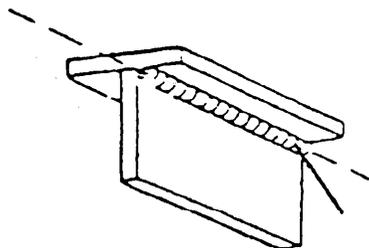
3F



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.

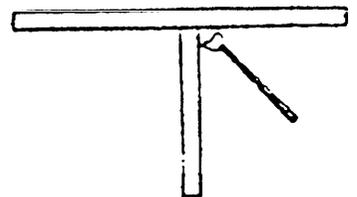
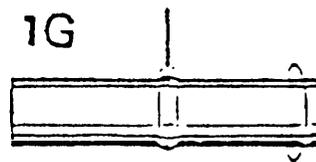
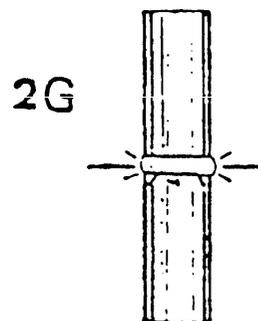


FIGURE 3. Fillet weld in sheet: positions 1F, 2F, 3F, and 4F.

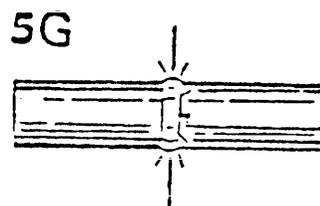
horizontal rolled position. The position of a pipe joint in which the axis of the pipe is approximately horizontal, and welding is performed in the flat position by rotating the pipe.



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  $45^\circ$  to the horizontal and the pipe is not rotated during welding.

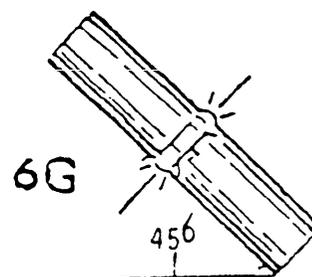
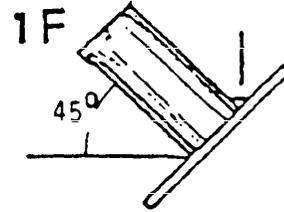
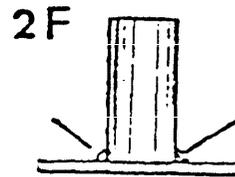


FIGURE 4. Groove weld in tube: positions 1G, 2G, 5G, and 6G.

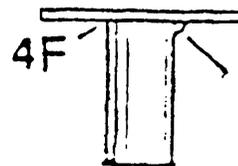
flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal and the pipe is rotated during welding.



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.

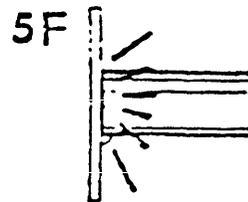


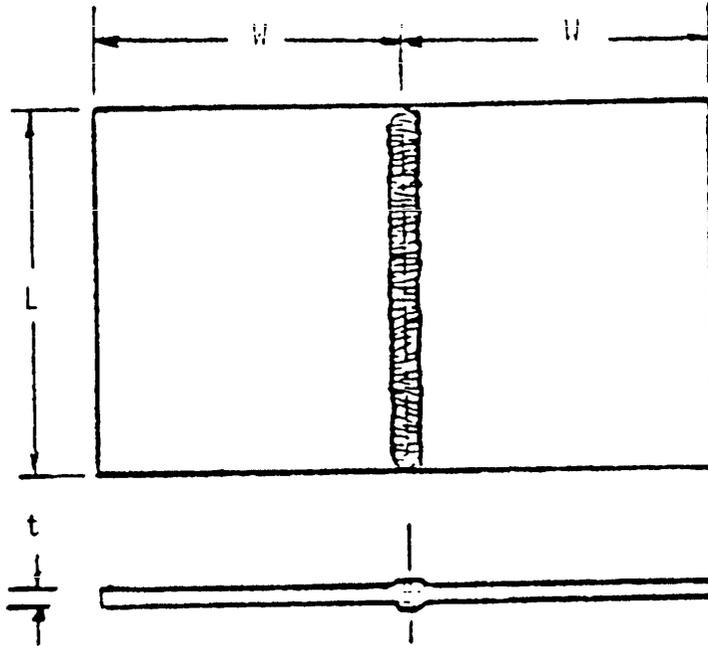
FIGURE 5. Fillet weld in tube: positions 1F, 2F, 4F, and 5F.

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TABLE V. Welding conditions qualified by test weld.

Test weld	Qualified							
	Backing		Groove weld				Current type <u>1/</u>	
	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

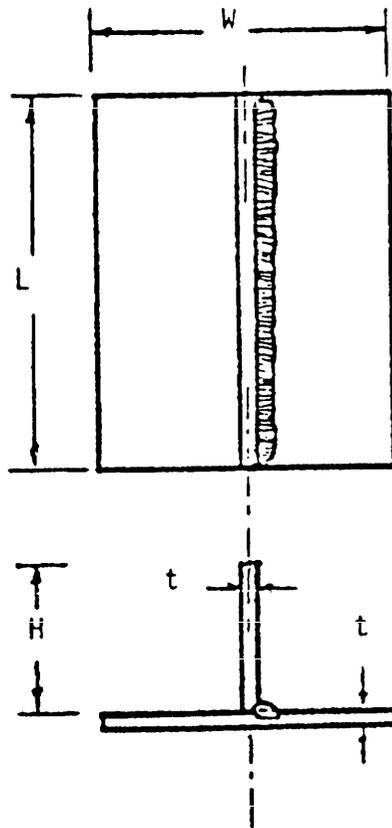
1/ Applicable only to GTAW process (see 5.6.1).



BASE METAL THICKNESS $t$	MINIMUM DIMENSIONS	
	W	L
$\leq 0.063$	2	5
$> 0.063$	3	8

INCHES

FIGURE 6. Groove test weld in sheet.



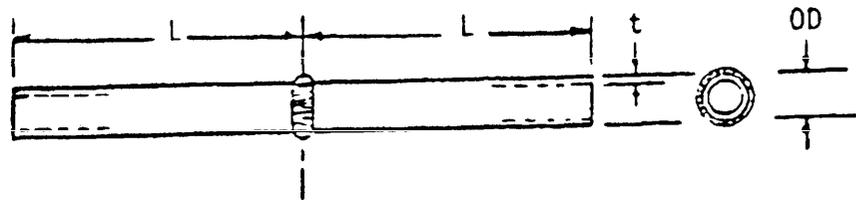
BASE METAL THICKNESS $t$	MINIMUM DIMENSIONS		
	W	L	H
$\leq 0.063$	4	5	2
$> 0.063$	4	8	3

INCHES

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

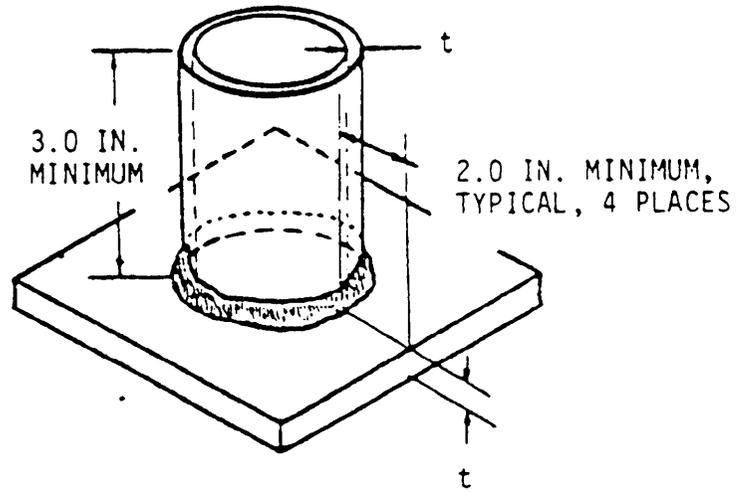
FIGURE 7. Fillet test weld in sheet.

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BASE METAL WALL THICKNESS	MINIMUM DIMENSIONS
t	L
INCHES	
$\leq 0.063$	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.

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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.

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

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

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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	Radio graphic	Bend			Metallographic			
	Form	Thickness t, inch			Applica- bility	Figure reference	Specimens required	Applica- bility	Figure reference	Specimens required	Cross sections required
1	2	3	4	5	6	7	8	9	10	11	12
Groove	Sheet	$\leq 0.063$	All	All 1/	1/	10 & 11	1	None			
		$> 0.063$	All	All 1/	1/	10 & 11	2	None			
Groove	Tube	$\leq 0.063$	All	All	None			None			
		$> 0.063$	All	All 1/	1/	12 & 13	2	None			
Fillet	Sheet	$\leq 0.063$	All	None	None			All	19	4	8
		$> 0.063$	All	None	All 2/	14	1	2/	19	4	8
Fillet	Tube	$\leq 0.063$	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.

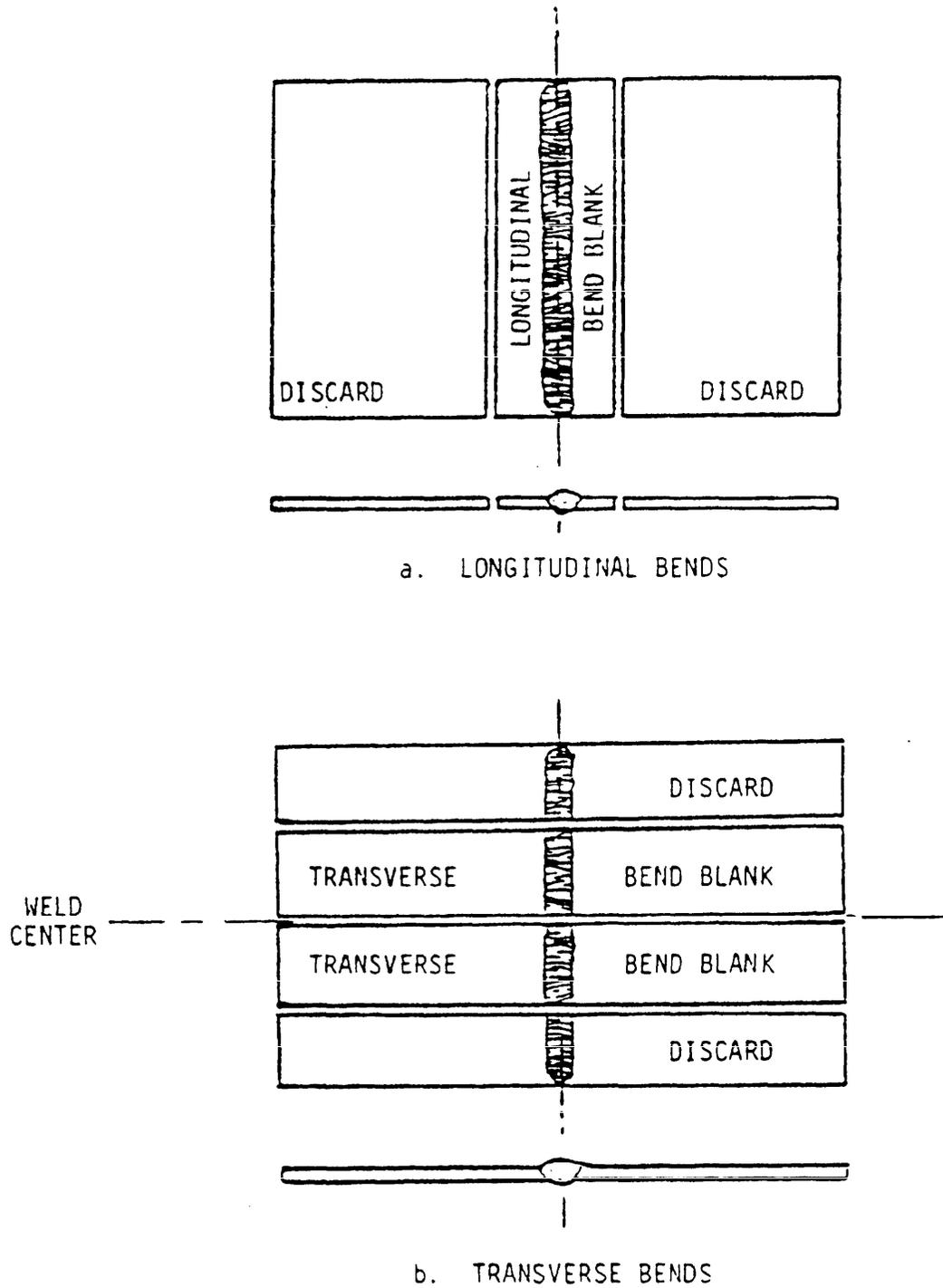
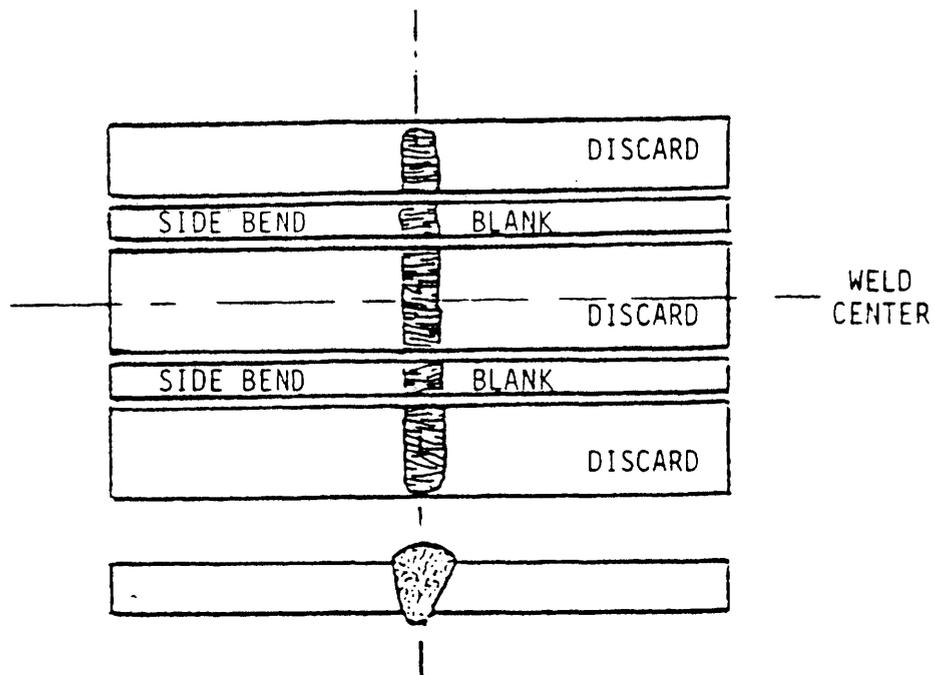


FIGURE 10. Blank locations for bend specimens in groove-welded sheet.



c. SIDE BENDS

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

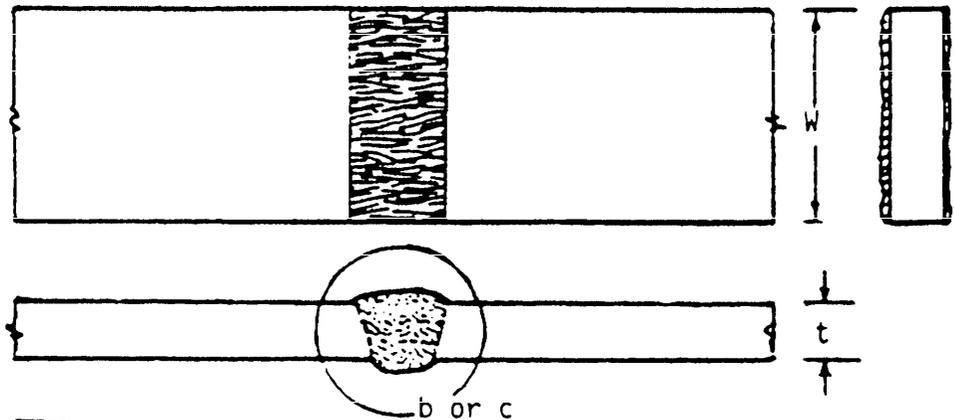
FIGURE 10. Blank locations for bend specimens in groove-welded sheet. Continued.

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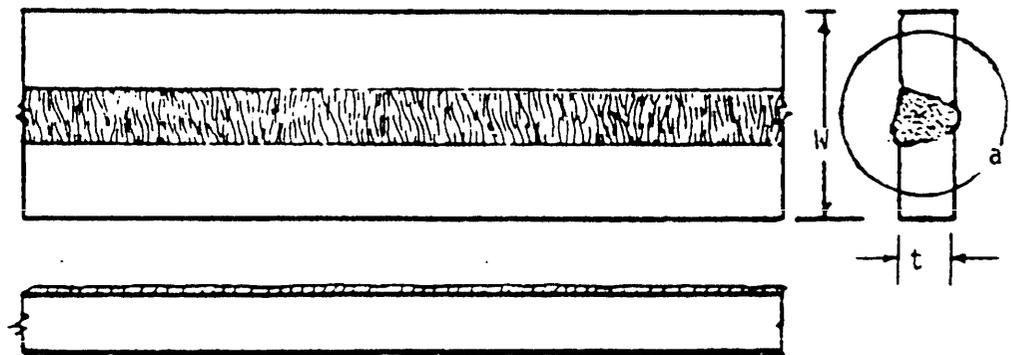
TABLE VIII. Bend specimens for groove welds in sheet.

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

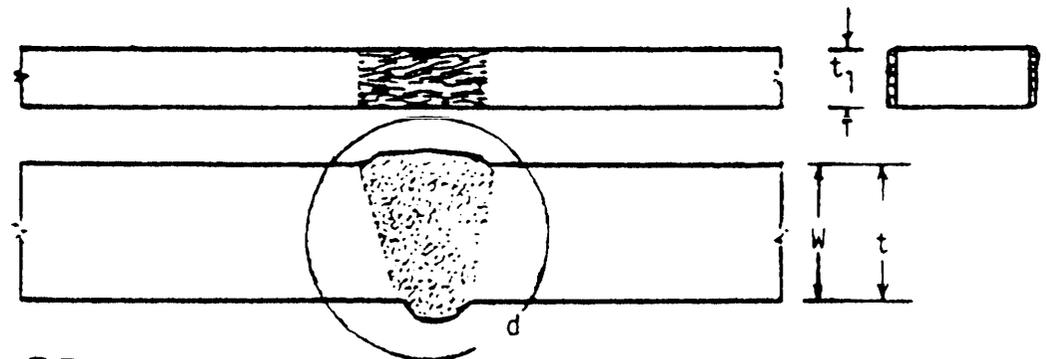
- 1/ The weld face and root surfaces shall be dressed to produce smooth surfaces with a maximum weld metal thickness variation of 10 percent.
- 2/ A96061 and A96063 of Base Metal Group IV.
- 3/ For base metal thicknesses of > 0.750 to 1.50 inch, W is equal to t. For base metal thicknesses of > 1.50 inch 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.



**TB** TRANSVERSE BEND

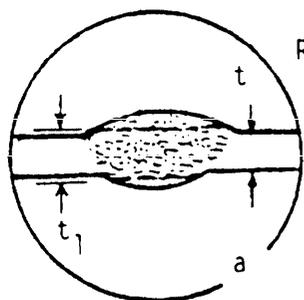


**LB** LONGITUDINAL BEND

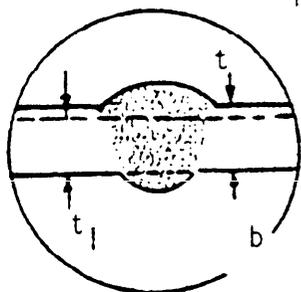


**SB** SIDE BEND

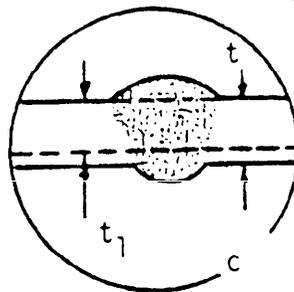
FIGURE 11. Bend specimens in groove-welded sheet.



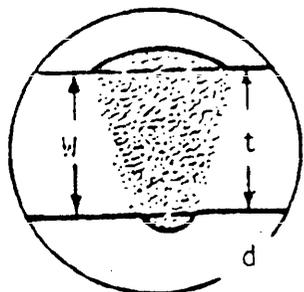
ROOT BEND



ROOT BEND



FACE BEND



SIDE BEND

- NOTES: - Longitudinal corners of 6b, 6c, and 6d specimens shall be rounded to a radius not exceeding 10 percent of the finished thickness.
- Dashed lines indicate machined surfaces.
- Where members of the test weld differ in thickness, the finished dimensions of the bend specimen shall be based on the thickness of the thicker member.

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

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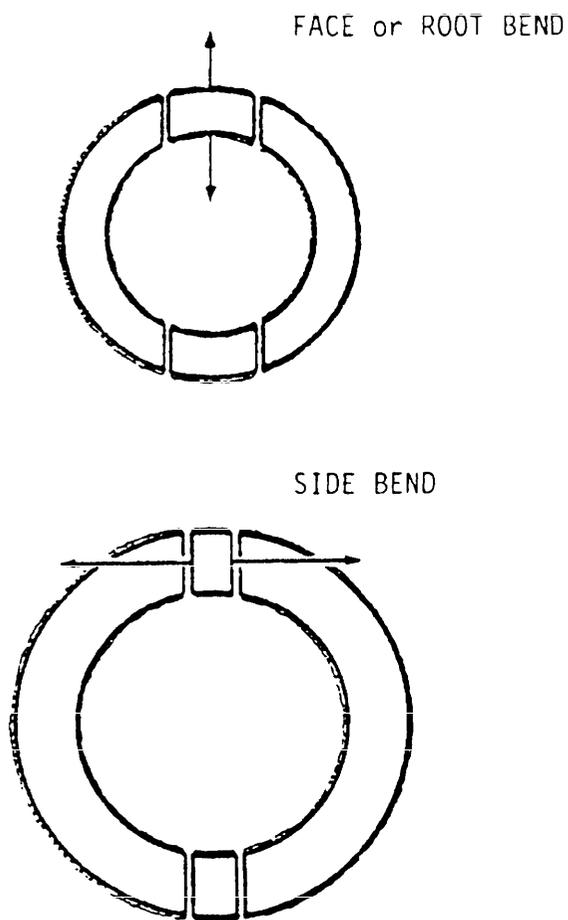


FIGURE 12. Blank locations for bend specimens in groove-welded tube.

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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 not 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.

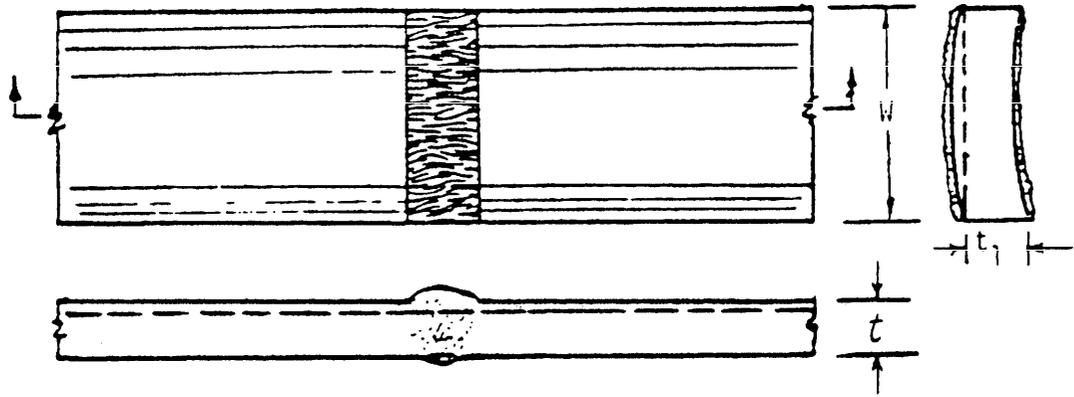
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TABLE IX. Bend specimens for groove welds in tube.

Tube			Bend test specimen				
Outside diameter inch	Wall thickness t, inch	Base metal number	Type shown in Fig. 13	Dimensions, inch			
				t <sub>1</sub>		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	<u>1</u> /	TB-e & TB-f	0.115	0.135	0.750	0.800
		Others	TB-e & TB-f	<u>2</u> /	<u>2</u> /	0.750	0.800
	<0.375- 0.750	<u>1</u> /	TB-e & TB-f or SB-g	0.115	0.135	t	t
		Others	TB-e & TB-f or SB-g	<u>3</u> /	<u>3</u> /	0.750	0.800
	>0.750	<u>1</u> /	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	<u>1</u> /	TB-e & TB-f	0.115	0.135	1.50	1.55
		Others	TB-e & TB-f	<u>2</u> /	<u>2</u> /	1.50	1.55
	>0.375- 0.750	<u>1</u> /	TB-e & TB-f or SB-g	0.115	0.135	t	t
		Others	TB-e & TB-f or SB-g	<u>3</u> /	<u>3</u> /	1.50	1.55
	>0.750	<u>1</u> /	SB-g	0.115	0.135	<u>4</u> /	t
Others		SB-g	0.350	0.400	<u>4</u> /	t	

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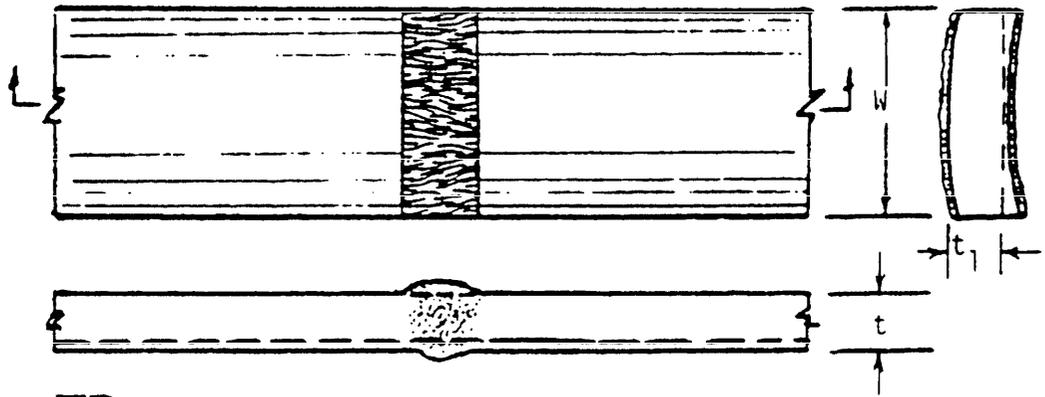
- 1/ A96061 and A96063 of Base Metal Group IV.
- 2/ The maximum  $t_1$  is the thickness resulting from dressing of the curved surface to a plane. The minimum  $t_1$  is 0.9 times the maximum.
- 3/ The maximum  $t_1$  is the thickness resulting from dressing the curved surface to a plane, or 0.400 in., 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.



**TB**

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

a. TRANSVERSE ROOT BEND



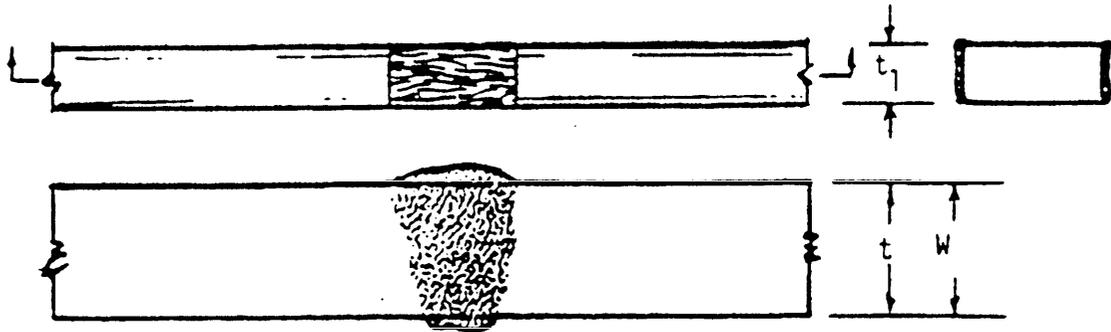
**TB**

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

b. TRANSVERSE FACE BEND

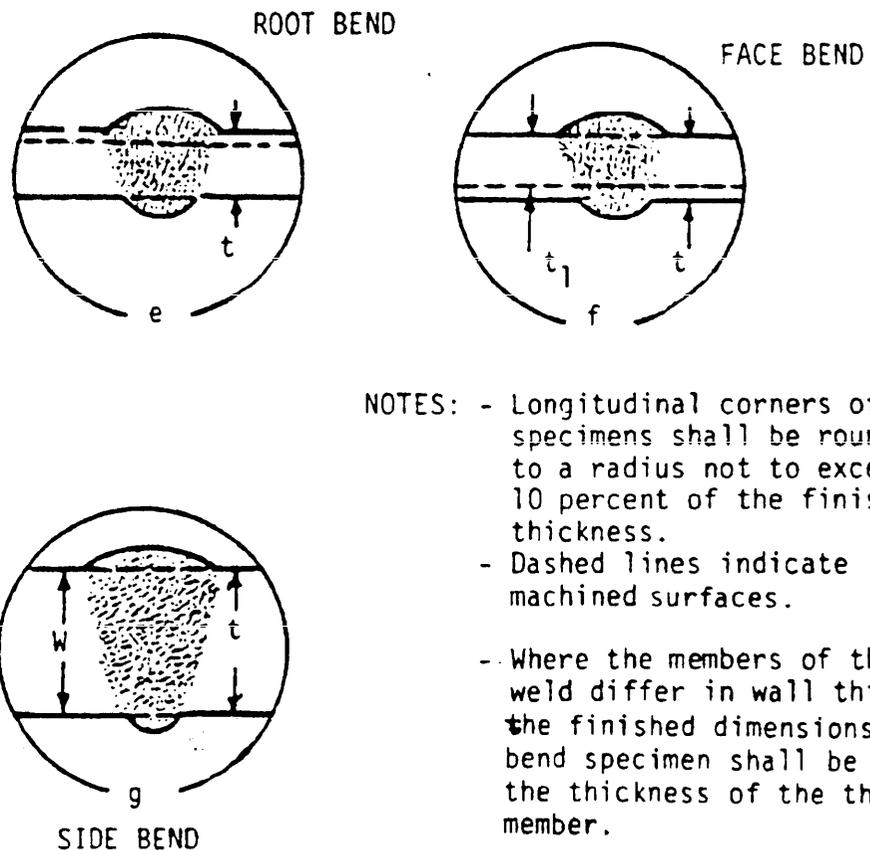
FIGURE 13. Bend specimens in groove-welded tube.

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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.

d. BEND SPECIMEN SECTION DETAILS

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

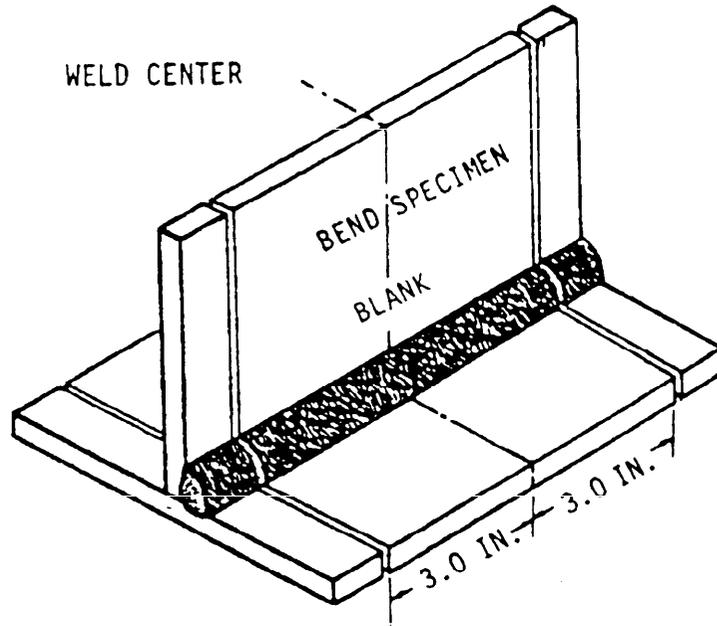
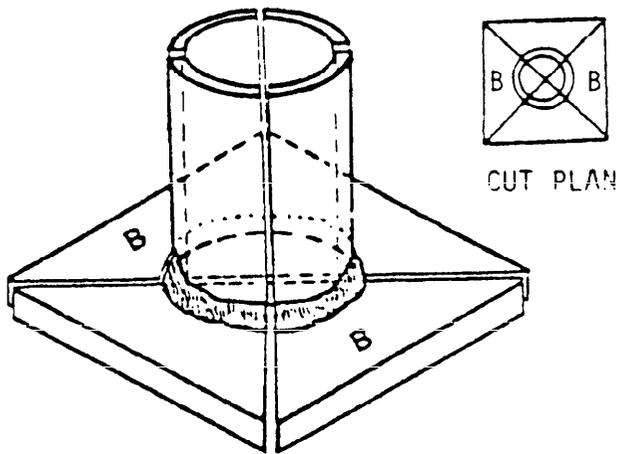
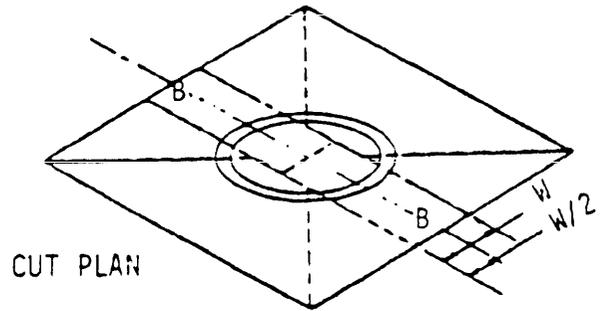
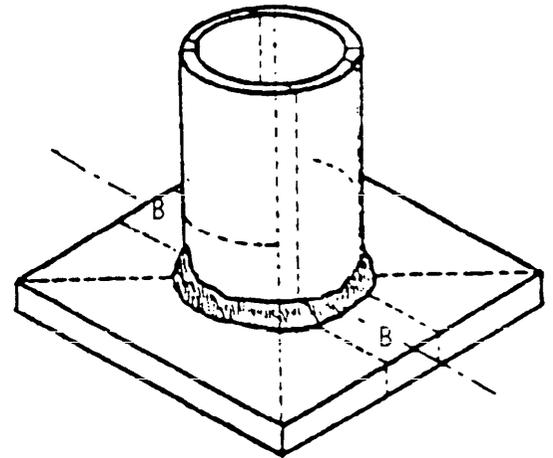


FIGURE 14. Blank location for bend specimens in fillet-welded sheet.

B = BEND SPECIMEN BLANK



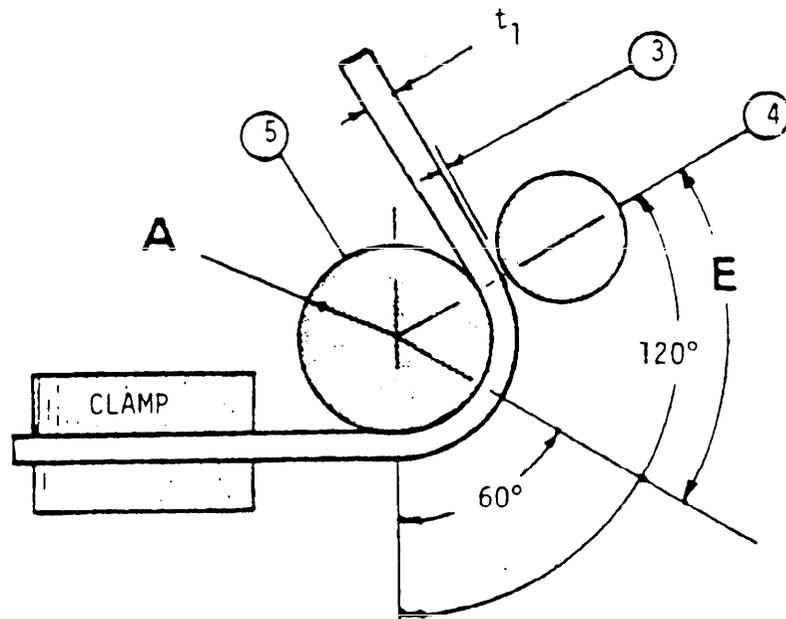
a. For tubes  $< 1.5$  in. in outside diameter, OD



b. For tubes  $\geq 1.5$  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.

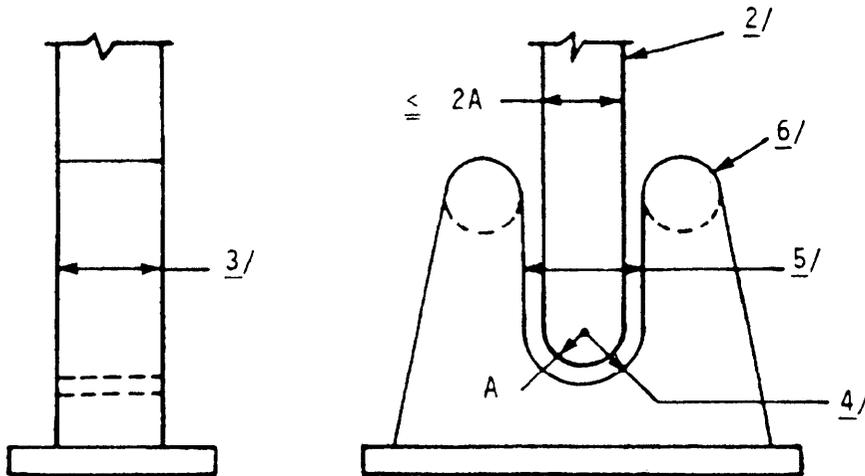


$A = Ft_1$ , where  $A$  is the bend radius  
 $F$  is the bend factor  
 $t_1$  is the bend specimen thickness

## 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.

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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:

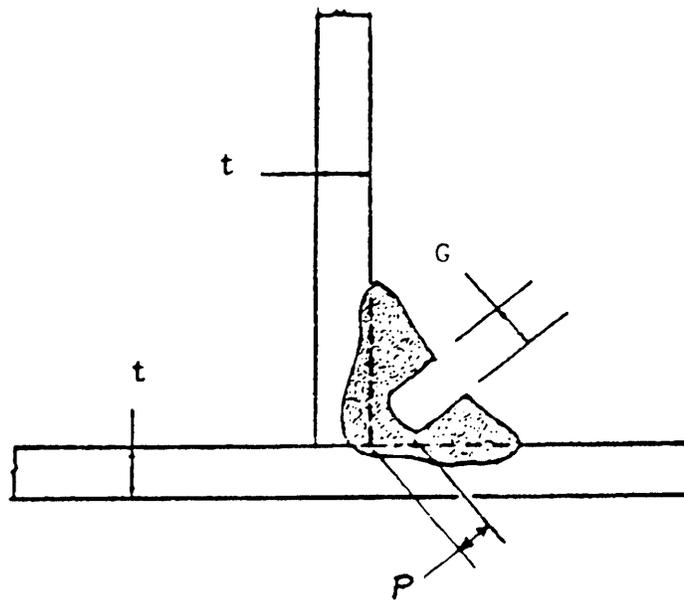
- a. Any type of crack.
- b. Incomplete joint penetration.
- c. Underfill.

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TABLE X. Bend specimen thickness and bend radius.

Bend Radius A Inch <sup>2/</sup>	Bend specimen thickness <sup>1/</sup>					
	Unified number					
	R54520 R54810 R56320 R56400	A96061 A96063	R50400 R50550 R52400	R50250	A95083 A95086 A95456	Others
	F = 12 <sup>3/</sup>	F = 8	F = 5	F = 4	F = 3	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 0.065	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 0.079	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  $\pm 0.001$  in. or  $\pm 1\%$ , 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.

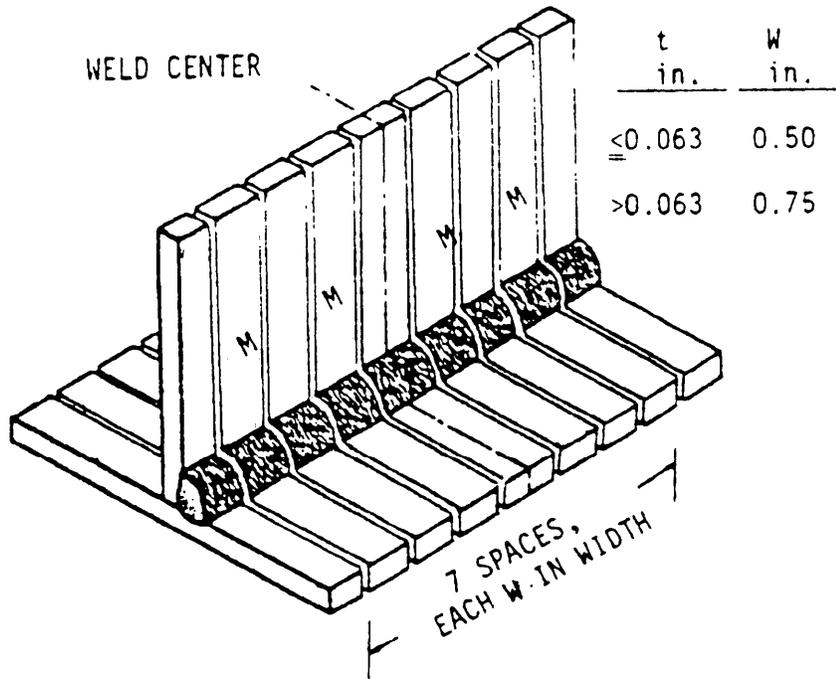


FIGURE 19. Blank locations for metallographic specimens in fillet-welded sheet.

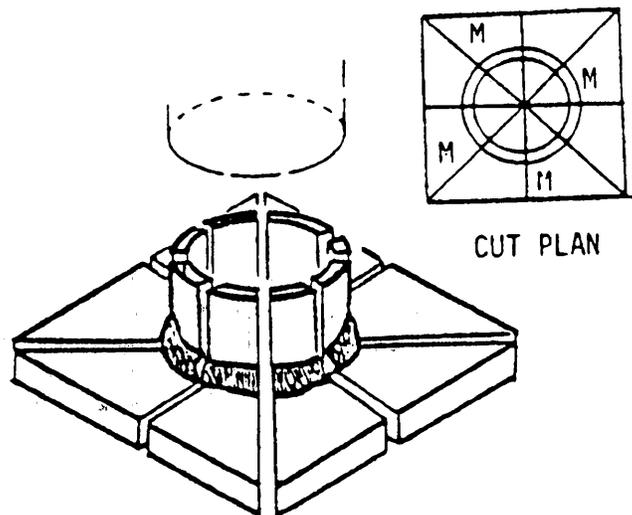


FIGURE 20. Blank locations for metallographic specimens in fillet-welded tube.

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- 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.

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TABLE XI. Maximum allowable weld reinforcement.

Base metal thickness $t$ , in.	Maximum allowable weld reinforcement <sup>1/</sup>			
	Face		Root	
	Base metal group	Any location	Base metal group	Any location
$\leq 0.063$	A11	0.020 inch + $t$ or 0.050 inch	IV and V  Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	0.030 inch + $t$ or 0.070 inch  0.020 inch + $t$ or 0.050 inch
$> 0.063$	A11	0.8 $t$ or 0.25 inch	IV and V  Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	$t$ or 0.25 inch  0.8 $t$ or 0.25 inch

<sup>1/</sup> 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, 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 XI.
- 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 <sup>1/</sup>	
	Base metal thickness, inch	
	≤ 0.063	> 0.063
Length of any indication	2 t	t or 0.38 inch <sup>2/</sup>
Accumulated length in any 1 inch weld length	2 t	t or 0.38 inch <sup>2/</sup>
Average length	t	0.5 t or 0.18 inch <sup>2/</sup>

<sup>1/</sup> Where the members of the test weld differ in thickness, t is the thickness of the thicker member.

<sup>2/</sup> The applicable maximum is the smaller of the two values.

TABLE XIII. Maximum allowable porosity.

Porosity	Porosity size, area, or amount	
	Base metal thickness <u>1/</u>	
	$\leq 0.063$ <u>2/</u>	$> 0.063$ <u>3/</u>
Any pore	0.6 t	0.4 t or 0.18 inch <u>4/</u>
Pores of $> 0.3$ t	8 pores	NA
Pores of $> 0.2$ t or $> 0.12$ inch <u>4/</u>	NA	12 pores
Total porosity area	$0.10 t \text{ inch}^2$	$0.10 \text{ inch}^2$
Cluster porosity area in any $1/2$ inch of weld length	$0.04 t \text{ inch}^2$	$0.025 t \text{ inch}^2$
Aligned porosity area <u>5/</u>	$0.02 t \text{ inch}^2$	$0.015 t \text{ inch}^2$

1/ Where the members of the test weld differ in thickness, t is the thickness of the thicker member.

2/ These values apply to a 4 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

3/ These values apply to a 6 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

4/ The applicable maximum is the lesser of the two values.

5/ Aligned porosity is defined as a group of more than 3 pores within  $1/2$  inch of weld length, and which may be intersected by a straight line.

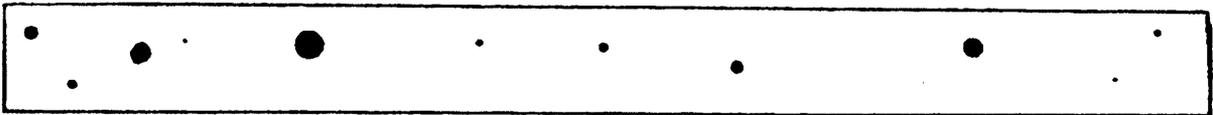
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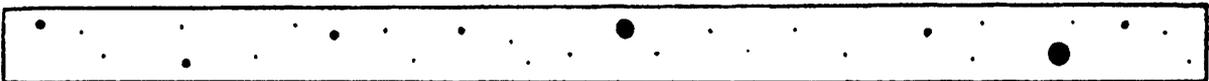
- a. Base metal thickness: 0.032 inch  
Represents 1 inch of weld length at 5X magnification



- b. Base metal thickness: 0.063 inch  
Represents 2 inches of weld length at 3X magnification

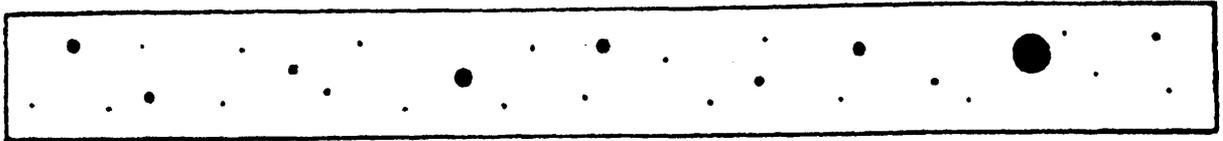


- c. Base metal thickness: 0.125 inch  
Represents 2 inches of weld length at 3X magnification

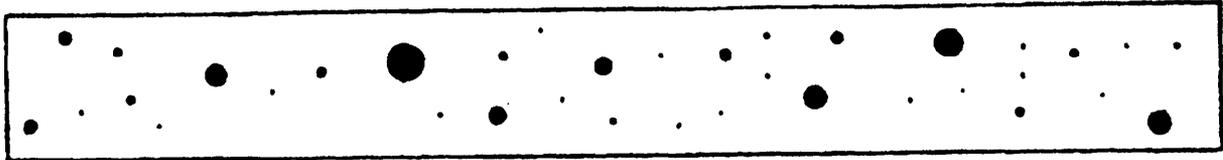


- d. Base metal thickness: 0.250 inch  
Represents 6 inches of weld length at no magnification

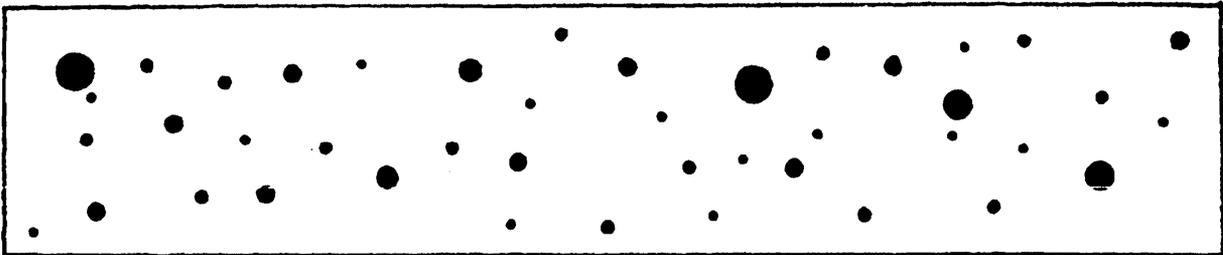
FIGURE 21. Allowable maximum total porosity area and maximum pore size.



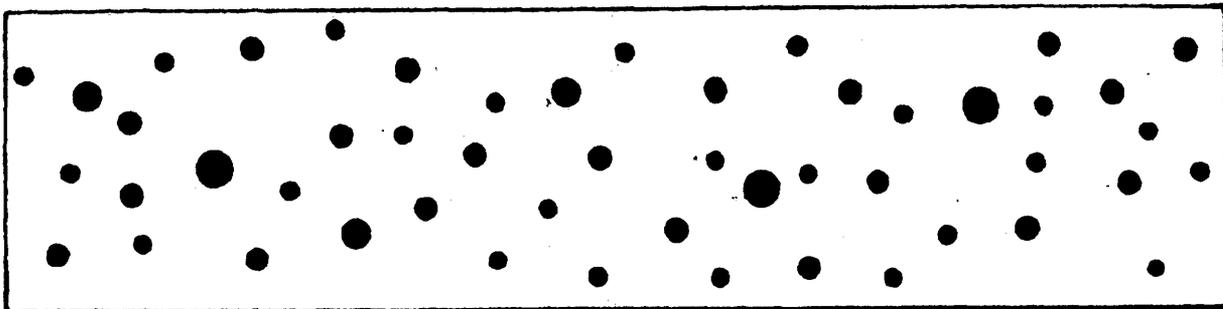
e. Base metal thickness: 0.50 inch  
Represents 6 inches of weld length at no magnification



f. Base metal thickness: 1.00 inch  
Represents 6 inches of weld length at no magnification



g. Base metal thickness: 2.00 inches  
Represents 6 inches of weld length at no magnification



h. Base metal thickness: 4.00 inches  
Represents 6 inches of weld length at no magnification

FIGURE 21. Allowable maximum total porosity area and maximum pore size. Continued.

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5.14.3 Bend specimens.

5.14.3.1 Groove welds. Groove welds bend specimens having open defects exceeding  $t$  or 0.12 inch, whichever is the lesser, on the convex surface are not acceptable. Cracks occurring on the corners shall not be considered, unless it is evident that they result from weld defects.

5.14.3.2 Fillet welds. Fillet weld bend specimens which exhibit less than complete fusion to the root of the joint are not acceptable. The left-hand fillet of Figure 22 illustrates this condition prior to bending. The right-hand fillet illustrates minimum acceptable root fusion.

5.14.4 Metallographic examination.

5.14.4.1 Interpretation of defects.

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

5.14.4.2 Fillet weld defects. Fillet welds which have any of the following defects are unacceptable:

- a. A crack which intersects the weld face.
- b. A crack at the weld root which exceeds 0.2 times the actual throat size or 0.12 inch, whichever is the lesser.
- c. Incomplete fusion at the weld face.
- d. Overlap.
- e. Undercut at any cross section in excess of  $0.1 t$  or 0.063 inch, whichever is the lesser.

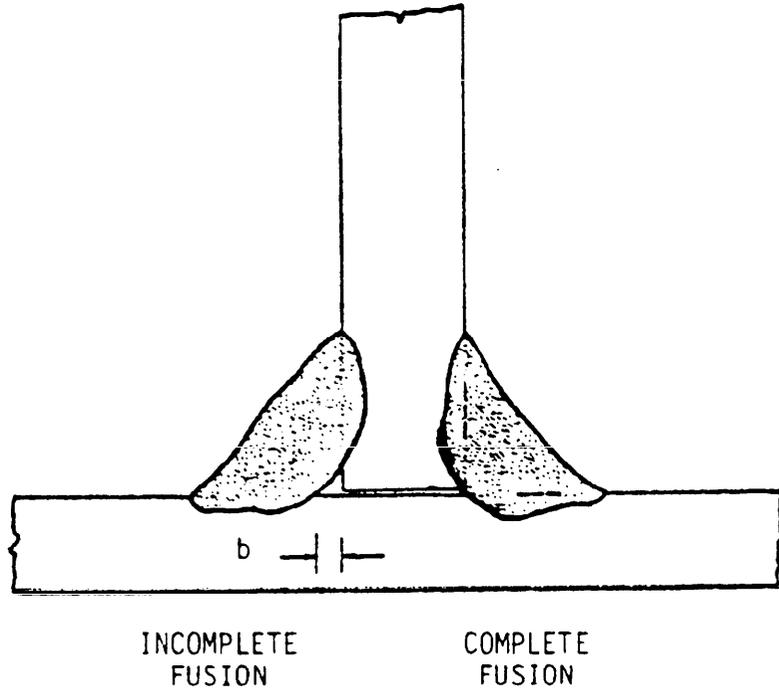


FIGURE 22. Complete and incomplete fusion in fillet welds.

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- f. For base metal thickness of equal to or less than 1.00 inch, a leg size less than  $t$ . For a base metal thickness of more than 1.00 inch, the minimum leg size shall be more than 1 inch. Where members of the test weld differ in thickness, the minimum leg size shall be based on the thinner member.
- g. A ratio of the leg of larger size to the leg of smaller size greater than 1.5 at any cross section.
- h. For a convex weld, at any cross section a convexity in excess of 0.1 times the average of the two leg sizes.
- i. For a concave weld, an actual throat size of less than 0.5  $t$  at any cross section. Where the members of the test weld differ in thickness, the minimum actual throat shall be based on the thinner member.
- j. Any linear defect in excess of 0.3 times the actual throat size or 0.12 inch, whichever is the lesser.
- k. A total porosity area, on any cross section, greater than 0.05 times the area of the weld metal.

5.14.4.3 Base metal thickness of equal to or less than 0.063 inch. Fillet welds in sheet or tube with a base metal thickness of equal to or less than 0.063 inch, which have any of the following defects, are unacceptable:

- a. Weld metal at a sheet or tube surface opposite the weld bead and extending more than  $t$  beyond the sheet or tube surface; at any cross section.
- b. A leg size larger than 6  $t$  or  $t$  plus 0.18 inch, whichever is the lesser. Where members of the test weld differ in thickness the maximum leg size shall be based on the thinner member.
- c. Incomplete fusion, at either weld leg, as shown in Figure 22, with a dimension  $b$  in excess of 0.3 times the actual throat size.
- d. An individual pore size in excess of 0.6  $t$ , where  $t$  is the thickness of the thicker member of the test weld.

5.14.4.4 Base metal thickness 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. Fusion evident at any sheet or tube surface opposite the weld bead.
- b. A leg size larger than 3  $t$  or  $t$  plus 0.25 inch, whichever is the lesser. Where members of the test weld differ in thickness, the maximum leg size shall be based on the thinner member.

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- c. Less than complete fusion to the root of the joint, as illustrated in Figure 22.
- d. An individual pore size in excess of 0.4 t or 0.18 inch, whichever is the lesser. Where the members of the test weld differ in thickness, t shall be based on the thickness of the thicker member.

Custodians:

Air Force - 20  
Army - MR  
Navy - AS

Preparing activity:

Air Force - 20

(Project THJM-0090)

Review activities:

Air Force - 99  
Army - EA, AR, MI

User activities:

Army - AV

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APPENDIX

SPECIFIC BASE METALS OF BASE METAL GROUPS

10. GENERAL

10.1 Scope. The classification of metals by base metal groups for welder and welding operator qualification is given in this Appendix. The base metals are identified by the Unified Number of the Unified Numbering System for Metals and Alloys and by the common description.

10.2 This Appendix is a mandatory part of this Standard.

Base Metal Group Ia. Carbon and Alloy Steels

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
G10050	Carbon steel	G15220	Carbon steel
G10060	Carbon steel	G15240	Carbon steel
G10080	Carbon steel	G15270	Carbon steel
G10090	Carbon steel	J02502	Carbon steel
G10100	Carbon steel	J02503	Carbon steel
G10110	Carbon steel	J02504	Carbon steel
G10120	Carbon steel	J02505	Carbon steel
G10130	Carbon steel	J02506	Low alloy steel
G10150	Carbon steel	J03002	Carbon steel
G10160	Carbon steel	J03003	Carbon steel
G10170	Carbon steel	J03004	Carbon steel
G10180	Carbon steel	J03011	Carbon steel
G10190	Carbon steel	J11522	Low alloy steel
G10200	Carbon steel	J11549	Low alloy steel
G10210	Carbon steel	J12072	Low alloy steel
G10220	Carbon steel	J12080	Carbon steel
G10230	Carbon steel	J12082	Low alloy steel
G10250	Carbon steel	J12092	Carbon steel
G10260	Carbon steel	J12522	Low alloy steel
G10290	Carbon steel	J12524	Low alloy steel
G10300	Carbon steel	J13005	Low alloy steel
G10330	Carbon steel	J13047	Low alloy steel
G10340	Carbon steel	J21890	Low alloy steel
G10350	Carbon steel	J22000	Low alloy steel
G10370	Carbon steel	J22091	Low alloy steel
G10380	Carbon steel	J31550	Low alloy steel
G10390	Carbon steel	J42045	Alloy steel
G10400	Carbon steel	J82090	Alloy steel

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## Base Metal Group Ia. Carbon and Alloy Steels (continued)

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
K01200	Carbon steel	K02700	Carbon steel
K01201	Carbon steel	K02701	Carbon steel
K01501	Carbon steel	K02702	Carbon steel
K01502	Carbon steel	K02703	Carbon steel
K01504	Carbon steel	K02704	Carbon steel
K01506	Carbon steel	K02705	Carbon steel
K01601	Carbon steel	K02707	Carbon steel
K01700	Carbon steel	K02800	Carbon steel
K01701	Carbon steel	K02801	Carbon steel
K01800	Carbon steel	K02802	Carbon steel
K01801	Carbon steel	K02803	Carbon steel
K01802	Carbon steel	K02804	Carbon steel
K01805	Carbon steel	K02900	Carbon steel
K01806	Carbon steel	K03000	Carbon steel
K01807	Carbon steel	K03002	Carbon steel
K01808	Carbon steel	K03003	Carbon steel
K02000	Carbon steel	K03004	Carbon steel
K02001	Carbon steel	K03005	Carbon steel
K02003	Low alloy steel	K03006	Carbon steel
K02004	Carbon steel	K03007	Carbon steel
K02005	Carbon steel	K03008	Carbon steel
K02007	Carbon steel	K03009	Carbon steel
K02008	Carbon steel	K03010	Carbon steel
K02100	Carbon steel	K03011	Carbon steel
K02101	Carbon steel	K03012	Carbon steel
K02102	Carbon steel	K03013	Carbon steel
K02104	Carbon steel	K03100	Carbon steel
K02200	Carbon steel	K03101	Carbon steel
K02201	Carbon steel	K03102	Carbon steel
K02202	Carbon steel	K03103	Carbon steel
K02203	Carbon steel	K03200	Carbon steel
K02300	Carbon steel	K03300	Carbon steel
K02400	Carbon steel	K03501	Carbon steel
K02401	Carbon steel	K03502	Carbon steel
K02402	Carbon steel	K03503	Carbon steel
K02403	Carbon steel	K03504	Carbon steel
K02404	Carbon steel	K03505	Carbon steel
K02500	Carbon steel	K03506	Carbon steel
K02500	Carbon steel	K03507	Carbon steel
K02501	Carbon steel	K04001	Carbon steel
K02502	Carbon steel	K04700	Carbon steel
K02503	Carbon steel	K05001	Carbon steel
K02504	Carbon steel	K05200	Carbon steel
K02505	Carbon steel	K07501	Carbon steel
K02506	Carbon steel	K11224	Low alloy steel
K02600	Carbon steel	K11267	Low alloy steel
K02601	Carbon steel	K11422	Low alloy steel

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## Base Metal Group Ia. Carbon and Alloy Steels (continued)

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
K11430	Carbon steel	K12021	Low alloy steel
K11501	Carbon steel	K12022	Low alloy steel
K11510	Carbon steel	K12023	Low alloy steel
K11511	Low alloy steel	K12032	Low alloy steel
K11522	Low alloy steel	K12039	Low alloy steel
K11523	Low alloy steel	K12040	Low alloy steel
K11526	Low alloy steel	K12042	Low alloy steel
K11535	Low alloy steel	K12043	Low alloy steel
K11538	Low alloy steel	K12044	Low alloy steel
K11540	Low alloy steel	K12045	Low alloy steel
K11541	Low alloy steel	K12047	Low alloy steel
K11547	Low alloy steel	K12054	Low alloy steel
K11552	Low alloy steel	K12122	Low alloy steel
K11562	Low alloy steel	K12143	Low alloy steel
K11564	Low alloy steel	K12202	Low alloy steel
K11567	Low alloy steel	K12203	Low alloy steel
K11572	Low alloy steel	K12211	Low alloy steel
K11576	Low alloy steel	K12320	Low alloy steel
K11578	Low alloy steel	K12520	Low alloy steel
K11591	Low alloy steel	K12521	Low alloy steel
K11597	Low alloy steel	K12524	Low alloy steel
K11625	Low alloy steel	K12529	Low alloy steel
K11630	Low alloy steel	K12539	Low alloy steel
K11646	Low alloy steel	K12542	Low alloy steel
K11662	Low alloy steel	K12554	Low alloy steel
K11682	Low alloy steel	K12609	Low alloy steel
K11683	Low alloy steel	K12700	Low alloy steel
K11695	Low alloy steel	K12765	Alloy steel
K11742	Low alloy steel	K12766	Alloy steel
K11757	Low alloy steel	K12822	Low alloy steel
K11789	Low alloy steel	K13502	Low alloy steel
K11803	Low alloy steel	K20622	Low alloy steel
K11820	Low alloy steel	K20747	Low alloy steel
K11847	Low alloy steel	K21509	Low alloy steel
K11856	Low alloy steel	K21590	Low alloy steel
K11872	Low alloy steel	K21604	Low alloy steel
K12000	Low alloy steel	K21650	Low alloy steel
K12003	Low alloy steel	K21703	Low alloy steel
K12010	Low alloy steel	K21903	Low alloy steel
K12020	Low alloy steel	K22035	Low alloy steel

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Base Metal Group Ia. Carbon and Alloy Steels (continued)

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
K22036	Low alloy steel	K42544	Alloy steel
K22103	Low alloy steel	K51255	Alloy steel
K22375	Low alloy steel	K51545	Alloy steel
K31509	Low alloy steel	K61595	Alloy steel
K31545	Low alloy steel	K71340	Alloy steel
K31718	Low alloy steel	K81340	Alloy steel
K31918	Low alloy steel	K81590	Alloy steel
K32018	Low alloy steel	K90941	Alloy steel
K32025	Low alloy steel	K92810	18Ni maraging steel
K41245	Alloy steel	K93601	Alloy steel
K41545	Alloy steel	NA	9Ni-4Co steel
K41583	Alloy steel		

Base Metal Group Ib. Alloy Steels

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
G41300	4130	K24728	D6AC
G41350	4135	K44315	300M
G41400	4140	T20811	H11
G43400	4340		
G86300	8630		

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Base Metal Group IIa. Stainless Steels

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
J91150	Stainless steel	S31008	310S
J91151	Stainless steel	S31500	Stainless steel
J91540	Stainless steel	S31600	316
J92500	Stainless steel	S31603	316L
J92600	Stainless steel	S31609	316H
J92710	Stainless steel	S31651	316N
J92800	Stainless steel	S31700	317
J92900	Stainless steel	S31703	317L
J93400	Stainless steel	S32100	321
J93402	Stainless steel	S32109	321H
J94202	Stainless steel	S32900	329
J95150	Stainless steel	S33100	Stainless steel
K63198	19-9 DL	S34700	347
K63199	19-9 DX	S34709	347H
K64299	29-9	S34800	348
R30155	N155	S34809	348H
R30590	S590	S35000	AM350 PH stainless steel
S15500	15-5 PH stainless steel	S35500	AM355 PH stainless steel
S16800	Stainless steel	S38100	Stainless steel
S17400	17-4 PH stainless steel	S40300	403
S20100	201	S40500	405
S20200	202	S40900	409
S20910	Stainless steel	S41000	410
S21600	216	S41008	410S
S21603	216L	S41040	Stainless steel
S21900	21-6-9	S41460	Stainless steel
S21904	21-6-9 LC	S41461	Stainless steel
S24000	Stainless steel	S41800	Greek Ascoloy
S30100	301	S42000	420
S30200	302	S42200	422
S30215	302B	S42900	429
S30400	304	S43000	430
S30403	304L	S43035	Stainless steel
S30409	304H	S44300	443
S30451	304N	S44400	Stainless steel
S30452	Stainless steel	S44600	446
S30500	305	S44625	Stainless steel
S30800	308	S45000	Custom 450
S30900	309	S45500	Custom 455
S30908	309S	NA	16-25-6
S31000	310		

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Base Metal Group IIb. Precipitation Hardening Stainless Steels

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
K66286	A286 stainless steel	S15700	PH 15-7Mo stainless steel
K66545	W545	S17700	17-7PH stainless steel
S13800	PH 13-8Mo stainless steel		

Base Metal Group IIIa. Nickel and Nickel-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
N02200	Nickel 200	N08330	RA330
N02201	Nickel 201	N08800	Incoloy 800
N04400	Monel 400	N08810	Incoloy 800H
N06002	Hasteloy X	N08825	Incoloy 825
N06007	Hasteloy G	N08904	Fe-Ni-Cr alloy
N06455	Hasteloy C4	N10001	Hasteloy B
N06600	Inconel 600	N10002	Hasteloy C
N06625	Inconel 625	N10003	Hasteloy N
N06975	Hasteloy G2	N10276	Hasteloy 276
N08020	Carpenter Cb3	N10665	Hasteloy B2
N08320	Haynes 20 Mod		

Base Metal Group IIIb. Precipitation Hardening Nickel-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
N05500	Monel K500	N07750	Inconel X750
N06601	Inconel 601	N09706	Inconel 706
N07001	Waspaloy	N09901	Incoloy 901
N07041	Rene 41	NA	Rene 77
N07252	M252	NA	Rene 80
N07500	Udimet 500	NA	Udimet 700
N07718	Inconel 718		

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## Base Metal Group IV. Aluminum and Aluminum-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
A03560	356	A95086	5086
A91060	1060	A95154	5154
A91100	1100	A95254	5254
A92014	2014	A95454	5454
A92219	2219	A95456	5456
A93003	3003	A95652	5652
A93004	3004	A96061	6061
A95052	5052	A96063	6063
A95083	5083		

## Base Metal Group V. Magnesium-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
M10100	AM100A	M13210	HM21A
M11311	AZ31B	M13310	HK31A
M11610	AZ61A	M13312	HM31A
M11800	AZ80A	M13320	HZ32A
M11910	AZ91A	M14141	LA141A
M11920	AZ92A	M16620	ZH62A
M12330	EZ33A	M18220	QE22A

## Base Metal Group VI. Titanium and Titanium-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
R50250	Titanium	R56260	Ti-6Al-2Sn-4Zr-6Mo
R50400	Titanium	R56320	Ti-3Al-2.5V
R50550	Titanium	R56400	Ti-6Al-4V
R52400	Titanium	R56620	Ti-6Al-6V-2Sn
R54520	Ti-5Al-2.5Sn	R58640	Ti-3Al-8V-6Cr-4Mo-4Zr
R54620	Ti-6Al-2Sn-4Zr-2Mo	NA	Ti-6Al-2Sn-2Zr-2Cr-2Mo
R54810	Ti-8Al-1Mo-1V	NA	Ti-15V-3Cr-3Mo-3Sn
R56210	Ti-6Al-2Cb-1Ta-1Mo		

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Base Metal Group VII. Cobalt-Base Alloys

<u>Unified Number</u>	<u>Common Description</u>	<u>Unified Number</u>	<u>Common Description</u>
R30006	Stellite 6	R30031	Stellite 31
R30021	Stellite 21	R30188	HS188
R30023	Stellite 23	R30605	L605
R30027	Stellite 27	R30816	S816
R30030	Stellite 30		

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