

Standard Methods for Mechanical Testing of Welds



Documents

Document Sharing Hub

AWS B4.0:2016-AMD1
An American National Standard

Approved by
American National Standards Institute

Standard Methods for Mechanical Testing of Welds

8th Edition

Supersedes AWS B4.0:2007

Prepared by the
AWS Committee on B4 Committee on Mechanical Testing of Welds

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

Mechanical test methods that are applicable to welds and welded joints are described. For each testing method, information is provided concerning applicable American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), and American Petroleum Institute (API) documents; the required testing apparatus, specimen preparation, procedure to be followed, and report requirements are also described.



ISBN: 978-0-87171-889-1
© 2016 by American Welding Society
All rights reserved
Printed in the United States of America

Photocopy Rights. No portion of this standard may be reproduced, stored in a retrieval system, or transmitted in any form, including mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner. Authorization to photocopy items for internal, personal, or educational classroom use only or the internal, personal, or educational classroom use only of specific clients is granted by the American Welding Society provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, tel: (978) 750-8400; Internet: <www.copyright.com>.

Statement on the Use of American Welding Society Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

AWS American National Standards are developed through a consensus standards development process that brings together volunteers representing varied viewpoints and interests to achieve consensus. While AWS administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its standards.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this standard. AWS also makes no guarantee or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this standard available, AWS is neither undertaking to render professional or other services for or on behalf of any person or entity, nor is AWS undertaking to perform any duty owed by any person or entity to someone else. Anyone using these documents should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. It is assumed that the use of this standard and its provisions is entrusted to appropriately qualified and competent personnel.

This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page (www.aws.org). Users should ensure that they have the latest edition, amendments, errata, and addenda.

Publication of this standard does not authorize infringement of any patent or trade name. Users of this standard accept any and all liabilities for infringement of any patent or trade name items. AWS disclaims liability for the infringement of any patent or product trade name resulting from the use of this standard.

AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so. Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Managing Director, Technical Services Division, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex B). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS B4 Committee on Mechanical Testing of Welds. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the B4 Committee on Mechanical Testing of Welds and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS B4 Committee on Mechanical Testing of Welds to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

Personnel (Amendment)

AWS Committee on Mechanical Testing of Welds

P. S. Lester, Chair	<i>AZZ WSI</i>
J. A. Grantham, Vice Chair	<i>Welding & Joining Management Group</i>
S. P. Hedrick, Secretary	<i>American Welding Society</i>
D. A. Fink	<i>The Lincoln Electric Company</i>
J. W. Sowards	<i>NIST Boulder</i>
L. Van Leaven	<i>Consultant</i>
R. F. Waite	<i>Consultant</i>

Advisors to the AWS Committee on Mechanical Testing of Welds

J. J. DeLoach, Jr	<i>Naval Surface Warfare Center</i>
E. L. Lavy	<i>Consultant</i>
L. Li	<i>University of Alberta</i>
J. A. Major	<i>The Lincoln Electric Company</i>
T. McGaughy	<i>Edison Welding Institute</i>
K. M. Merlo-Joseph	<i>Apeks Supercritical</i>
H. W. Mishler	<i>Consultant</i>
G. R. Pearson	<i>Anderson Laboratories</i>
A. G. Portz	<i>Consultant</i>
J. H. Smith	<i>Consultant</i>
W. W. StCyr II	<i>Consultant</i>
R. J. Wong	<i>Naval Surface Warfare Center</i>
K. Zerkle	<i>Consultant</i>

This page is intentionally blank.

Personnel (Original)

AWS Committee on Mechanical Testing of Welds

L. Van Leaven, Chair	<i>Consultant</i>
P. S. Lester, Vice Chair	<i>AZZ WSI</i>
S. P. Hedrick, Secretary	<i>American Welding Society</i>
J. R. Crisci	<i>Consultant</i>
D. A. Fink	<i>The Lincoln Electric Company</i>
J. A. Grantham	<i>Welding & Joining Management Group</i>
J. W. Sowards	<i>NIST Boulder</i>
R. F. Waite	<i>Consultant</i>

Advisors to the AWS Committee on Mechanical Testing of Welds

J. J. DeLoach, Jr	<i>Naval Surface Warfare Center</i>
E. L. Lavy	<i>Consultant</i>
L. Li	<i>University of Alberta</i>
J. A. Major	<i>The Lincoln Electric Company</i>
T. McGaughy	<i>Edison Welding Institute</i>
K. M. Merlo-Joseph	<i>Apeks Supercritical</i>
H. W. Mishler	<i>Consultant</i>
G. R. Pearson	<i>Anderson Laboratories</i>
A. G. Portz	<i>Consultant</i>
J. H. Smith	<i>Consultant</i>
W. W. StCyr II	<i>Consultant</i>
R. J. Wong	<i>Naval Surface Warfare Center</i>
K. Zerkle	<i>Consultant</i>

Foreword

This foreword is not part of this standard but is included for informational purposes only.

This standard covers the common tests for the mechanical testing of welds. They are defined and illustrated in sections related to tension tests, shear tests, bend tests, fracture toughness tests, hardness tests, break tests (nick and fillet welds), selected weldability tests and process specific tests (stud weld tests and resistance weld tests).

This document extensively references American Society for Testing and Materials (ASTM) Standard Methods and specifies how to use these methods when testing weldments. It takes into consideration the variations in properties that can occur between different regions (base metal, heat-affected zone, and weld metal) of a weldment.

Methods of hardness testing and mechanical property tests for base metals are covered by ASTM standards or the individual material specification. The joint tests for brazements are covered in AWS C3.2M/C3.2, *Standard Methods for Evaluating the Strength of Brazed Joints*. Additional information on the mechanical testing of welded joints may be obtained from the AWS Welding Handbook, Ninth Edition, Volume 1, which describes selected weldability test methods.

AWS B4.0:2016, *Standard Methods for the Mechanical Testing of Welds*, is the eighth edition of the document initially published in 1942. The second edition (1974) incorporated metric conversions and the third edition (1977) incorporated minor changes. The fourth edition (1985) added the plane-strain fracture toughness test and the fifth edition (1992) added hardness testing and stud weld tests, and organized the tests by weld type. The sixth edition (1998) added six new weldability tests. The seventh edition included three new weldability tests (WIC, trough, and GBOP) and resistance weld tests. The current edition includes two new annexes (C and D) which address tensile testing of narrow groove welds. Several figures were updated and changes in text are indicated by a vertical margin line. Previous editions of the document are as follows:

AWS A4.0-42, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0-74, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0-77, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0-85, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0-92, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0-98, *Standard Methods for Mechanical Testing of Welds*

AWS B4.0:2007, *Standard Methods for Mechanical Testing of Welds*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, Committee on Standard Methods for Mechanical Testing of Welds, American Welding Society, 8669 NW 36 St, Miami, FL 33166.

Amendments

The following Amendments have been identified and incorporated in this reprint.

AWS Standard: B4.0:2016

Amendment Number: 1

Subject: Clause 7.2, replace reference ASTM A370 with ASTM E23:

ASTM Documents:

ASTM E23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

ASTM E208, Standard Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

ASTM E399, Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials

ASTM E604, Standard Test Method for Dynamic Tear Testing of Metallic Materials

ASTM E1820, Standard Test Method for Measurement of Fracture Toughness

ASTM E1823, Standard Terminology Relating to Fatigue and Fracture Testing

ASTM E1921, Standard Method for Determination of Reference Temperature, T_0 , for Ferritic Steels in the Transition Range.

AWS Standard: B4.0:2016

Amendment Number: 1

Subject: Clause 7.5.1, replace “ASTM A370” with “ASTM E23”:

7.5.1 The apparatus for conducting the various fracture toughness tests shall be in accordance with the latest edition of the following ISO and ASTM Standard Test Methods:

- (1) Charpy V-notch, ASTM E23;

AWS Standard: B4.0:2016

Amendment Number: 1

Subject: Clause 7.7.1, replace “ASTM A370” with “ASTM E23”:

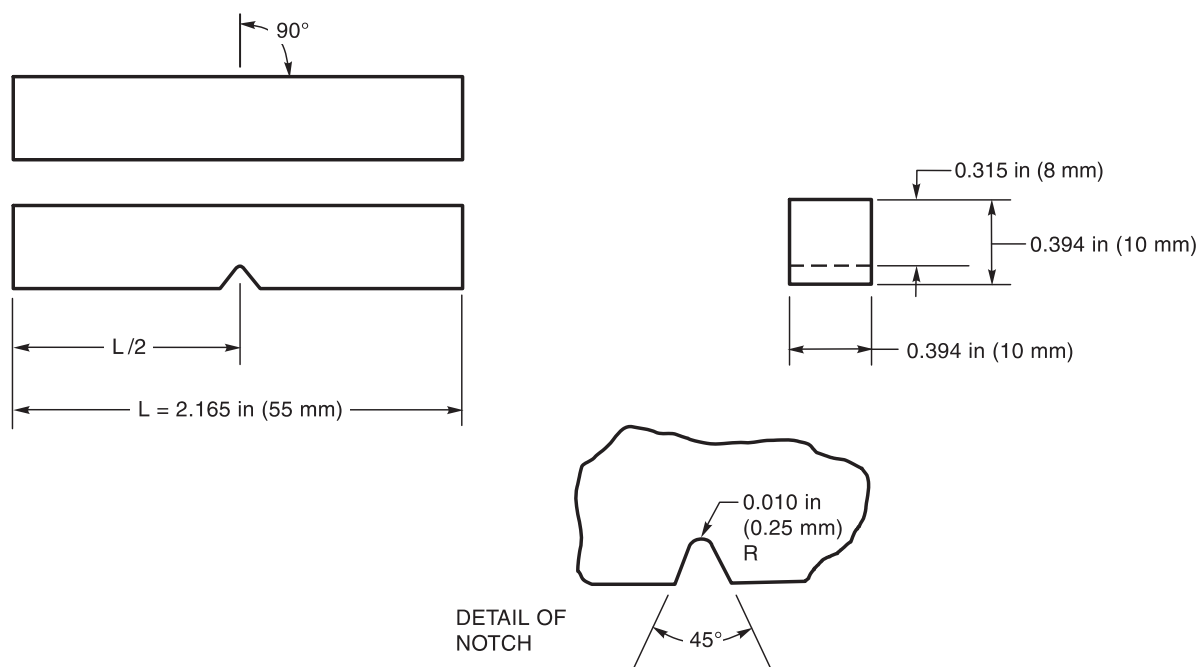
7.7.1 Test specimen preparation and test procedure for measuring the fracture toughness of a weldment shall be in accordance with the following ISO and ASTM standard test methods:

- (1) Charpy V-notch, ASTM E23, except that values up to and including 100% of the testing machine capacity shall be accepted and reported as fracture energy if the specimen breaks. The full machine capacity followed by a plus sign (+), shall be reported if the specimen is not broken. All these results may be used to calculate the average energy absorbed provided the minimum average required for acceptance is within the verified range of the machine;

AWS Standard: B4.0:2016

Amendment Number: 1

Subject: Figure 7.1, replace existing figure with new figure:



NOTE—Dimensional Tolerances shall be as follows:

Notch length to edge	$90^\circ \pm 2^\circ$
Adjacent sides shall be at	$90^\circ \pm 10 \text{ minutes}$
Cross section dimensions	$\pm 0.003 \text{ in (0.076 mm)}$
Length of specimen (L)	$+0, -0.100 \text{ in (+0, -2.5 mm)}$
Centering of notch ($L/2$)	$\pm 0.039 \text{ in (1 mm)}$
Angle of notch	$\pm 1^\circ$
Radius of notch	$\pm 0.001 \text{ in (0.025 mm)}$
Finish requirements	63 microinches (1.5 micrometers) R_a on notched surface and opposite face; 125 microinches (3 micrometers) R_a on other two surfaces
Ligament length	$\pm 0.001 \text{ in (0.025 mm)}$

Figure 7.1—Charpy V-Notch Impact Specimen

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
<i>List of Tables</i>	xiii
<i>List of Figures</i>	xiii
1. Scope	1
2. Normative References	1
3. Terms and Definitions	2
4. Tension Tests	2
4.1 Scope	2
4.2 Normative References	2
4.3 Nomenclature	3
4.4 Summary of Methods	3
4.5 Significance	3
4.6 Apparatus	3
4.7 Specimens	3
4.8 Procedure	4
4.9 Report	6
4.10 Commentary	6
5. Shear Tests	13
5.1 Scope	13
5.2 Normative References	13
5.3 Summary of Method	13
5.4 Significance	13
5.5 Apparatus	13
5.6 Specimens	13
5.7 Procedure	14
5.8 Report	14
5.9 Commentary	14
6. Bend Tests	17
6.1 Scope	17
6.2 Normative References	17
6.3 Nomenclature	17
6.4 Summary of Method	17
6.5 Significance	17
6.6 Apparatus	18
6.7 Specimens	18
6.8 Procedure	19
6.9 Report	20
6.10 Commentary	20
7. Fracture and Notch Toughness Tests	32
7.1 Scope	32
7.2 Normative References	32

7.3	Summary of Method.	33
7.4	Significance	33
7.5	Apparatus	33
7.6	Specimens.	33
7.7	Procedure	33
7.8	Report.	34
8.	Hardness Tests	41
8.1	Scope	41
8.2	Normative References	41
8.3	Summary of Method.	41
8.4	Significance	41
8.5	Apparatus	41
8.6	Specimens.	42
8.7	Procedure	42
8.8	Report.	42
8.9	Commentary.	42
9.	Break Tests (Nick and Fillet Weld)	45
9.1	Nick Break Test	45
9.2	Fillet Weld Break Test	55
10.	Weldability Testing	60
10.1	Controlled Thermal Severity (CTS) Test	61
10.2	Cruciform Test	68
10.3	Implant Test	76
10.4	Lehigh Restraint Test	82
10.5	Varestraint Test.	86
10.6	Oblique Y-Groove Test.	92
10.7	Welding Institute of Canada (WIC) Test	99
10.8	Trough Test.	104
10.9	Gapped Bead on Plate (GBOP) Test	109
11.	Process Specific Tests	111
11.1	Stud Weld Test	111
11.2	Resistance Welding Test.	114
	Annex A (Informative)—Bibliography.	141
	Annex B (Informative)—Requesting an Official Interpretation on an AWS Standard	143
	Annex C (Informative)—Recommended Practice for All-Weld-Metal Tensile Testing Of Narrow Groove Welds	145
	Annex D (Informative)—Recommended Practice for All-Weld-Metal Tensile Testing Of Narrow Groove Pipeline Girth Welds.	155
	List of AWS Documents of the Mechanical Testing of Welding	167

List of Tables

Table	Page No.
D.1 Tension Test Specimen Dimensions.	160

List of Figures

Figure	Page No.
Tension Tests	
4.1 Round Tensile Specimens	7
4.2 Transverse Rectangular Tension Test Specimen (Plate).	9
4.3 Longitudinal Tension Test Specimens (Plates)	10
4.4 Reduced Rectangular Section Tension Specimens for Pipe.	11
4.5 Full Section Tension Specimen for Pipe	12
Fillet Weld Shear Tests	
5.1 Longitudinal Fillet Weld Shear Specimen	15
5.2 Transverse Fillet Weld Shear Specimen	16
5.3 Shear Strength Calculation.	16
Bend Tests	
6.1 Typical Bottom Ejecting Guided Bend Test Fixture	21
6.2 Typical Bottom Guided Bend Test Fixture	22
6.3 Typical Wraparound Guided Bend Test Fixture.	23
6.4 Transverse Side Bend Specimens (Plate and Pipe)	24
6.5 Transverse Face Bend and Root Bend Specimen (Plate).	25
6.6 Transverse Face Bend and Root Bend Specimens (Pipe)	26
6.7 Longitudinal Face Bend and Root Bend Specimens (Plate)	27
6.8 Fillet Weld Root Bend Test Specimen	28
6.9 Surfacing Weld Face Bend and Side Bend Specimen	29
6.10 Longitudinal Guided Fillet Weld Bend Test.	30
6.11 Bend Test Nomograph	31
Fracture and Notch Toughness Tests	
7.1 <u>Charpy (Simple-Beam) Impact Test Specimens V-Notch and U-Notch</u>	35
7.2 Dynamic Tear Test Specimen, Anvil Supports, and Striker	36
7.3 Compact Tension Fracture Toughness Specimen.	37
7.4 Standard Drop Weight Nil-Ductility Temperature Test Specimen.	38
7.5 Orientation of Weld Metal Fracture Toughness Specimens in a Double-Groove Weld Thick Section Weldment	39
7.6 Crack Plane Orientation Code for Compact Tension Specimens from Welded Plate	39
7.7 Recommended Ratio of Weld Metal to Specimen Thickness for Weld-Metal Fracture Toughness Specimen (Compact Tension Specimen)	40

Hardness Tests

8.1	Example Butt Weld Hardness Testing Locations	43
8.2	Example Fillet Weld Hardness Testing Locations	44

Nick-Break Tests

9.1.1	Nick-Break Testing Fixture Made Out of 6 in (152 mm) Pipe	48
9.1.2	Nick-Break Test Using Vise	49
9.1.3	Nick-Break Test Using Anvil	49
9.1.4	Nick-Break Test Specimen	50
9.1.5	Specimen for Flash Butt Welds	51
9.1.6	Specimens for Nick-Break Test of Branch Joint Connections	52
9.1.7	Pipe Sleeve Test Specimen	53
9.1.8	Fillet Welded Plate Specimens	54

Fillet Weld Break Tests

9.2.1	Fillet Weld Break Specimen for Procedure Qualification	57
9.2.2	Fillet Weld Break Specimen for Primer Coated Materials	57
9.2.3	Fillet Weld Break Specimen for Galvanized Materials	58
9.2.4	Fillet Weld Break Specimen for Welder Qualification	58
9.2.5	Fillet Weld Break Specimen for Tack Welder Qualification	59
9.2.6	Method of Testing Fillet Weld Break Specimen	59

Weldability Testing**Controlled Thermal Severity (CTS) Test**

10.1.1	Fixture Used to Position CTS Specimen for Welding	63
10.1.2	CTS Test Specimen	64
10.1.3	Cooling Bath Arrangement for CTS Test	65
10.1.4	Sectioning of CTS Specimen	66
10.1.5	Typical Locations of Microhardness Impressions for this Optional Test on CTS Specimens	66
10.1.6	Suggested Data Sheet for CTS Test	67

Cruciform Test

10.2.1	Cruciform Test Assembly	71
10.2.2	Locations of Specimens for Examination of Cracks in Cruciform Test	72
10.2.3	Schematic Illustration of the Attached Plate in the Slotted Cruciform Specimen	72
10.2.4	Sectioning for the Longitudinal Notch	73
10.2.5	Sectioning for the Transverse Notch	73
10.2.6	Location of Metallographic Specimens for Examination of Cracks in the Slotted Cruciform Test	74
10.2.7	Suggested Data Sheet for Cruciform Test	75

Implant Test

10.3.1	Implant Test Specimen and Fixture	79
10.3.2	Typical Data for Implant Test Series	80
10.3.3	Suggested Data Sheet for Implant Test	81

Lehigh Restraint Test

10.4.1	Lehigh Restraint Weld-Metal Cracking Test Specimen	84
10.4.2	Suggested Data Sheet for Lehigh Test	85

Varestraint Test

10.5.1	Varestraint Test Fixture and Specimen	89
10.5.2	Auxiliary Bending Plates	90
10.5.3	Typical Indications on Top Surface of Test Weld	90
10.5.4	Suggested Data Sheet for Varestraint Test	91

Oblique Y-Groove Test

10.6.1	Oblique Y-Groove Test Assembly	95
10.6.2	Oblique Y-Groove Test Weld Configuration	96
10.6.3	Suggested Data Sheet for Oblique Y-Groove Test	98

Welding Institute of Canada (WIC) Test

10.7.1	Schematic Illustration of the WIC Test Assembly	102
10.7.2	Illustration of the Straight Y Joint Design for the WIC Specimen.	102
10.7.3	Illustration of the Oblique Y Joint Design for the WIC Specimen	102
10.7.4	Suggested Data Sheet for WIC Test.	103

Trough Test

10.8.1	Trough Test Specimen	107
10.8.2	Location of Weld Starts, Stops, and Tension Test Specimens (Side View)	107
10.8.3	Suggested Data Sheet for Trough Test.	108

Gapped Bead On Plate (GBOP) Test

10.9.1	Specimen Dimensions and Test Set-Up	110
--------	---	-----

Stud Weld Tests

11.1.1	Equipment for Bend Tests for Welded Studs	112
11.1.2	Equipment for Applying a Tensile Load to a Welded Stud Using Torque	113

Resistance Weld Tests

11.2.1	Peel Test Specimen.	122
11.2.2	Peel Test	123
11.2.3	Measurement of a Weld Button Resulting from the Peel Test	123
11.2.4	Bend Test Specimen.	124
11.2.5	Spot Weld Chisel Test	125
11.2.6	Specimen for Tension Shear Test and Tension Shear Impact Test.	126
11.2.7	Twisting Angle (γ at Fracture in Tension Shear Test	126
11.2.8	Cross-Tension Test Specimens.	127
11.2.9	Fixture for Cross-Tension Test [for Thicknesses up to 0.19 in (4.8 mm)]	128
11.2.10	Fixture for Cross-Tension Test [for Thicknesses 0.19 in (4.8 mm) and Over]	129
11.2.11	Specimen for U Specimen Tension Test and U Specimen Shear Impact Test	130
11.2.12	U-Tension Test Jig	131
11.2.13	Pull Test (90 ° Peel Test)	132
11.2.14	Test Specimen and Typical Equipment for Torsion-Shear Test	133
11.2.15	Drop-Impact Test Specimen.	134
11.2.16	Drop-Impact Test Machine.	135
11.2.17	Test Fixture for Shear-Impact Loading Test.	135
11.2.18	Test Fixture for Tension-Impact Loading Test.	136
11.2.19	Fatigue Testing Machine	137
11.2.20	Pillow Test for Seam Welds	138
11.2.21	Suggested Data Sheet for Resistance Spot and Projection Welding	139
11.2.22	Suggested Data Sheet for Resistance Seam Welding.	140

All-Weld-Metal Tensile Testing of Narrow Groove Welds

C.1	Tensile Specimen Location in Narrow Groove Weld Cross Section	145
C.2	Typical Narrow Groove Weld Joints	146
C.3	AWM Strip Tensile Blank	147
C.4	Preparation of AWM Strip Tensile Blank.	147
C.5	Photographs of Blanks Etched with 3%–5% Nital	148
C.6	Measurement of Weld Width for Determination of Specimen Width	149
C.7	AWM Strip Tensile Specimen Dimensional Requirements	150
C.8	AWM Strip Tensile Specimen Prior to Test	151
C.9	AWM Strip Tensile Test.	152

All-Weld-Metal Tensile Testing of Narrow Groove Pipeline Girth Welds

D.1	Tensile Specimen Location in Narrow Groove Weld Cross Section	155
D.2	Typical Narrow Groove Weld Joints	156
D.3	Schematic Diagram of AWM Strip Tensile Blank	157
D.4	AWM Strip Tensile Blank	158

D.5	Preparation of AWM Strip Tensile Blank.	159
D.6	Photographs of Blanks Etched with 3%–5% Nital	162
D.7	Measurement of Weld Width for Determination of Specimen Width	163
D.8	AWM Strip Tensile Specimen Dimensional Requirements	164
D.9	AWM Strip Tensile Specimen Prior to Test	164
D.10	AWM Strip Tensile Test.	165

Standard Methods for Mechanical Testing of Welds

1. Scope

This specification establishes standard methods for mechanical testing of welds. The significance of each test, test apparatus, preparation of the test specimens, and the test procedure are described. Example test results sheets are provided.

It is beyond the scope of this document to define the required mechanical properties or acceptance criteria for the weld metal.

This standard makes sole use of U.S. Customary Units. Approximate mathematical equivalents in the International System of Units (SI) are provided for comparison in parentheses or in appropriate columns in tables and figures.

Safety and health issues and concerns are beyond the scope of this standard and therefore are not addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS documents:

AWS A1.1, *Metric Practice Guide for the Welding Industry*;

AWS A2.4, *Standard Symbols for Welding, Brazing and Nondestructive Examination*; and

AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.

3. Terms and Definitions

The welding terms used in this standard are in accordance with AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.

4. Tension Tests

4.1 Scope. This clause covers the tension testing of welded joints. These requirements supplement the referenced ASTM standards for tensile testing of metallic materials to ensure proper evaluation of welds and weld metal.

4.1.1 Purpose and Intended Use This standard is applicable to the following, when specified:

- (1) Characterize the performance of weld metal and/or welded joints under tensile load with respect to:

- tensile strength
- yield strength, as applicable
- ductility, as applicable
- assessing joint efficiency
- facilitating engineering design and/or analysis
- facilitating product development

- (2) Qualification of materials and welding procedures where specified mechanical properties are required,

(3) Information as a basis for acceptance and manufacturing quality control where mechanical properties are requested.

4.1.2 This standard does not specify required properties or acceptance criteria. When this standard is used as a portion of a specification for a welded structure or assembly or for qualification, the following information shall be furnished, as a minimum:

- (1) The specific type(s) and number of specimens required,
- (2) Base metal specification/identification,
- (3) Filler material specification/identification,
- (4) The anticipated mechanical property values and whether they are maximum and/or minimum requirements,
- (5) Location and orientation of the specimens,
- (6) Report form when required,
- (7) Applicable postweld thermal or mechanical processing treatments of the weld prior to tensile testing, and
- (8) Applicable postweld processing of the tension test specimen, such as aging, prior to test.

4.2 Normative References. The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this test. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. In cases where the procedures herein conflict with the referenced ASTM or ASME standards, these B4.0 provisions take precedent.

ASME Documents:

ASME B46.1, *Surface Texture, Surface Roughness, Waviness and Lay*

ASTM Documents:

ASTM E4, *Standard Practices for Force Verification of Testing Machines*

ASTM E8, *Standard Methods for Tension Testing of Metallic Materials*

ASTM E83–10a, *Standard Practice for Verification and Classification of Extensometer Systems*

ASTM B557, *Standard Test Methods for Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products*

4.3 Nomenclature. For the purposes of this test, the following nomenclature apply:

A	=	length of reduced section
B	=	length of end section
C	=	dimension of grip section
D	=	diameter
D_o	=	original diameter
D_f	=	final diameter
E	=	length of shoulder and fillet
F	=	diameter of shoulder
G	=	gage length
ID	=	inner diameter
OD	=	outer diameter
L	=	overall length
P	=	load
R	=	radius of fillet
T	=	specimen thickness
t	=	thickness of test weldment
W	=	specimen width
π	=	ratio of the circumference of a circle to its diameter having a value to five decimal places of 3.14159

4.4 Summary of Method. Tension testing of welded joints is done by means of a calibrated testing machine and devices following the procedures described in 4.8.

4.5 Significance. Tension tests provide information on the load bearing capacities and joint efficiencies of welded joints, as well as weld metal strength and ductility.

4.5.1 The data obtained from tension tests may include:

- (1) Ultimate tensile strength,
- (2) Yield strength,
- (3) Yield point if it occurs,
- (4) Percent elongation,
- (5) Percent reduction of area,
- (6) Uniform strain,
- (7) Strain hardening,
- (8) Elastic modulus,
- (9) Stress-strain diagram, and
- (10) Location and mode of fracture.

4.5.2 Tension tests provide quantitative data that is often compared and analyzed for use in the design and analysis of welded structures. Fracture surfaces may also provide information on the presence and effects of discontinuities such as incomplete fusion, incomplete joint penetration, porosity, inclusions, and cracking.

4.6 Apparatus. The test shall be performed on a tensile testing machine in conformance with the requirements of ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*. The machine shall be calibrated in accordance with ASTM E4, *Standard Practices for Force Verification of Testing Machines*.

4.7 Specimens

4.7.1 Test specimen type shall be specified by an applicable code, specification, or fabrication document. It is recommended that test specimens that provide the largest cross-sectional area be tested within the capabilities of available test equipment.

4.7.2 Unless otherwise stated, specimens shall be tensile tested in the as-received condition.

4.7.3 Round Tension Test Specimens. The specimen having the largest diameter of those shown in Figure 4.1, that can be machined from the material shall be tested.

4.7.3.1 Round All-Weld-Metal Specimen. The all-weld metal tension specimen is used most often for evaluation of the deposited weld metal ultimate tensile strength, yield strength, elongation, and reduction in area. It may also be used for assessment of elastic modulus, uniform strain, and strain hardening behavior of undiluted weld metal. When base metal dilution must be minimized for the specimen to be representative of weld metal, the groove faces may be buttered with the same filler materials to be used in the weld joint or alternatively the root opening may be increased by 1/4 in (6 mm). The reduced section of the tension specimens between the gage marks shall be located so that no buttering is included. It is recommended that the surface of the reduced section of the specimen be at least 1/8 in (3 mm) from the fusion line along the bevel faces (see Figure 4.1).

4.7.3.2 Round Transverse Weld Specimen. The transverse weld specimen is used together with the base metal or all weld metal tension tests to evaluate joint efficiency. Only the ultimate tensile strength may be determined for specimens taken transverse to the longitudinal axis of the weld. A transverse weld tension test is not suitable for determination of yield strength, elongation, or reduction in area because the strain through the gage length during yielding is not uniform. Accordingly, yield strength for a transverse weld tension test specimen should not be reported. In the event of use of a set of round transverse tensile specimens at various locations in the thickness of the weld specimen, when no other governing specification indicates otherwise, the results of the set of round transverse tensile specimens shall be averaged to approximate the tensile properties of the full thickness joint.

4.7.4 Rectangular Tension Test Specimen. The tension specimens for welded butt joints other than pipe or tubing shall be either transverse weld tension specimens or longitudinal weld tension specimens that comply with Figure 4.2 or 4.3. When thickness of the test weldment is beyond the capacity of the available test equipment, the weld shall be divided through its thickness into as many specimens as required to cover the full weld thickness and still maintain the specimen size within the test equipment capacity. Unless otherwise specified, the results of the partial thickness specimens shall be averaged to determine the properties of the full thickness joint. Only ultimate tensile strength may be determined in specimens taken transverse to the longitudinal axis of the weld. A transverse weld tension test is not suitable for determination of yield strength, elongation, or reduction in area because the strain through the gage length during yielding is not uniform. Accordingly, yield strength for a transverse weld tension test specimen should not be reported.

4.7.5 Tubular Tension Test Specimen. Two types of specimens are used in determining the tensile properties of welded tubular products.

4.7.5.1 For pipe or tubing larger than 3 in (76 mm) nominal diameter, the reduced rectangular section specimen may be used. The reduced rectangular section specimen shall comply with Figure 4.4.

4.7.5.2 The full section specimen may be used to test weld joints in pipe or tubing 3 in (76 mm) or less nominal diameter and may be used for larger sizes subject to limitations of testing equipment. The full section specimen shall comply with Figure 4.5.

4.7.5.3 Only ultimate tensile strength may be determined in specimens taken transverse to the centerline of the weld. A transverse weld tension test is not suitable for determination of yield strength, elongation, or reduction in area because the strain through the gage length during yielding is not uniform. Accordingly, yield strength for a transverse weld tension test specimen should not be reported.

4.7.6 Preparation. Excessively deep machine cuts that will cause invalid test data or that leave tears in the surface of the finished dimensions shall be avoided. The surface finish on surfaces requiring machining shall be as specified in the specimen drawings. Imperfections present within the gage length due to welding shall not be removed.

4.8 Procedure

4.8.1 The testing procedure for weld specimens shall be as specified in ASTM E8, *Standard Methods for Tension Testing of Metallic Materials*.

4.8.2 Round Tension Specimens. Mechanical properties, namely ultimate tensile strength (UTS), yield strength at the specified offset, yield point if it occurs, elongation in a specified gage length, and reduction of area are determined for round all-weld-metal tension specimens. If a yield point is reported, it shall have been determined in accordance with ASTM E8/ASTM E8M. The minimum original dimension diameter shall be used for all calculations. For round transverse weld tension specimens, only ultimate tensile strength is determined.

The ultimate tensile strength is given by:

$$\frac{\text{Maximum Load}}{\text{Original Cross Sectional Area}} = \frac{P_{(Maximum)}}{\left(\frac{\pi D_o^2}{4}\right)}$$

where

$P_{(Maximum)}$ = maximum load, and
 D_o = original diameter.

The yield strength at specified offset is given by:

$$\frac{\text{Load at Specified Offset}}{\text{Original Cross Sectional Area}} = \frac{P_{(Specified Offset)}}{\left(\frac{\pi D_o^2}{4}\right)}$$

where

$P_{(Specified Offset)}$ = Load at Specified Offset, and
 D_o = Original Diameter.

The yield point is given by:

$$\frac{\text{Maximum Load prior to Specific Offset}}{\text{Original Cross Sectional Area}} = \frac{P_{(yp)}}{\left(\frac{\pi D_o^2}{4}\right)}$$

where

$P_{(yp)}$ = maximum load prior to specific offset, and
 D_o = original diameter.

The percent elongation is given by:

$$\begin{aligned} & \frac{\text{Final gage length} - \text{Original gage length}}{\text{Original gage length}} \times 100 \\ &= \frac{G_f - G_o}{G_o} \times 100 \end{aligned}$$

where

G_f = final gage length
 G_o = original gage length.

The percent reduction of area is given by:

$$\begin{aligned} & \frac{\left(\text{Original Diameter}\right)^2 - \left(\text{Final Diameter}\right)^2}{\left(\text{Original Diameter}\right)^2} \times 100 \\ &= \frac{D_o^2 - D_f^2}{D_o^2} \times 100 \end{aligned}$$

where

D_f = final diameter
 D_o = original diameter.

4.8.3 Rectangular Tension Tests (Figures 4.2, 4.3, 4.4). The ultimate tensile strength calculation for rectangular tests is the following:

The ultimate tensile strength is given by:

$$\frac{\text{Maximum Load}}{\text{Original Area}} = \frac{P_{(\text{Maximum})}}{W \times T}$$

where

$P_{(\text{Maximum})}$ = maximum load,
 W = original width, and
 T = original thickness.

4.8.4 Tubular Tension Tests. The ultimate tensile strength calculation for reduced section (Figure 4.4) is the same as shown in 4.8.3. The ultimate tensile strength calculation for full section (Figure 4.5) is as follows:

The ultimate tensile strength is given by:

$$\frac{\text{Maximum Load}}{\text{Original Area}} = \frac{P_{(\text{Maximum})}}{\frac{\pi}{4} \times (OD^2 - ID^2)}$$

where

$P_{(\text{Maximum})}$ = maximum load,
 OD = original outside diameter, and
 ID = original inside diameter.

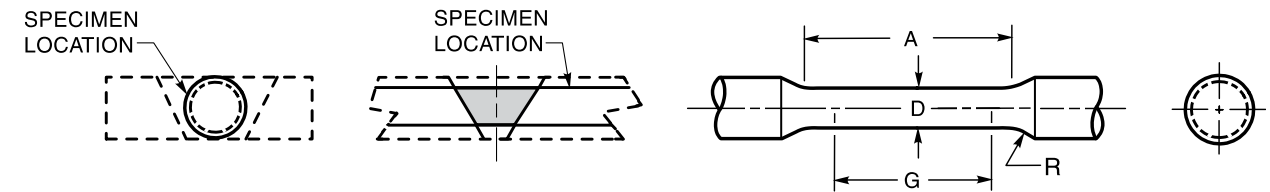
4.9 Report. In addition to the requirements of applicable documents, the report shall include the following:

- (1) Base metal specification,
- (2) Filler metal specification,
- (3) Welding procedure (process and parameters),
- (4) Specimen type,
- (5) Joint geometry,
- (6) Location of fracture and type of failure (ductile or brittle),
- (7) Calculated ultimate tensile strength, and
- (8) Any observation of unusual characteristics of the specimens or procedure.

In addition, the report for round all-weld-metal specimens shall contain the following, as a minimum:

- (1) Yield strength at the specified offset,
- (2) Yield point if it occurs,
- (3) Percent elongation in the specified gage length, and
- (4) Percent reduction of area.

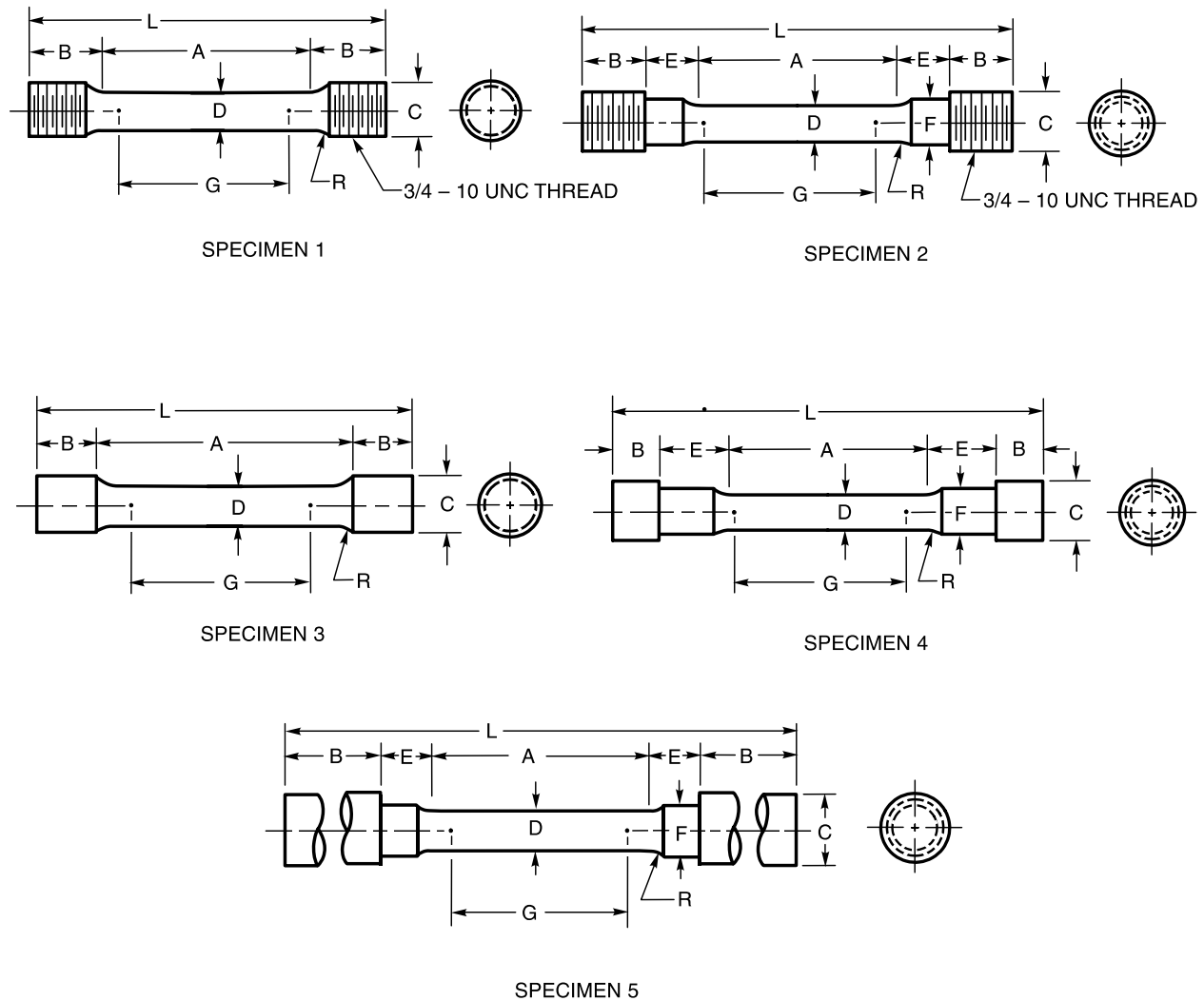
4.10 Commentary. Descriptions of two tensile specimens are included in this document, one with a 4:1 ratio of gage length to diameter and one with a 5:1 ratio of gage length to diameter. Users are cautioned that calculated values of elongation for a given material will differ when tested using specimens with different ratios of gage length to specimen diameter.



Dimensions					
	Standard Specimen		Small-size specimens proportional to standard specimen		
Nominal Diameter	in (mm) 0.500 (13)	in (mm) 0.350 (9)	in (mm) 0.250 (6)	in (mm) 0.160 (4)	in (mm) 0.113 (3)
G. gage length	2.000 ± 0.005 (50 ± 0.127)	1.400 ± 0.005 (35 ± 0.127)	1.000 ± 0.005 (25 ± 0.127)	0.640 ± 0.005 (16 ± 0.127)	0.450 ± 0.005 (12 ± 0.127)
D. diameter	0.500 ± 0.010 (13 ± 0.25)	0.350 ± 0.007 (9 ± 0.18)	0.250 ± 0.005 (6 ± 0.127)	0.160 ± 0.003 (4 ± 0.08)	0.113 ± 0.002 (3 ± 0.05)
R. radius of fillet, min.	3/8 (10)	1/4 (6)	3/16 (5)	5/32 (4)	3/32 (2.4)
A. length of reduced section, min.	2-1/4 (60)	1-3/4 (44)	1-1/4 (32)	3/4 (20)	5/8 (15)

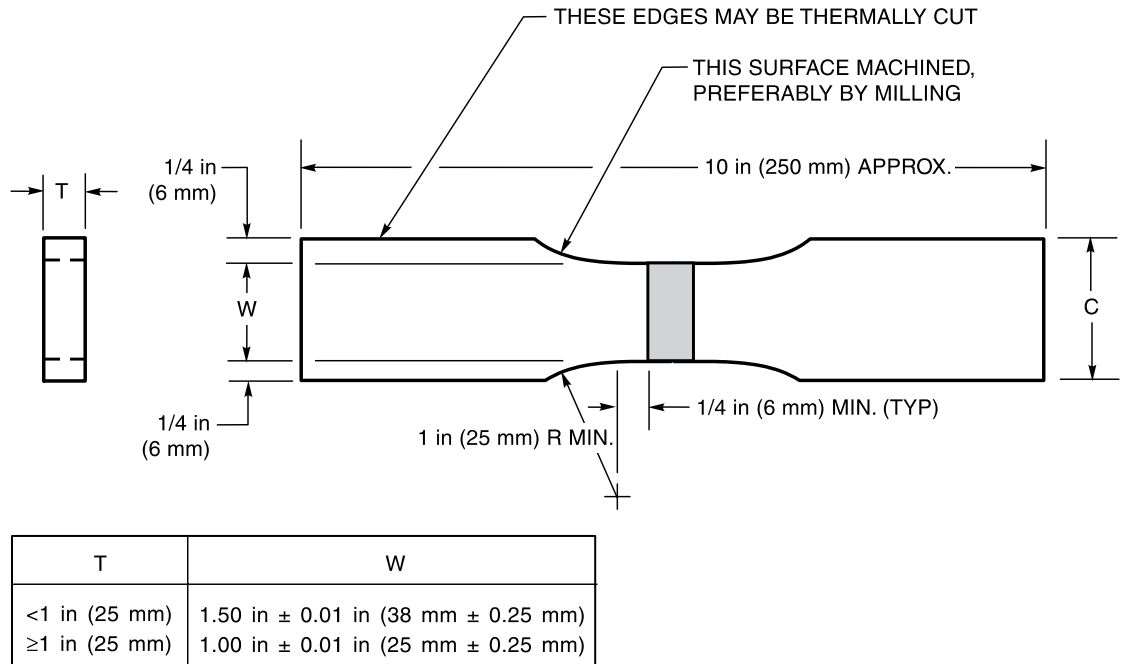
- Notes:
1. The reduced section may have a gradual taper from the ends toward the center with the ends not more than 1% larger in diameter than the center (controlling dimension).
 2. If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length.
 3. The gage length and fillets shall be as shown but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in wedge grips it is desirable to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to 2/3 or more of the length of the grips.
 4. The use of specimens smaller than 0.250 in (6 mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.
 5. For transverse weld specimens, the weld shall be approximately centered between gage marks.
 6. Any standard thread is permissible that provides for proper alignment and aids in assuring that the specimen will break within the reduced section.
 7. On specimen 5, it is desirable to make the length of the grip section sufficient to allow the specimen to extend into the grips a distance equal to 2/3 or more of the length of the grips.
 8. The use of UNF series of threads [3/4 in (19 mm) by 16, 1/2 in (13 mm) by 20, 3/8 in (10 mm) by 24, and 1/8 in (3 mm) by 28] is recommended for high-strength, brittle materials to avoid fracture in the threaded portion.
 9. Surface finish within the gage length shall be no rougher than 63 microinches (1.6 micrometers) R_a .
 10. On the round specimens in this figure, the gage lengths are equal to 4 times the nominal diameter. In some product specifications other specimens may be provided for but unless the 4:1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen. Note that most metric based codes use a 5:1 ratio of gage length to diameter.

Figure 4.1—Round Tensile Specimens



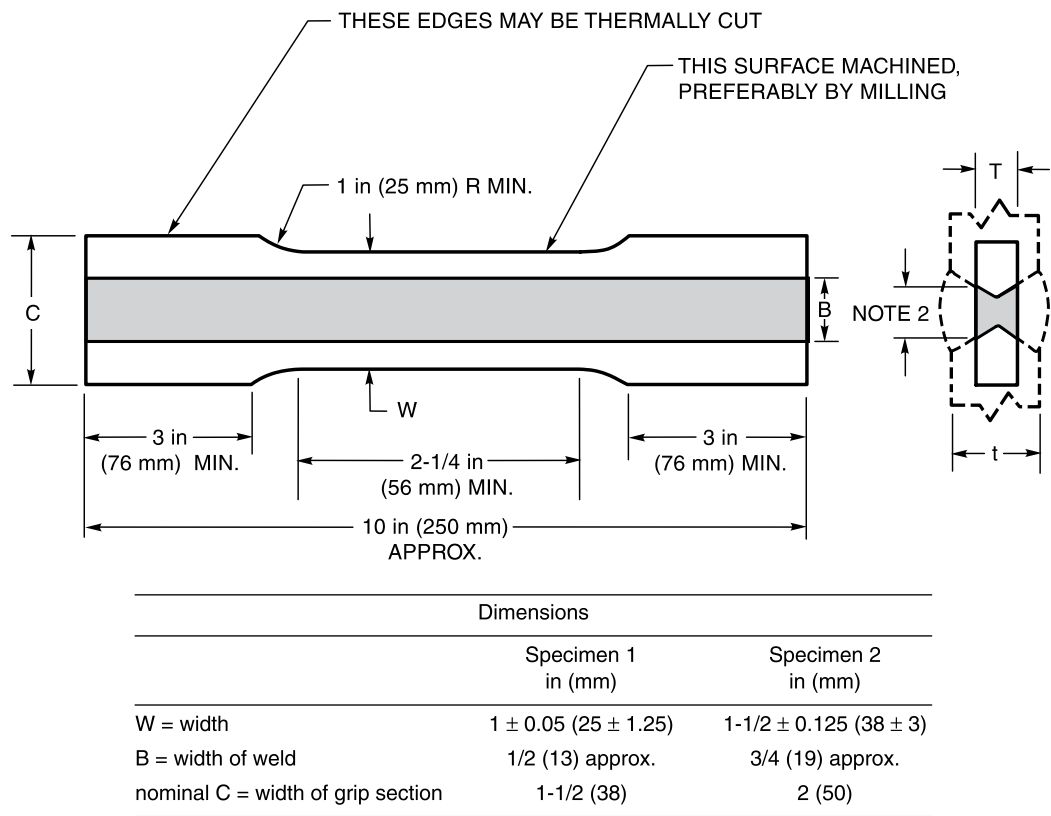
	Dimensions				
	Specimen 1 in (mm)	Specimen 2 in (mm)	Specimen 3 in (mm)	Specimen 4 in (mm)	Specimen 5 in (mm)
G — gage length	2.000 ± 0.005 (50 ± 0.127)	2.000 ± 0.005 (50 ± 0.127)	2.000 ± 0.005 (50 ± 0.127)	2.000 ± 0.005 (50 ± 0.127)	2.000 ± 0.005 (50 ± 0.127)
D — diameter (Note 1)	0.500 ± 0.010 (13 ± 0.254)	0.500 ± 0.010 (13 ± 0.254)	0.500 ± 0.010 (13 ± 0.254)	0.500 ± 0.010 (13 ± 0.254)	0.500 ± 0.010 (13 ± 0.254)
R — radius of fillet, min.	3/8 (10)	3/8 (10)	1/16 (1.6)	3/8 (10)	3/8 (10)
A — length of reduced section (Note 2)	2-1/4 (56) min.	2-1/4 (56) min.	4 (101) approx.	2-1/4 (56) min.	2-1/4 (56) min.
L — over-all length approx.	5 (126)	5-1/2 (139)	5-1/2 (139)	4-3/4 (120)	9-1/2 (241)
B — length of end section	1-3/8 (35) approx.	1 (25) approx.	3/4 (19) approx.	1/2 (13) approx.	3 (76) min.
C — diameter of end section	3/4 (19)	3/4 (19)	23/32 (18)	7/8 (22)	3/4 (19)
E — length of shoulder and fillet section, approx.	—	5/8 (16)	—	3/4 (19)	5/8 (16)
F — diameter of shoulder	—	5/8 (16)	—	5/8 (16)	19/32 (15)

Figure 4.1 (Continued)—Round Tensile Specimens



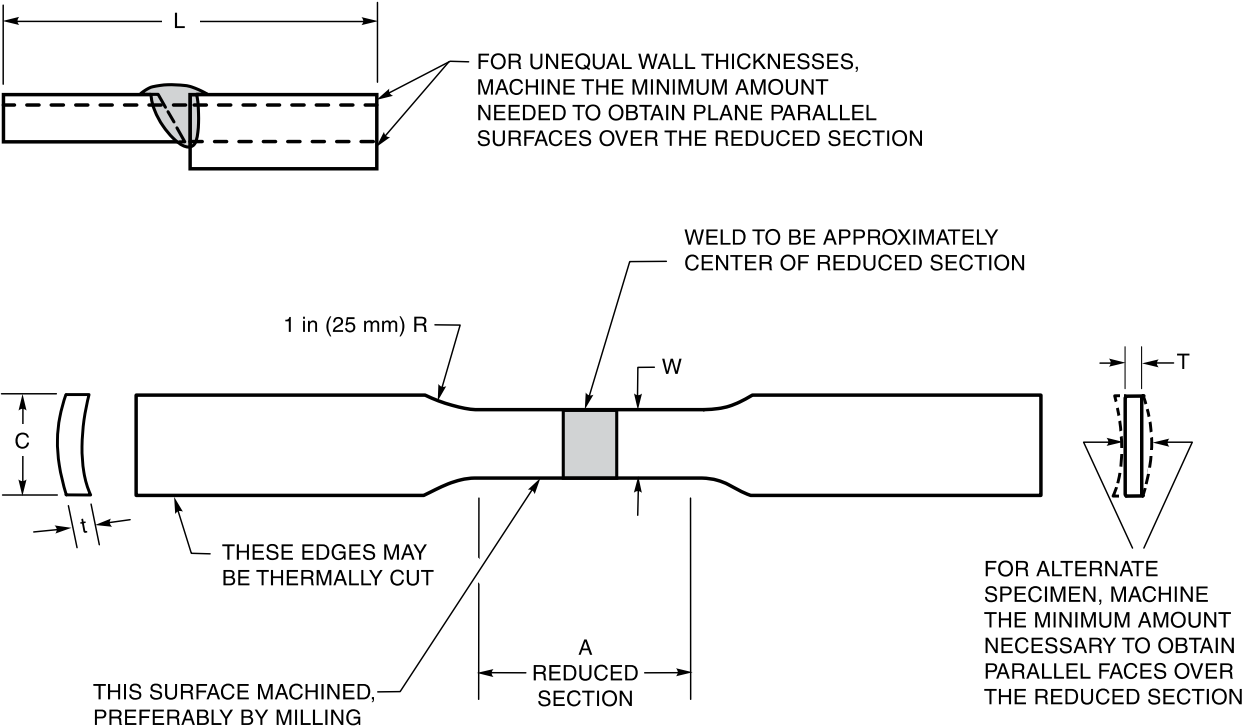
- Notes:
1. Thin base metal being tested tends to tear and break near the shoulder. In such cases, dimension C shall be no greater than 1-1/3 times the width of the reduced section.
 2. Weld reinforcement and backing strip, if any, shall be removed flush with the surface of the specimen.
 3. When the thickness, t, of the test weldment is such that it would not provide a specimen within the capacity limitations of the available test equipment, the specimen shall be parted through its thickness into as many specimens as required.
 4. The length of reduced sections shall be equal to the width of the widest portion of weld, plus 1/4 in (6 mm) minimum on each side.
 5. All surfaces in the reduced section shall be no rougher than 125 microinches (3 micrometers) R_a .
 6. Narrower widths (W and C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.

Figure 4.2—Transverse Rectangular Tension Test Specimen (Plate)



- Notes:
1. The weld reinforcement and backing, if any, shall be removed, flush with the surface of the specimen.
 2. The width of the weld may be varied to approximate 1/2 W by selecting an appropriate specimen thickness, T, and its location within the weld.
 3. The width, W, may be varied within reason to accommodate the width of the weld if it is not possible to meet the requirements of Note 2.
 4. The grip sections of the specimen shall be symmetrical with the center line of the reduced section, within 1/8 in (3 mm).
 5. All surfaces in the reduced section shall be no rougher than 125 microinches (3 micrometers) Ra.
 6. Narrower widths (W and C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.

Figure 4.3—Longitudinal Tension Test Specimens (Plates)



Specimen No.	W in (mm)	C in (mm)	A in (mm)
1	$1/2 \pm 1/64$ (13 $\pm$ 0.4)	3/4 (19) approx.	2-1/4 (60) min.
2	$3/4 \pm 1/32$ (20 $\pm$ 2.4)	1 (25) approx.	2-1/4 (60) min. 4-1/2 (115) min.
3	$1 \pm 1/16$ (25 $\pm$ 1.6)	1-1/2 (38) approx.	2-1/4 (60) min. 4-1/2 (115) min.
4	$1-1/2 \pm 1/8$ (38 $\pm$ 3.2)	2 (50) approx.	2-1/4 (60) min. 4-1/2 (115) min. 9 (229) min.

- Notes:
1. The weld reinforcement and backing, if any, shall be removed flush with the specimen.
 2. Alternate specimen shall not be used for nominal wall thickness less than 3/8 in (10 mm).
 3. Only grip sections of the specimen may be flattened.
 4. In the case of full wall thickness specimens, cross-sectional area may be calculated by multiplying W and t (t = T)
 5. T is the thickness of the test specimen as provided for in the applicable specification.
 6. The reduced section shall be parallel within 0.010 in (0.25 mm) and may have a gradual taper in width from the ends toward the center with the ends not more than 0.010 in (0.25 mm) wider than the center.
 7. The grip section of the specimen shall be symmetrical with the center line of the reduced section within 1/8 in (3 mm).
 8. All surfaces in the reduced section shall be no rougher than 125 microinches (3 micrometers) R_a .
 9. Narrower widths (W and C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.

Figure 4.4—Reduced Rectangular Section Tension Specimens for Pipe

WELD REINFORCEMENT MAY BE
RETAINED UNLESS THE APPLICABLE
CODE OR SPECIFICATION CALLS
FOR MACHINING FLUSH WITH
BASE METAL

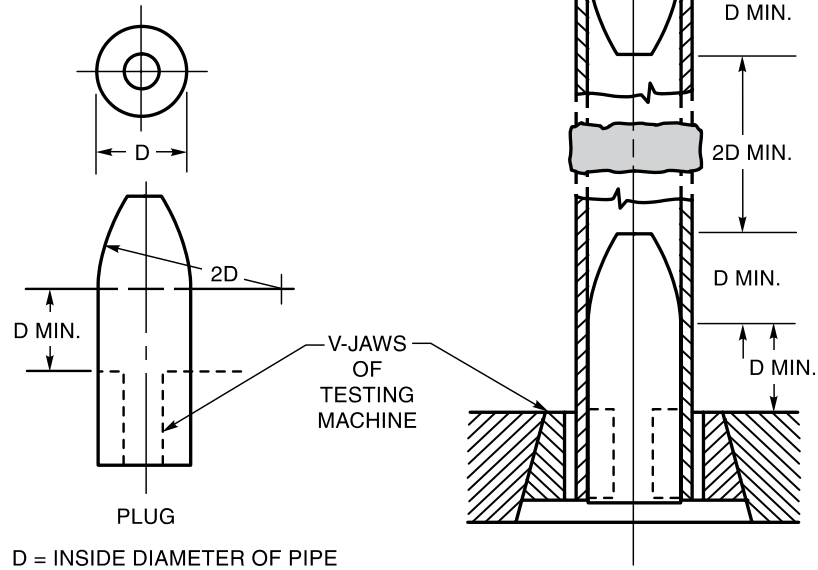


Figure 4.5—Full Section Tension Specimen for Pipe

5. Shear Tests

5.1 Scope. This clause covers shear tests of fillet welds in plate.

5.1.1 The preparation of the test specimens and the testing procedure shall conform to this standard.

5.1.2 This standard does not specify requirements or acceptance criteria.

5.1.3 This standard is applicable to the following when specified:

- (1) Qualification of welding personnel and welding procedures;
- (2) Information, basis for inspection, and fabrication quality control when acceptance criteria have been established; and
- (3) Research and development.

5.1.4 When this standard is used, the following information shall be furnished:

- (1) Welding process used,
- (2) The specified test and required number of specimens,
- (3) Base metal specification/identification and thickness,
- (4) Position(s) of welding,
- (5) Filler metal specification/identification and diameter,
- (6) Report form including type of data and observations to be made, and
- (7) Acceptance criteria.

5.2 Normative References. The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this test. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

ASTM Documents:

ASTM E4, *Standard Practices for Force Verification of Testing Machines*

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

5.3 Summary of Method. The shear test places a tensile load on a specimen prepared so that the fillet welds fail in shear.

5.4 Significance

5.4.1 Shear tests provide information on the load bearing capacities and joint efficiencies of welded joints. The data obtained from shear tests may include:

- (1) Unit shear load,
- (2) Shear strength, and
- (3) Location and mode of fracture.

5.4.2 Shear tests provide quantitative data which can be compared, analyzed, and used in the design and analysis of welded structures. Fracture surfaces may also provide information on the presence and effects of discontinuities such as lack of fusion/penetration, porosity, inclusions, and cracking. The weld shearing strength is reported as (1) load per unit length of weld, and (2) shear stress on the throat of the weld.

5.5 Apparatus. The test shall be performed on a tensile machine in conformance with ASTM E8, *Standard Methods for Tension Testing of Metallic Materials*. The machine shall be calibrated in accordance with ASTM E4, *Standard Practices for Force Verification of Testing Machines*.

5.6 Specimens

5.6.1 Longitudinal Shear Strength Specimen. The specimen shall be welded as shown in Figure 5.1 and inspected visually. The surface contour and size of the fillet welds shall be in accordance with the applicable standard or other specified acceptance criteria. The specimen shall be machined before testing as shown in Figure 5.1.

5.6.2 Transverse Shear Strength Specimen. The specimen shall be prepared as shown in Figure 5.2 and inspected visually. The surface contour and size of the fillet welds shall be in accordance with the applicable standard or other specified acceptance criteria. Wider plates may be used to obtain multiple specimens. When multiple specimens are prepared from a single welded assembly, the results for each individual specimen are to be reported.

5.6.3 Preparation. The data obtained from a shear strength specimen may be affected by certain preparation and testing variables. For the transverse specimen, the gap between the lapped plates should be minimized to avoid magnification of stresses at the root of the weld which should lower the observed strength of the weldment. Nonuniformity of fillet weld contour will affect the test values. The specimen is also sensitive to any underbead cracking or undercut.

5.7 Procedure. Shear strength is derived using formulas from Figure 5.3.

5.7.1 The length of weld and average leg dimension of each weld shall be measured and reported. The theoretical throat is calculated from these dimensions.

5.7.2 The specimen shall be positioned in the testing machine so that the tensile load is applied parallel to the longitudinal axis of the specimen.

5.7.3 The specimen shall be loaded in tension until the welds are sheared.

5.7.4 A test shall be considered invalid if the specimen fails in the base metal, and an additional test specimen shall be prepared and tested.

5.7.5 Unit shear load in terms of load per unit length of weld is determined by dividing the maximum load by the total length of weld sheared.

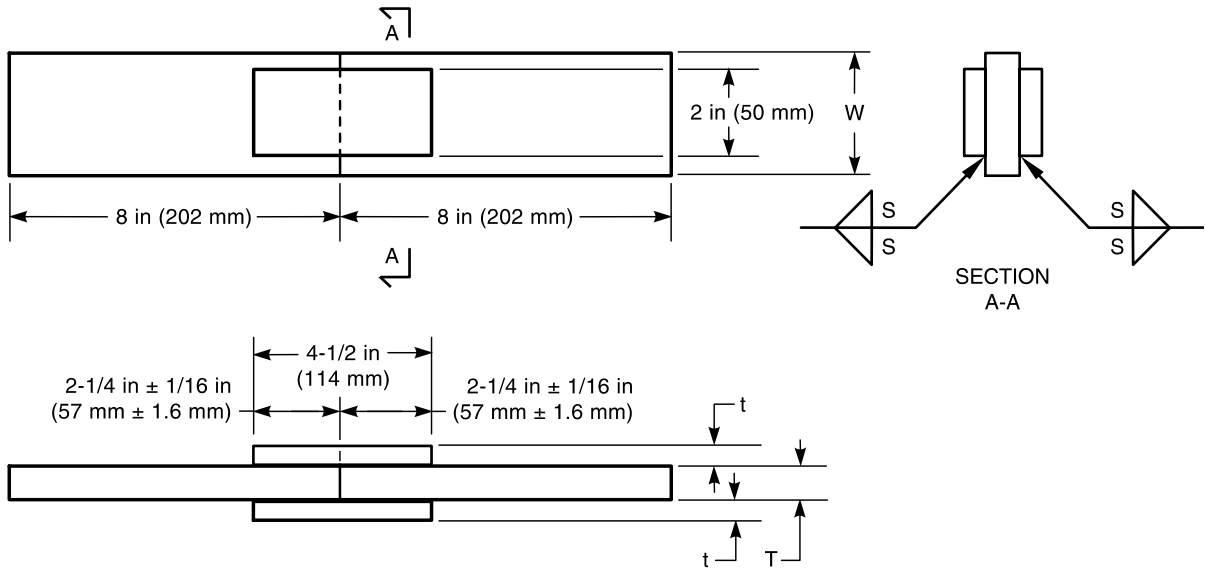
5.7.6 Shear strength in force per unit area acting on the throat of the fillet weld is determined by dividing the unit shear load by the average theoretical throat dimensions (see Fig. 5.3) of the welds that sheared.

5.7.7 Eccentric loading during testing will make the specimen more sensitive to certain defects such as weld discontinuities at the ends of the fillet welds.

5.8 Report. In addition to the requirements of the applicable standard or other user specified requirements, the report should indicate the following:

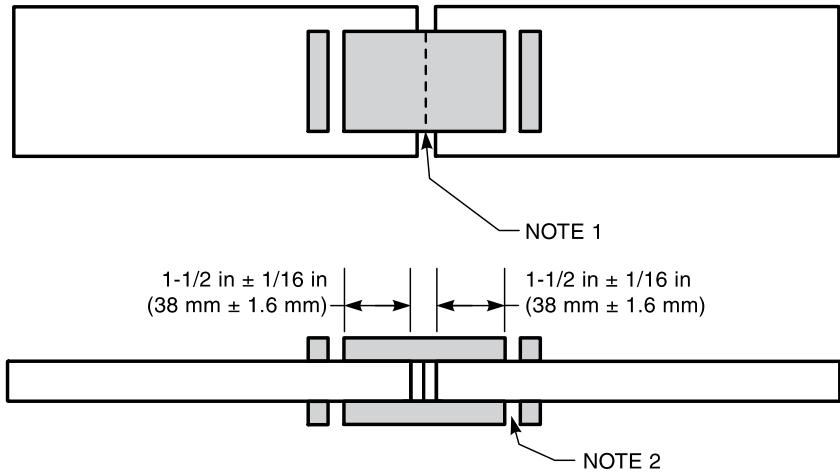
- (1) Specimen identification;
- (2) Welding procedure number or identification;
- (3) Specimen type (longitudinal or transverse);
- (4) Shear load and unit shear load;
- (5) Shear strength;
- (6) Location of fracture;
- (7) Actual throat dimensions, if measured, or theoretical throat dimensions, if calculated, and weld lengths; and
- (8) Any observation of unusual characteristics of the specimen, fracture surfaces or procedure.

5.9 Commentary. There are other national and international test methods whose objectives are to determine the shear properties of welds. These other test methods may not give the same test results as the test method described here.



(A) BEFORE MACHINING

	Dimensions			
	in (mm)	in (mm)	in (mm)	in (mm)
Size of Weld S	1/8 (3)	1/4 (6)	3/8 (10)	1/2 (12)
Thickness t	3/8 (10)	1/2 (12)	3/4 (19)	1 (25)
Thickness T	3/8 (10)	3/4 (19)	1 (25)	1-1/4 (32)
Width W	3 (75)	3 (75)	3 (75)	3-1/2 (89)



(B) AFTER MACHINING

- Notes:
1. Slot machined through root of test fillet weld.
 2. Depth of machined notch shall extend through thickness of lap plate.

Figure 5.1—Longitudinal Fillet Weld Shear Specimen

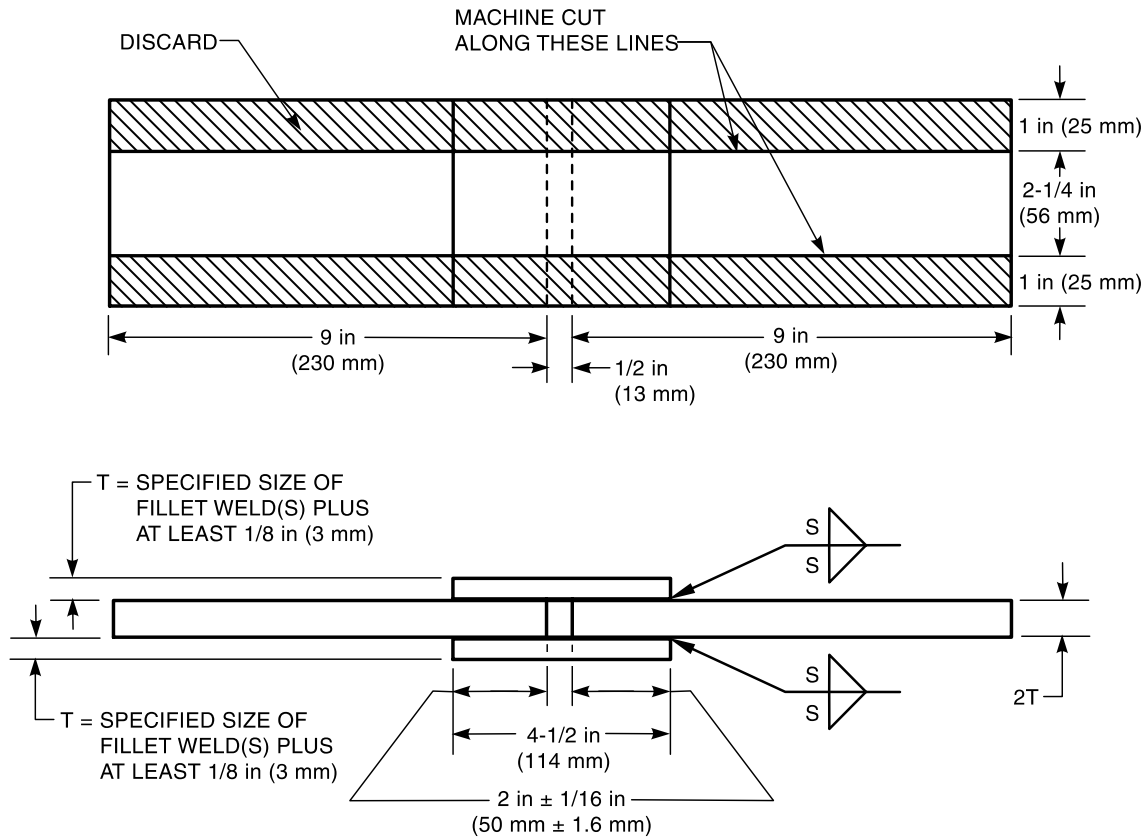
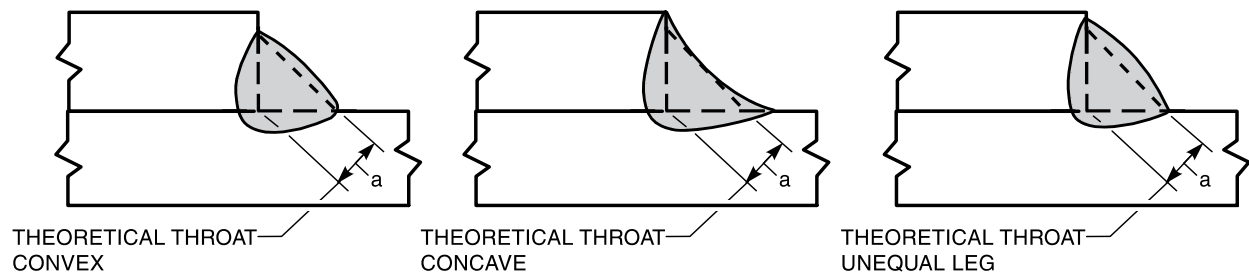


Figure 5.2—Transverse Fillet Weld Shear Specimen



$$\tau = \frac{P}{l \times a}$$

where

- P = load
- l = total length of welds sheared
- a = throat dimensions of welds sheared
- τ = shear strength

Figure 5.3—Shear Strength Calculation

6. Bend Tests

6.1 Scope

6.1.1 This clause covers the bend testing of fillet welds, groove welds in butt joints and the bend testing of surfacing welds. The standard gives the requirements for bend test specimen preparation, test parameters, and testing procedures, but does not specify acceptance criteria.

6.1.2 The base materials may be homogenous, clad or otherwise surfaced, except for hardfacing.

6.1.3 This standard is applicable to the following, where specified:

- (1) Qualification of materials, welding personnel, and welding procedures;
- (2) Information, specifications of acceptance, manufacturing quality control; and
- (3) Research and development.

6.1.4 When this standard is used, the following information shall be specified:

- (1) The specific location and orientation of the specimens;
- (2) The specific types of tests, for example, face bend, side bend, or root bend and number of specimens required;
- (3) Bend radius and specimen thickness (T), or percent (%) elongation. When not otherwise specified, the elongation is generally determined by the base metal or filler metal requirement, whichever is lower; and
- (4) Postweld thermal or mechanical processing treatments, as applicable.

6.2 Normative References. The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this test. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

ASME Documents:

ASME B46. 1, *Surface Texture, Surface Roughness, Waviness and Lay*

ASTM Documents:

ASTM A370, *Standard Test Methods and Definitions for Mechanical testing of Steel Products*

ASTM E190, *Standard Test Method for Guided Bend Test for Ductility of Welds*

6.3 Nomenclature. For the purposes of this test, the following nomenclature apply:

- A = plunger or mandrel radius
- B = die radius
- e = elongation of outer surface
- ID = inside diameter
- L = test plate length
- R = radius
- S = surfacing weld thickness
- T = specimen thickness
- t = thickness of test weldment
- W = specimen width

6.4 Summary of Method

6.4.1 Specimens are guided in the bending process by a test fixture that employs a mandrel with wraparound roller or end supports with a plunger.

6.4.2 Maximum strain on the tension surface is controlled by the thickness of the specimen and the radius of the mandrel or plunger.

6.5 Significance

6.5.1 The ductility of the welded joint, as evidenced by its ability to resist tearing and the presence of defects on the tension surface, is determined in a guided bend test.

6.5.2 Bend tests of weld cladding are used to detect incomplete fusion, tearing, delamination, macro-discontinuities, effect of brittle microstructures and the effect of bead configuration.

6.6 Apparatus

6.6.1 Guided bend specimens may be tested in either of two types of fixture. One type is the guided bend fixture, which is designed to support and load the specimen in a three point bending mode. The alternate is a wraparound bend fixture that fixes one end of the specimen and uses a roller to force the specimen to bend around a mandrel.

6.6.2 The guided bend fixture shall have the dimensions given in Figure 6.1, 6.2, or 6.10.

6.6.3 The wraparound bend fixture shall have the dimensions given in Figure 6.3.

6.6.4 The radius of the plunger, A, shown in Figures 6.1 and 6.2 or the mandrel shown in Figure 6.3 shall be specified or determined from the following equation:

$$A = T(50/e - 1/2)$$

where

A = Radius of mandrel or plunger, $\pm 1/16$ in (± 1.6 mm);

e = Elongation at outer surface, %; and

T = Specimen thickness, $\pm 1/64$ in (± 0.40 mm).

6.6.5 In lieu of using the calculation, the nomograph in Figure 6.11 may be used. See commentary for additional information.

6.6.6 The tolerances specified are for machining and to allow use of standard size mandrels and plungers. It is not the intent of the tolerances to purposely increase the minimum bend radius beyond the calculated value.

6.7 Specimens

6.7.1 Bend test specimens shall be prepared by cutting the weld and the base metal to form a specimen rectangular in cross section. For transverse bends, the surfaces cut transverse to the weld shall be designated as the sides of the specimen. For longitudinal specimens, the longitudinal surfaces that were cut to form the specimen shall be designated as the sides of the specimen and may or may not contain any weld metal. Of the two remaining full-length surfaces, the surface with the greatest weld face width shall be designated as the face while the remaining full length surface shall be designated as the root. Transverse specimens may have the side, face, or root of the weld as the tension surface. Longitudinal specimens may have the face or the root of the weld as the tension surface of the specimen. Where crack sensitive materials are tested, special care may be needed for specimen preparation (for example, grinding direction, surface finish, and corner radii in excess of the limits shown in the figures of this clause).

6.7.2 When specimens wider than 1.5 in (38 mm) are to be bent, the mandrel or plunger shall be at least 0.25 in (6 mm) wider than the specimen width.

6.7.3 It is generally recommended that bend test specimen thickness, T, be $3/8$ in $\pm 1/64$ in (10 mm ± 0.40 mm) unless otherwise dictated by the material thickness, available equipment, or the applicable specification. This is beneficial for side bend specimens in order to use standard jig dimensions of 1.5 in (38 mm) diameter mandrels for materials with 20% minimum specified elongation.

6.7.4 Transverse Side Bend. The longitudinal axis of the specimen is perpendicular to the weld, and the specimen is bent so that one of the side surfaces becomes the tension surface of the specimen. The side showing the more significant discontinuities (if any) shall be the tension side. Transverse side bend test specimens shall conform to Figure 6.4. Transverse side bend specimens are used for plates or pipe that are too thick for face bend or root bend specimens and are recommended for welds with narrow fusion zones.

6.7.5 Transverse Face Bend. The longitudinal axis of the specimen is perpendicular to the weld and the specimen is bent so that the weld face becomes the tension surface of the specimen. Transverse face bend specimens shall conform to the requirements of Figure 6.5 for plate and Figure 6.6 for pipe welds.

6.7.6 Transverse Root Bend. The longitudinal axis of the specimen is perpendicular to the weld and the specimen is bent so that the root surface of the weld becomes the tension surface of the specimen. Transverse root bend specimens shall conform to the requirements of Figure 6.5 for plate and Figure 6.6 for pipe welds.

6.7.7 Longitudinal Face Bend. The longitudinal axis of the specimen is parallel to the weld and the specimen is bent so that the face of the weld becomes the tension surface of the specimen. Longitudinal face bend specimens shall conform to the requirements of Figure 6.7.

6.7.8 Longitudinal Root Bend. The longitudinal axis of the specimen is parallel to the weld and the specimen is bent so that the root of the weld becomes the tension surface of the specimen. Longitudinal root bend test specimens shall comply with the requirements of Figure 6.7.

6.7.9 Fillet Weld Root Bend. The fillet weld root-bend test sample shall be welded and prepared as shown in Figure 6.8. The root of the weld shall be the tension surface of the specimen. The fillet weld root bend test is an alternate to the fillet weld break test in some codes and specifications (see 9.2).

6.7.10 Surfacing Weld Specimens. The face bend and side bend specimens for surfacing welds shall conform to the requirements of Figure 6.9. The length of the transverse bend specimen shall be perpendicular to the weld direction; the length of the longitudinal bend specimen shall be parallel to the weld direction. The surface weld shall be the tension surface of the face bend specimen.

6.7.11 Longitudinal Fillet Weld Specimen. The fillet weld bend test specimens are prepared by making two fillet welds on a T-joint and machining the specimen as shown in Figure 6.10. The fillet weld shall be the tension surface of the specimen.

6.8 Procedure

6.8.1 Unless otherwise specified, the specimen shall be tested at ambient temperature and deformation shall occur in a time period no shorter than 15 seconds and no longer than 2 minutes. If weld and heat-affected zone (HAZ) for transverse specimens are not within the curved portion of the specimen, the specimen shall be discarded and another specimen prepared and tested.

6.8.2 Guided Bend Testing

6.8.2.1 Transverse Specimens. The following procedure is applicable to guided bend testing of transverse specimens:

- (1) Place the tension side down on the supporting surface of the bend fixture shown in Figures 6.1, 6.2, and 6.10. The weld shall be centered in the fixture with the centerline of the weld within 1/16 in (1.6 mm) of the center of the fixture.
- (2) Any means may be used for smoothly moving the plunger in relation to the support members of the bend fixture.
- (3) For bend fixtures with a bottom open (Figures 6.1 and 6.10), apply a sufficient load on the plunger until the specimen is bottom ejected, or until the radius of the plunger has cleared the radius of the rollers (or shoulders). Caution must be used to prevent injury due to the force of the ejecting specimen.
- (4) For bend fixtures with a bottom radius (Figure 6.2), the plunger shall force the specimen into the die until the specimen reaches the bottom of the fixture.

6.8.2.2 Longitudinal Specimens. The following procedure is applicable to guided bend testing of longitudinal specimens:

- (1) Center the tension side of the specimen on the supporting surfaces of the bend fixture.
- (2) Proceed as described in 6.8.2.1(2) and (3) above for transverse specimens.

6.8.3 Wraparound Bend Testing. The specimen shall be firmly clamped on one end in the fixture (Figure 6.3) so that there is no sliding of the specimen relative to the mandrel during the bending operation. Alternatively, the specimen may be held stationary against a rotated, nonslipping mandrel of radius A by a stationary compressive roller. In this case the specimen is wrapped around the rotating mandrel by draw-bending the specimen from between the outer roller and the point where the rotating mandrel holds the specimen tight against the roller. For transverse bend specimens the weld and HAZs shall be centered within the bent portion of the specimen. Test specimens shall not be removed from the fixture until the point where the outer roller contacts the bend specimen and has moved 180° from its starting point along the convex surface of the bend specimen.

6.8.4 Specimen Inspection. The specimen shall be removed from the bend fixture and the tension surface of the specimen (weld metal and HAZ) visually examined for tears or other open defects, and all defect types, quantities, sizes,

and locations shall be recorded. When fracture of the weld specimen occurs prior to completing a 180° bend, the angle at which it fractured shall be recorded, if possible. For transverse bend specimens the weld and HAZ shall be centered and completely within the bent portion of the specimen after testing.

6.9 Report. In addition to the requirements of applicable documents, the report shall include the following:

- (1) Materials Identification
 - (a) Base metal specification
 - (b) Filler metal specification
- (2) Specimen thickness and width
- (3) Type of welded joint or surfacing weld
- (4) Welding procedure specifications and procedure qualification record numbers (if applicable) including any supplemental information
- (5) Specific tests performed
- (6) Bend radius
- (7) Test temperature
- (8) Number of tests per condition or lot
- (9) The following additional information should be included: number, type, size and location of defects, if any
- (10) Bend angle; also identify if specimen fractures prior to 180°
- (11) Any observation of unusual characteristics of the specimens or procedure

6.10 Commentary

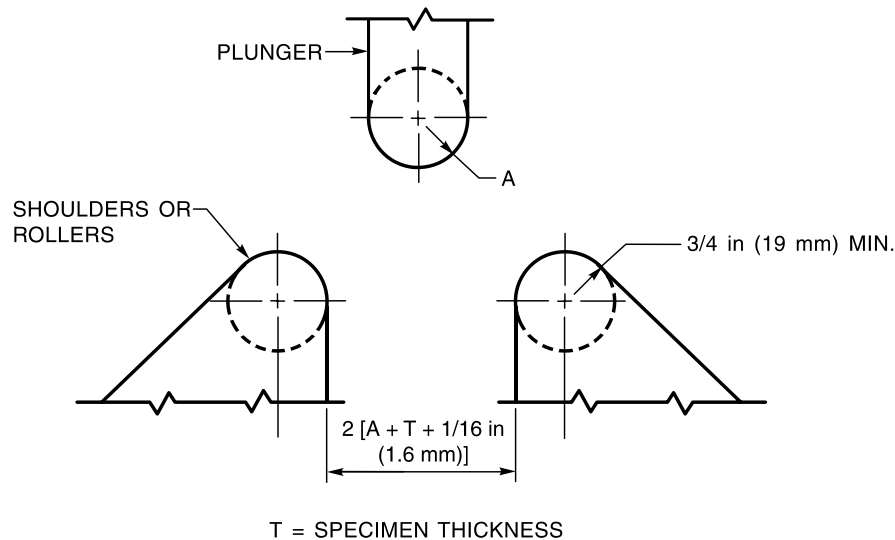
6.10.1 When testing weld specimens containing base metal and filler metal which have significantly different tensile and yield strengths, using the test fixtures shown in Figures 6.1 and 6.2, bending will not be uniformly distributed across the weld, HAZ, and base metal. For example, if the deposited weld metal has a yield strength less than that of the base metal, yielding will begin in the weld first, resulting in a true bend radius less than that of the plunger. A smaller effective bend radius results in a more severe test of the deposited weld metal.

On the other hand, when the deposited weld metal is stronger than the base metal, bending will begin in the HAZ and adjacent base metal, resulting in bending with a small radius at these points and little, if any, bending occurring in the weld metal. The result of this situation is a more severe test of the HAZ or base metal and a less severe test of the weld metal.

It is recommended that a wraparound fixture shown in Figure 6.3 be used in these situations or longitudinal bend specimens be used in place of the transverse guided bend specimens. Testing of welds in dissimilar metals (such as high tensile strength plate to ordinary structural grade steels) can produce similar effects because of the tendency for the specimens to shift (slide sideways) during loading when using the fixtures shown in Figures 6.1 and 6.2. The use of a mallet to adjust the specimen in the fixture after the specimen has begun bending is discouraged as it may result in rapid bending and undue failure.

6.10.2 For welds and materials with elongation exceeding 20%, bend testing at 20% elongation is normally considered sufficient. This takes into consideration the complexity of the welded joint and common requirements for weld strength. However, when elongation greater than 20% is required for serviceability of the joint, the contracting parties must specify the minimum acceptable elongation for the bend test.

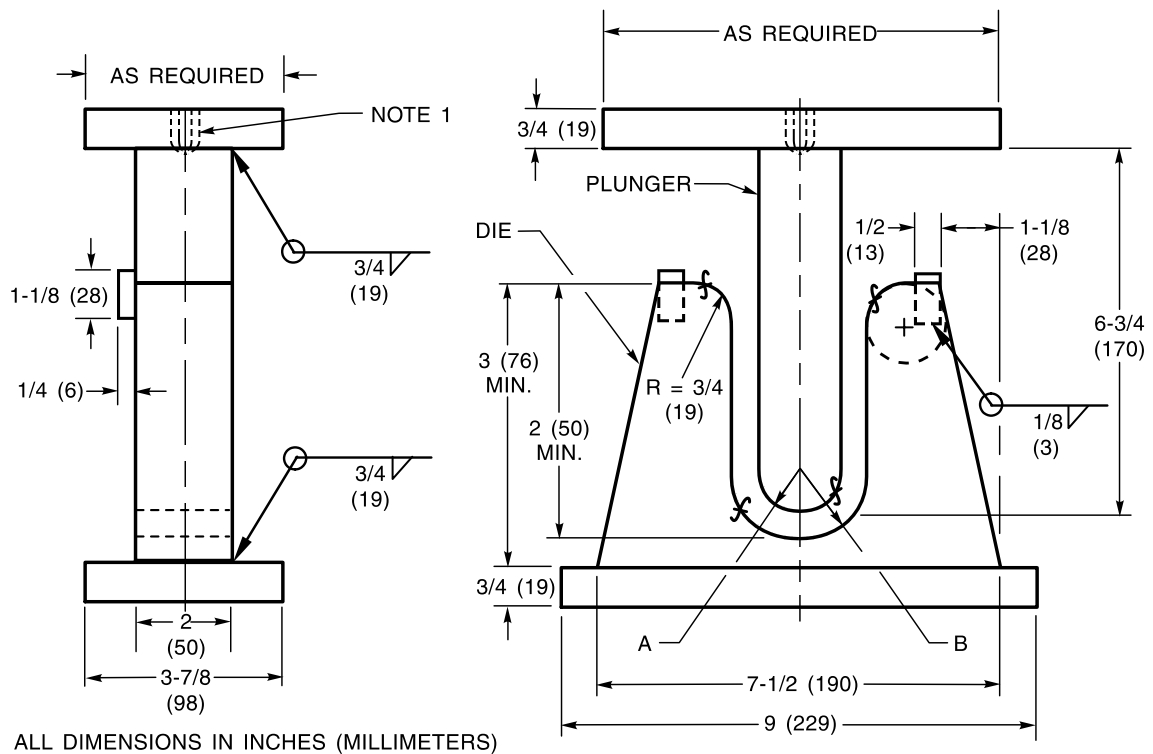
6.10.3 Users are to be aware that the nomograph is provided for ease of use. Previous copying errors and use of printed copies may result in some errors in bend radius. Users are cautioned to verify copied versions of the nomograph to ensure accuracy. When the nomograph bend radius differs from the calculated value, the calculated value is considered correct.



Notes:

1. Either hardened and greased shoulders or hardened rollers free to rotate should be used.
2. The shoulder or rollers shall have a minimum bearing length of 2 in (50 mm) for placement of the specimen.
3. The shoulders or rollers shall be high enough above the bottom of the fixture so that the specimen will clear the shoulders or rollers when the plunger is in the low position.
4. The plunger shall be fitted with an appropriate base and provision for attachment to the testing machine and shall be designed to minimize deflection or misalignment.
5. The shoulder or roller supports may be made adjustable in the horizontal direction so that specimens of various thickness may be tested in the same bend fixture.
6. The shoulder or roller supports shall be fitted to a base designed to maintain the shoulders or rollers centered and aligned with respect to the plunger, and minimize deflection or misalignment.
7. Plunger radius, A , shall be as specified, as determined from the formula in 6.6.4 or nomograph in Figure 6.11

Figure 6.1—Typical Bottom Ejecting Guided Bend Test Fixture

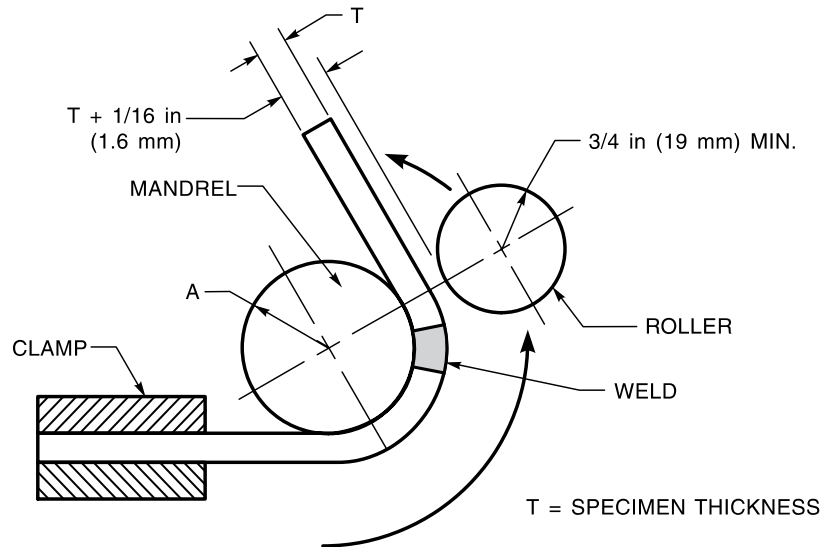


Weld Symbol Conversions	
US Customary (in)	SI Units (mm)
1/8	3
3/4	19

Fixture Dimensions for 20% Elongation of Weld		
Specimen Thickness, T in (mm)	Plunger Radius, A in (mm)	Die Radius, B in (mm)
3/8 (10)	3/4 (19)	1-3/16 (32)
T	2T	A + T + 1/16 (1.6)

- Notes:
1. Tapped hole of appropriate size, or other suitable means for attaching plunger to testing machine.
 2. Either hardened and greased shoulders or hardened rollers free to rotate should be used in die.
 3. The plunger and its base shall be designed to minimize deflection and misalignment.
 4. The plunger shall force the specimen into the die until the specimen becomes U-shaped. The weld and heat-affected zones shall be centered and completely within the bent portion of the specimen after testing.
 5. For a given specimen thickness, T, the plunger radius, A, shall be as specified or as determined from the formula in 6.6.4. For example, fixture dimensions for 20% elongation and a specimen thickness, T, of 3/8 in (10 mm) shall be plunger radius, A, equal to 3/4 in (19 mm) and die radius, B, equal to 1-3/16 in (32 mm).
 6. Weld sizes indicated are recommendations. The actual fillet weld size is the responsibility of the user to ensure rigidity and design adequacy.

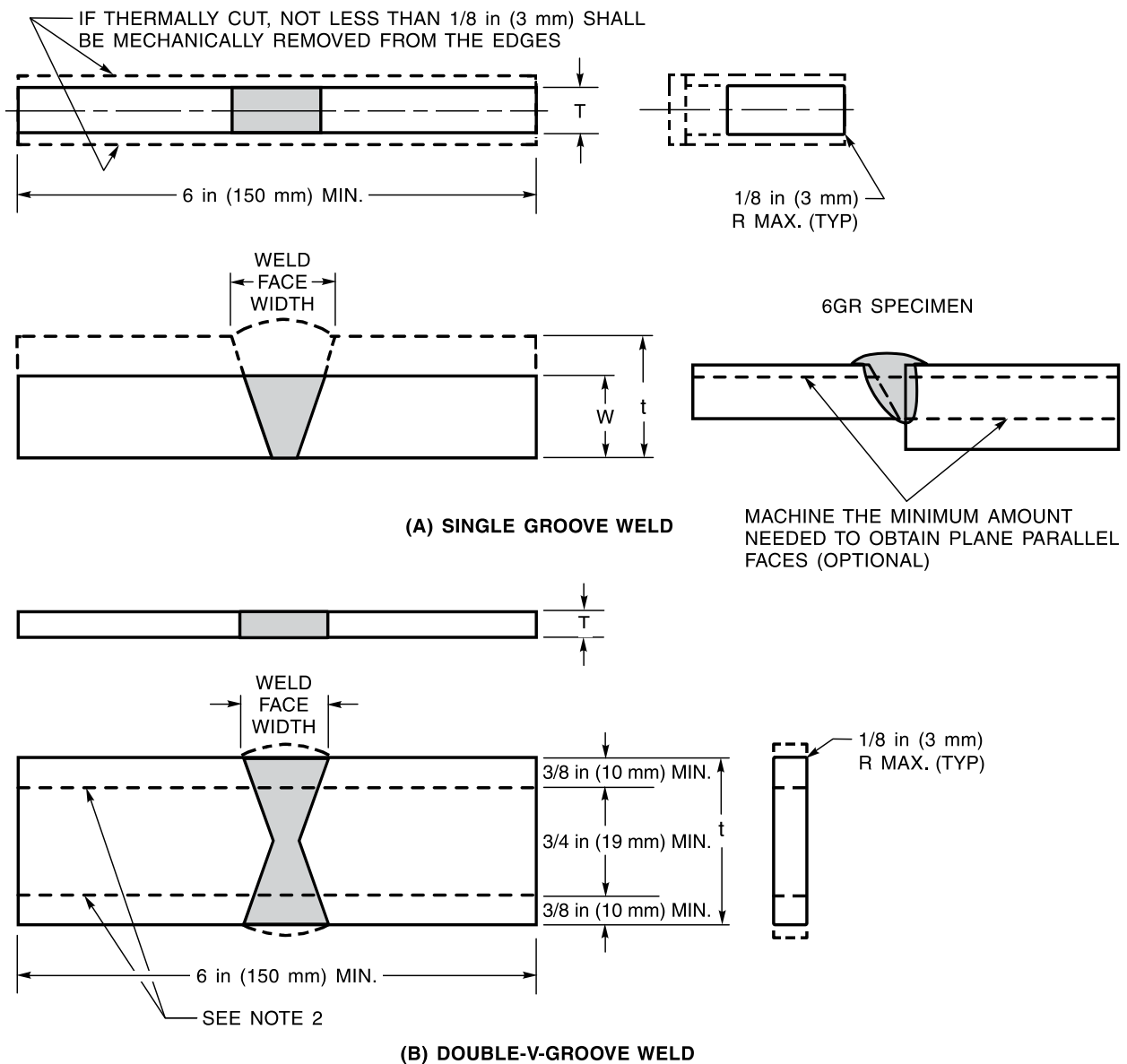
Figure 6.2—Typical Bottom Guided Bend Test Fixture



Notes:

1. Radius A shall be as specified, or as determined from the formula in 6.6.4. Dimensions not shown are the option of the designer, except that the minimum width of the components shall be 2 in (50 mm).
2. It is essential to have adequate rigidity so that the bend fixture will not deflect during testing. The specimen shall be firmly clamped on one end so that it does not slide during the bending operation.
3. Test specimens shall be removed from the bend fixture when the roller has traversed 180° from the starting point.

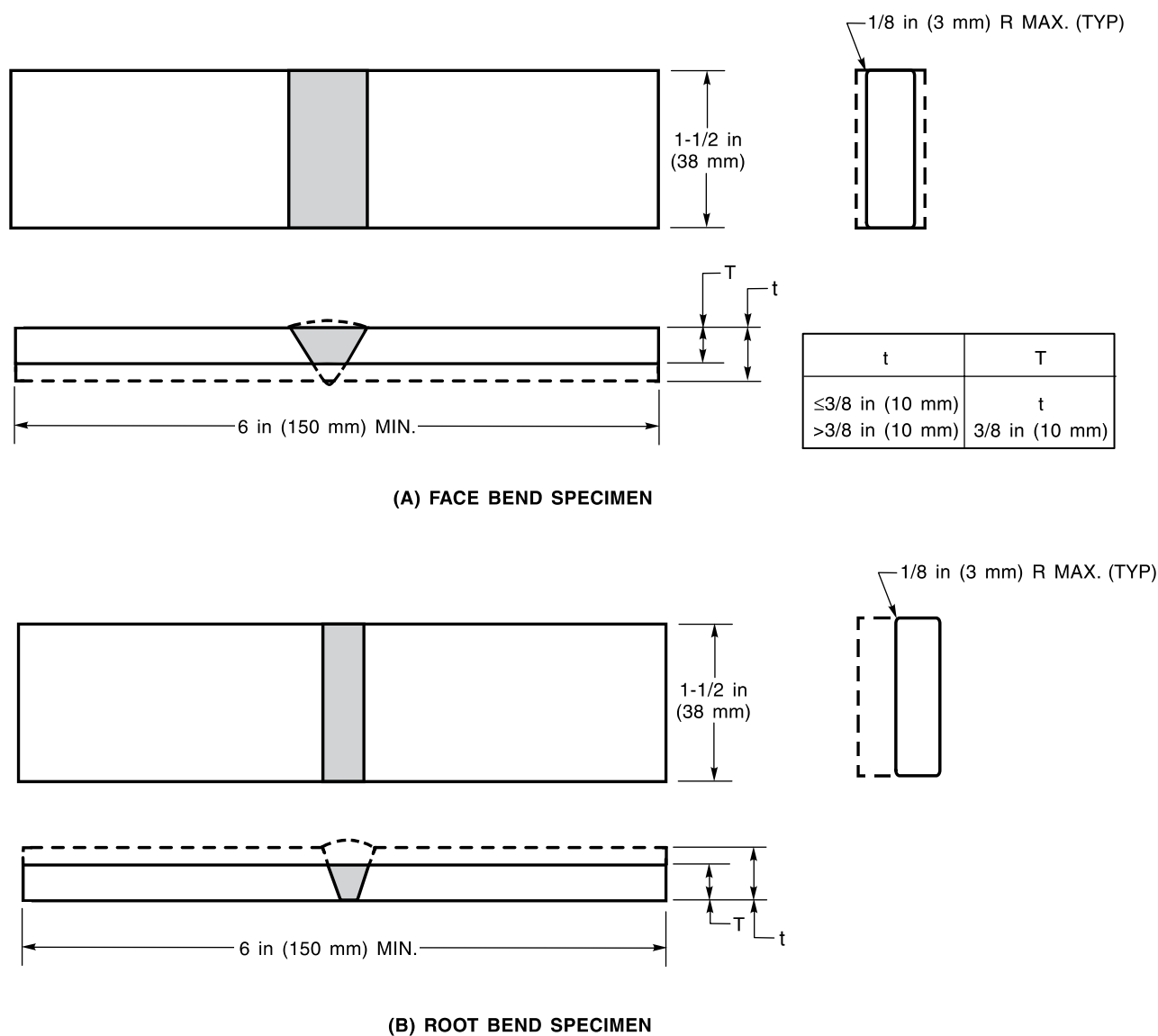
Figure 6.3—Typical Wraparound Guided Bend Test Fixture



Notes:

1. If the thickness, t , of a single-groove weld joint exceeds 1-1/2 in (38 mm), the specimen may be cut into approximately equal strips between 3/4 in (19 mm) and 1-1/2 in (38 mm) wide. Each strip shall be tested by bending to the same radius as specified, or as determined by the formula in 6.6.4. If the plate thickness, t , of a double-groove weld joint exceeds 1-1/2 in (38 mm), the specimen may be cut into multiple strips so that the root of the weld is centered in one of the strips as shown. Whenever possible it is recommended that the specimen thickness, T , be approximately 3/8 in (10 mm) with each specimen having a width exceeding its thickness. These strips shall be bent to the same radius as specified, or as determined by the formula in 6.6.4.
2. The weld reinforcement and backing, if any, shall be mechanically removed flush with the specimen surface. For performance qualification, if sufficient material is available, acceptable undercut should be removed while maintaining specimen dimensions.
3. The diameter of the test plunger should be equal to or exceed the width of the remaining weld face width in order to test the weld HAZ and base metal. If this requirement cannot be met, a greater thickness, T , may be chosen in accordance with the formula in 6.6.4 All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be oriented parallel to the longitudinal axis of the specimen.

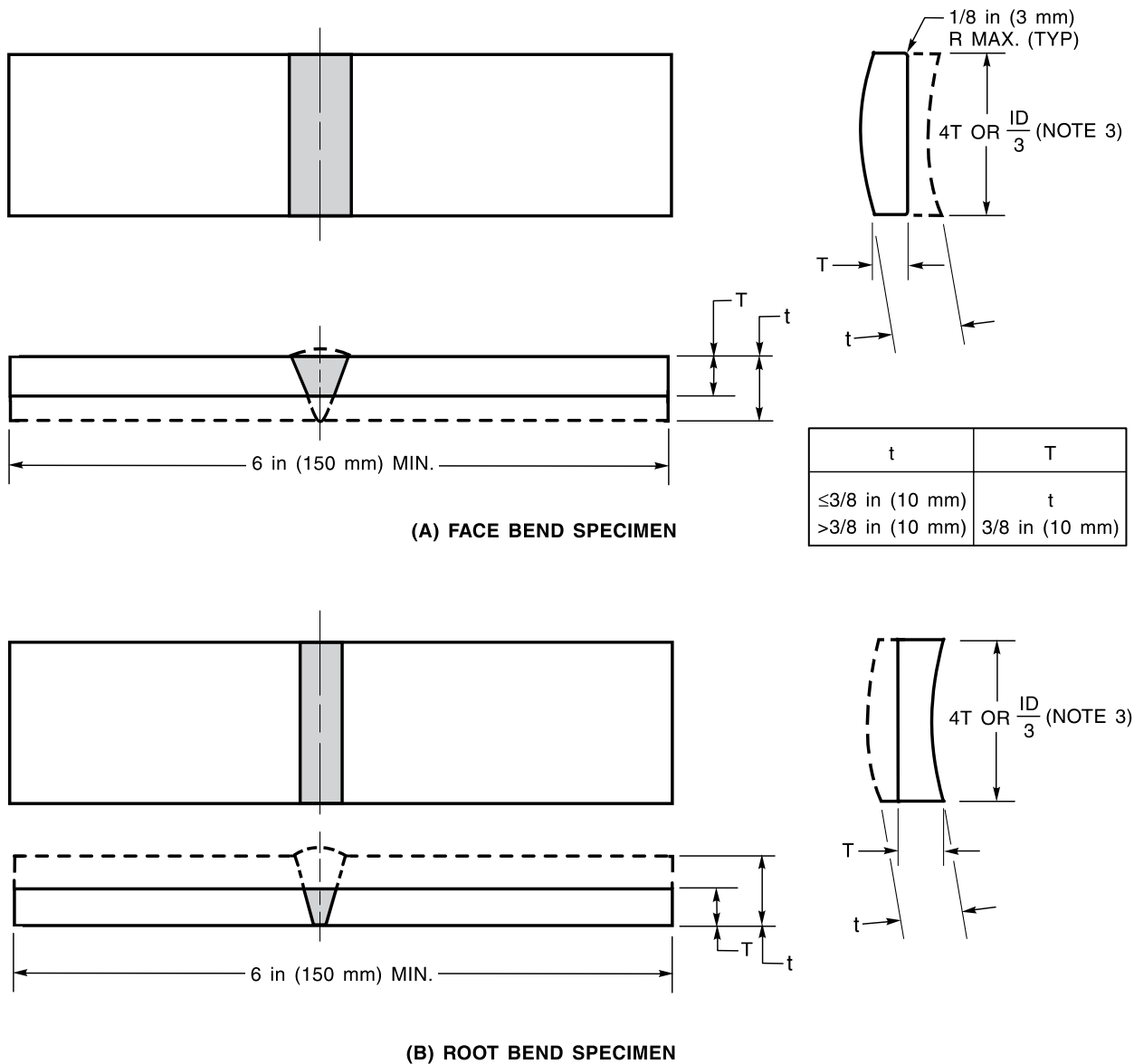
Figure 6.4—Transverse Side Bend Specimens (Plate and Pipe)



Notes:

1. The specimen edges may be thermally cut but, in this case, at least 1/8 in (3 mm) of material shall be mechanically removed from the thermally cut surface.
2. For clad metals having an elongation requirement of at least 25%, the specimen thickness, T, may be reduced when using a fixed bend-radius testing bend fixture. The specimen thickness shall be determined by the formula in 6.6.4. If the weld joins base metals of different thicknesses, the specimen should be reduced to a constant thickness based on the thinner base metal.
3. Unless otherwise specified, the weld reinforcement and backing, if any, shall be mechanically removed flush with the specimen surface. For performance qualification, if sufficient material is available, acceptable undercut should be removed while maximizing specimen dimensions.
4. The diameter of the test plunger should be equal to or exceed the width of the remaining weld face. If this requirement cannot be met, a greater thickness, T, may be chosen in accordance with the formula in 6.6.4.
5. All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be parallel to the longitudinal axis of the specimen.

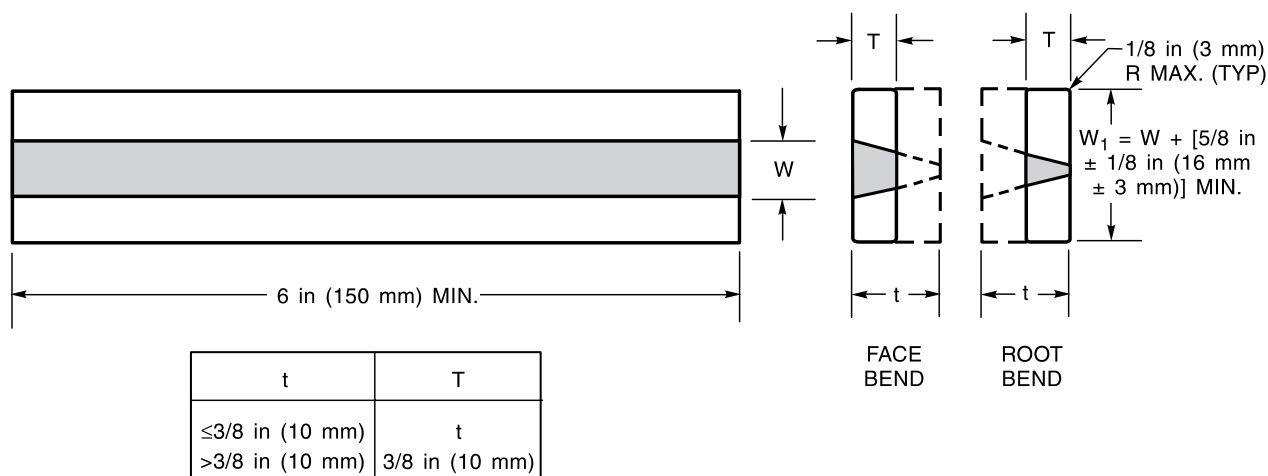
Figure 6.5—Transverse Face Bend and Root Bend Specimen (Plate)



Notes:

1. The specimen edges may be thermally cut but, in this case, at least $1/8$ in (3 mm) of material shall be mechanically removed from the thermally cut surfaces.
2. If the weld joins base metals of different thicknesses, the specimen should be reduced to a constant thickness based on the thinner base metal.
3. The specimen width shall be $4T$, except that it shall not exceed $ID/3$ where ID is the inside diameter of the pipe.
4. The weld reinforcement and backing, if any, shall be mechanically removed flush with the specimen surface. If the back of the joint is recessed, this surface of the specimen may be removed to a depth not exceeding the recess. For performance qualification, if sufficient material is available, acceptable undercut should be removed while maintaining specimen dimensions.
5. The diameter of the test plunger should be equal to or exceed the weld width. If this requirement cannot be met, a greater thickness, T , may be chosen in accordance with the formula in 6.6.4
6. All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be oriented parallel to the longitudinal axis of the specimen.

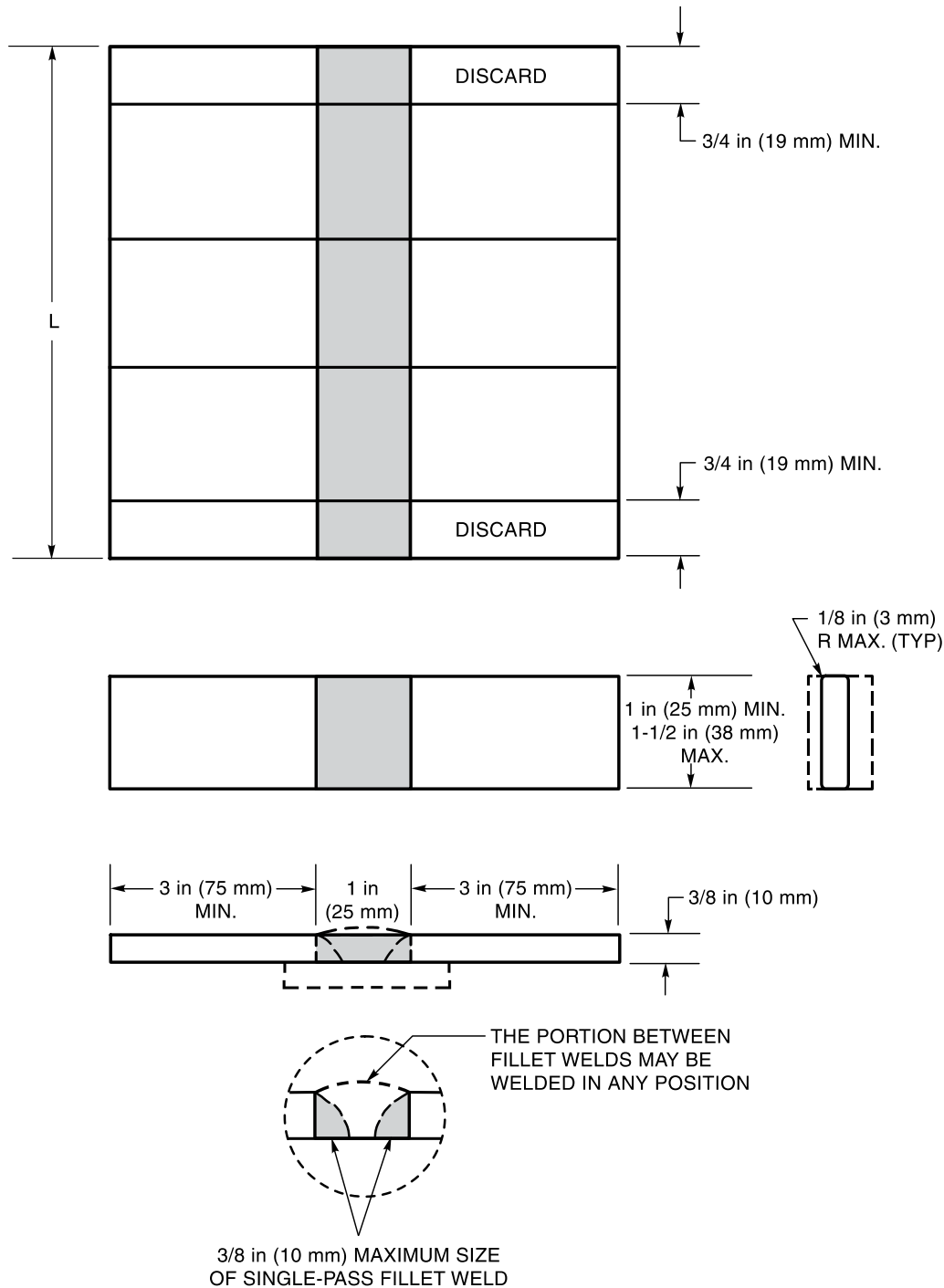
Figure 6.6—Transverse Face Bend and Root Bend Specimens (Pipe)



Notes:

1. The specimen edges may be thermally cut, but in this case, at least 1/8 in (3 mm) of material shall be mechanically removed from the thermally cut surface.
2. If the weld joins base metals of different thicknesses, the specimen should be reduced to a constant thickness based on the thinner base metal.
3. Weld reinforcement and backing, if any, shall be mechanically removed flush with the surface of the specimen. For performance qualification, if sufficient material is available, acceptable undercut should be removed while maintaining specimen dimensions.
4. All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be oriented parallel to the axis of the specimen.

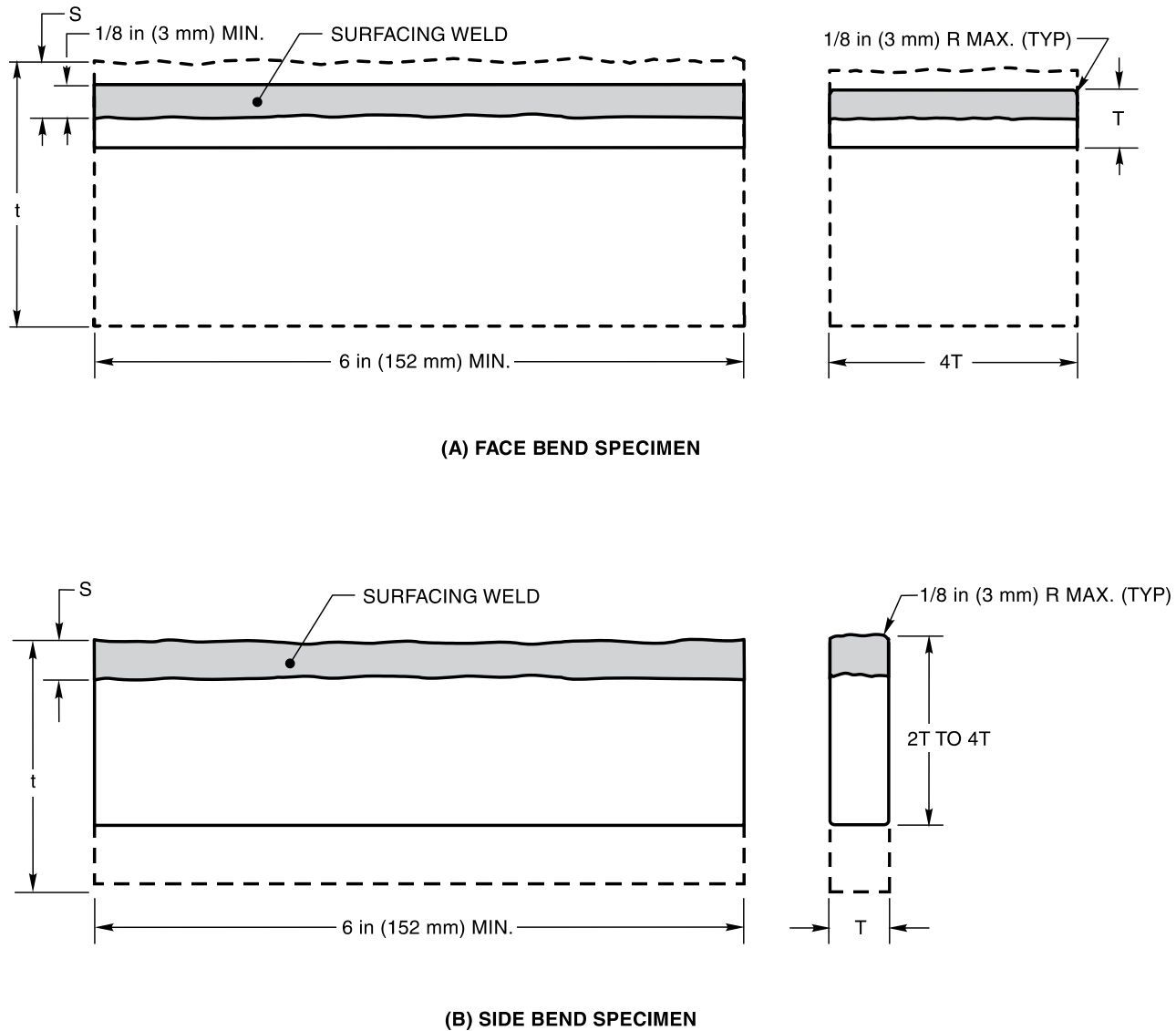
Figure 6.7—Longitudinal Face Bend and Root Bend Specimen (Plate)



Notes:

1. The backing shall be 3/8 in by 2 in (10 mm by 50 mm) minimum unless the test weld is to be inspected radiographically, in which case the backing bar shall be 3/8 in by 3 in (10 mm by 76 mm) minimum. The backing bar shall be in intimate contact with the base plate.
2. The test plate length L , shall be sufficient for the required number of specimens. Specimens shall be removed mechanically from the test plate.
3. The weld reinforcement and backing bar shall be removed mechanically, flush with the base plate.
4. All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be oriented parallel with the longitudinal axis of the specimen.

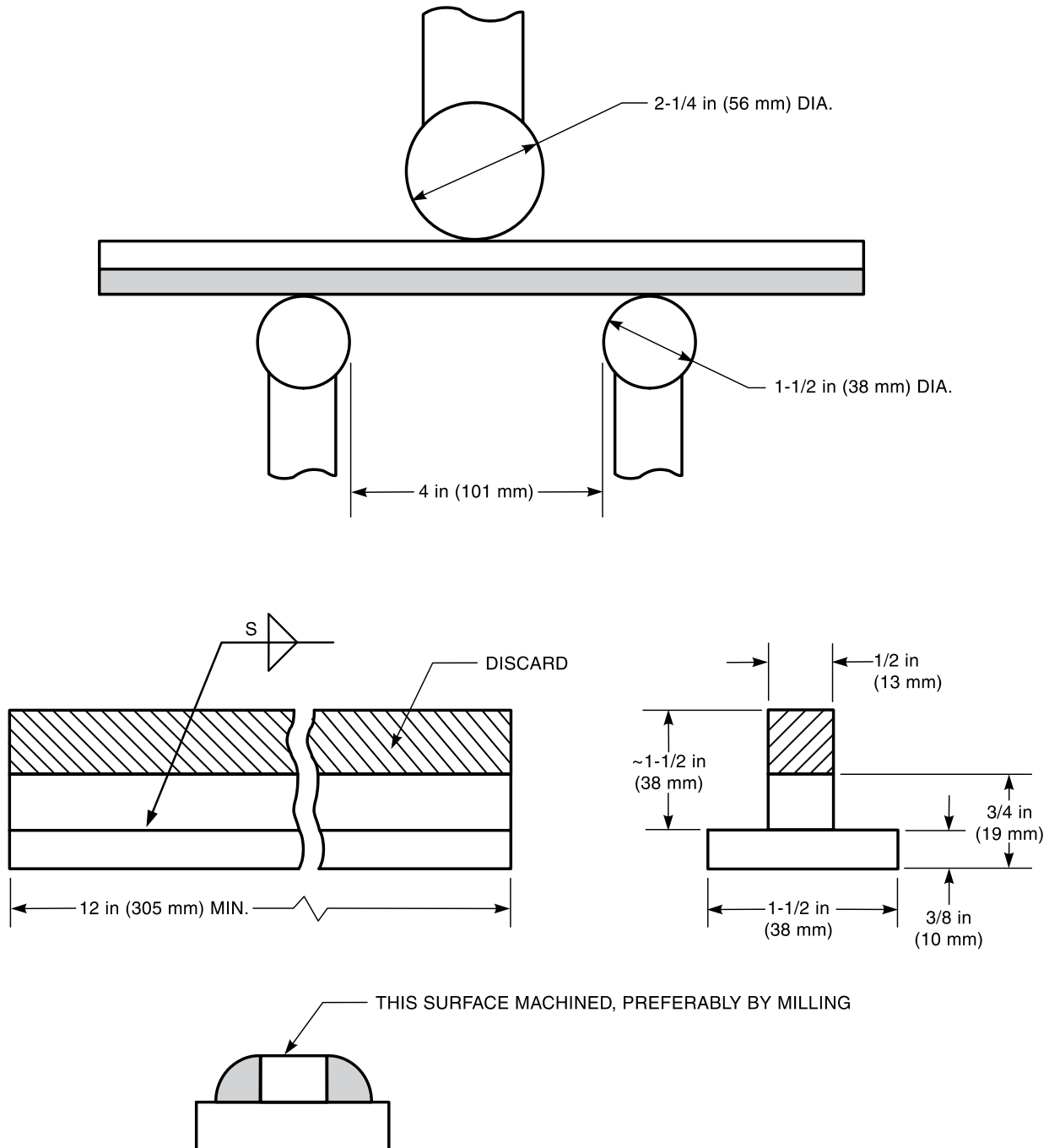
Figure 6.8—Fillet Weld Root Bend Test Specimen



Notes:

1. The dimension, T , is the thickness of the test specimen and shall be $3/8$ in (10 mm) unless otherwise specified.
2. For the longitudinal bend test, the long axis of the specimen shall be parallel to the welding direction. For the transverse bend test, the long axis shall be perpendicular to the weld direction length of the test specimen.
3. The amount of surfacing weld removed from the face-bend specimen surface shall be the minimum necessary to obtain a smooth surface. The minimum thickness of surfacing weld after finishing shall be $1/8$ in (3 mm).
4. All longitudinal surfaces shall be no rougher than 125 microinches (3 micrometers) R_a . It is recommended that the lay of the surface roughness be oriented with the longitudinal axis of the specimen.

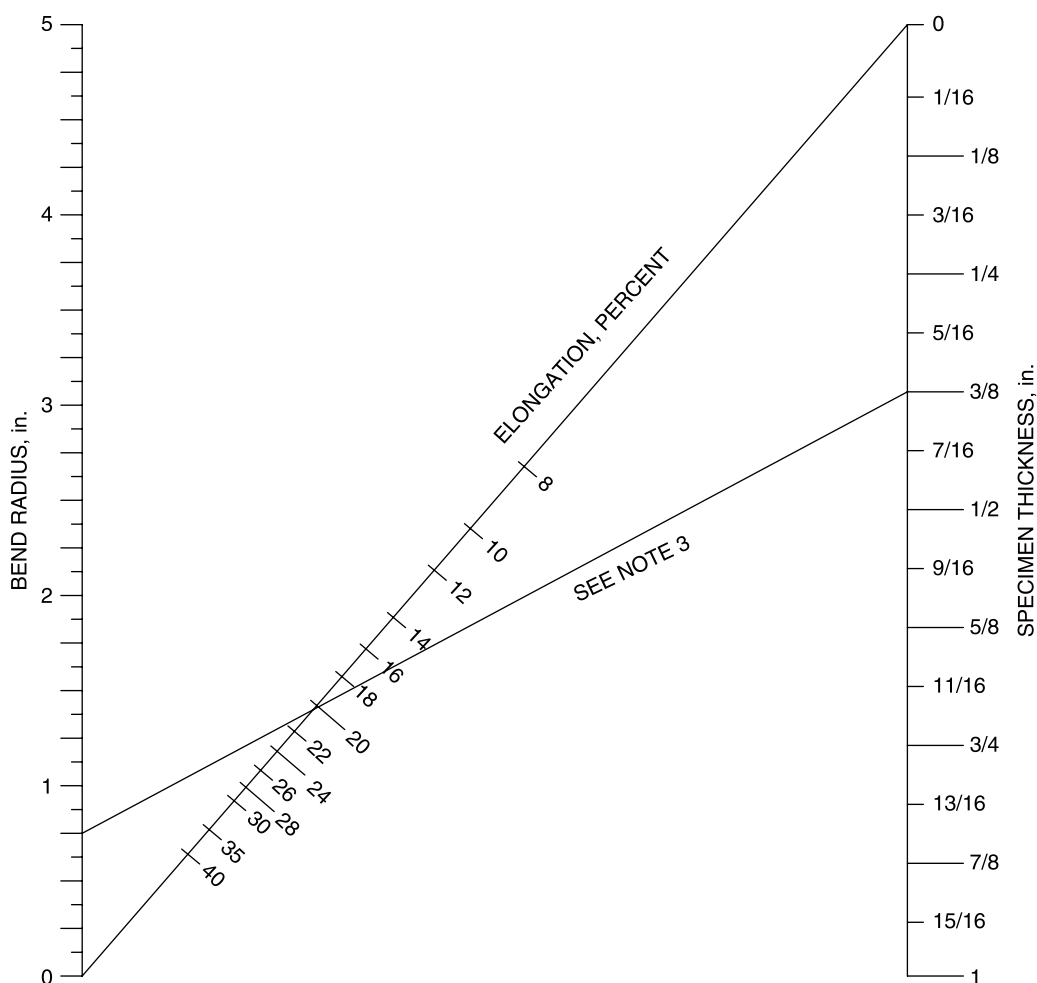
Figure 6.9—Surfacing Weld Face Bend and Side Bend Specimen



Notes:

1. Mandrel diameter shown is for a maximum 3/4 in (19 mm) thick specimen.
2. Other thicknesses of bottom plate and fillet weld leg size may be utilized, provided the mandrel diameter does not exceed 3 times the specimen thickness. In these cases, the support clearance should be the mandrel diameter plus twice the specimen thickness plus 1/4 in (6 mm).
3. Surface finish of the tension surface shall be no rougher than 125 microinches (3 micrometers) R_a .
4. Fillet weld size(s) should be 5/16 in to 1/2 in (8 mm to 13 mm).

Figure 6.10—Longitudinal Guided Fillet Weld Bend Test



or use the formula in 6.6.4

Notes:

1. It is generally recommended that the specimen thickness for the bend tests be approximately 3/8 in. However, the specimen thickness may be any value within the range given above as dictated by the material thickness, available equipment, or the applicable specification.
2. Required accuracy of measurement is as follows:
 - (1) Specimen thickness: $\pm 1/64$ in.
 - (2) Bend radius: $\pm 1/16$ in.
3. Example: If a standard requires a minimum elongation of 20 percent and if the specimen is 3/8 in. thick, a line is drawn between these two points and extended to determine the appropriate bend radius which would be 3/4 in.

Figure 6.11—Bend Test Nomograph

7. Fracture and Notch Toughness Tests

7.1 Scope

7.1.1 This clause covers the fracture toughness testing of weldments. Methods include Charpy V-Notch (C_v), Dynamic Tear (DT), Plane-Strain Fracture Toughness (K_{Ic}), a measure of Fracture Toughness (J_{Ic}), Crack Tip Opening Displacement (CTOD), and Drop Weight Nil-Ductility Temperature (DWNMT) Tests.

7.1.2 When a fracture toughness test is required, the preparation of the weld, the test specimen, and the test method shall conform to this standard.

7.1.3 This standard is applicable to the following when specified:

(1) For qualification of materials, welding procedures, and welding personnel where a specified level of fracture toughness is required;

(2) For information, specification of acceptance and manufacturing quality control where a minimum criterion for fracture toughness is requested. Detailed discussion of the selection of test method and a specified minimum value in a specific case is beyond the scope of this standard; and

(3) Research and development.

7.1.4 When this standard is used the following information shall be furnished:

(1) The specific types and number of specimens required,

(2) Base metal specifications/identification,

(3) Filler material specification/identification,

(4) The anticipated property values and whether they are maximum or minimum requirements,

(5) Location and orientation of the specimen and notch with respect to the weld and/or welding direction,

(6) Joint geometry,

(7) Test temperature, and

(8) Postweld thermal or mechanical treatments.

7.2 Normative References. The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this test. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

ASME Documents:

ASME B46.1, *Surface Texture, Surface Roughness, Waviness and Lay*

ASTM Documents:

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E208, *Standard Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels*

ASTM E399, *Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials*

ASTM E604, *Standard Test Method for Dynamic Tear Testing of Metallic Materials*

ASTM E1820, *Standard Test Method for Measurement of Fracture Toughness*

ASTM E1823, *Standard Terminology Relating to Fatigue and Fracture Testing*

ASTM E1921, *Standard Method for Determination of Reference Temperature, T_0 , for Ferritic Steels in the Transition Range.*

ISO Documents:

ISO 15653, *Metallic materials — Method of test for the determination of quasistatic fracture toughness of welds*

7.3 Summary of Method

7.3.1 The method selected for fracture toughness testing shall be that required in the specification of a material, fabrication document, or as otherwise specified.

7.3.2 Specimens shall be removed from a weldment so that the results of the test are representative of the structural performance of the weld joint.

7.4 Significance

7.4.1 Fracture toughness testing provides a measure of resistance to unstable crack extension (i.e., fracture initiation), ductile tearing (i.e., fracture propagation), or both.

7.4.2 The welding process and welding procedure have a significant effect on the mechanical properties of a weld joint. If the fracture toughness of a weld joint sample is to be representative of its structural performance, the same welding process, procedure, and weld cooling rates, as a function of distance and thickness, must be used for the sample and the structure.

7.5 Apparatus

7.5.1 The apparatus for conducting the various fracture toughness tests shall be in accordance with the latest edition of the following ISO and ASTM Standard Test Methods:

- (1) Charpy V-notch, ASTM E23;
- (2) Dynamic Tear, ASTM E604;
- (3) Plane-Strain Fracture Toughness, ASTM E399;
- (4) Drop-weight Nil-Ductility Transition Temperature, ASTM E208;
- (5) J_{IC} , K, and CTOD Fracture Toughness, ASTM E1820 and ISO 15653.

7.6 Specimens

7.6.1 Sufficient information shall be provided to properly locate specimens and weld joint; the orientation of the weld joint shall also be identified.

7.6.2 Test specimens shall not contain metal that has been affected thermally as a result of cutting or preparation.

7.6.3 Unless otherwise specified, the nominal dimensions, orientation and notch location of specimens shall be that shown in Figures 7.1 through 7.6, respectively. Working drawings are provided in the referenced documents.

7.6.4 Unless otherwise specified, the weld metal width to specimen thickness relationship for the compact tension specimen shall be as shown in Figure 7.7. Weld metal test specimens shall be located in the weld joint as close to the weld face as possible to provide maximum weld metal area in the test specimens. A valid measure of the weld metal fracture toughness requires that the fracture surface be entirely within the weld metal. A different value of the fracture toughness may be obtained when the fracture surface includes the weld metal, heat-affected zone (HAZ), and base metal.

7.6.5 When an evaluation of the base metal or HAZ or both is required, the specimen location and location of the notch shall be specified.

7.7 Procedure

7.7.1 Test specimen preparation and test procedure for measuring the fracture toughness of a weldment shall be in accordance with the following ISO and ASTM standard test methods:

- (1) Charpy V-notch, ASTM E23, except that values up to and including 100% of the testing machine capacity shall be accepted and reported as fracture energy if the specimen breaks. The full machine capacity followed by a plus sign (+), shall be reported if the specimen is not broken. All these results may be used to calculate the average energy absorbed provided the minimum average required for acceptance is within the verified range of the machine;
- (2) Dynamic Tear, ASTM E604;
- (3) Plane-Strain Fracture Toughness, ASTM E399;
- (4) Drop-Weight Nil-Ductility Transition Temperature, ASTM E208;
- (5) J_{IC} , K, and CTOD Fracture Toughness, ASTM E1820 and ISO 15653.