

Welding of Pipelines and Related Facilities

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Foreword

This standard was prepared by a formulating committee that included representatives of the API, the American Gas Association (AGA), the Pipe Line Contractors Association (PLCA), the American Welding Society (AWS), and the American Society for Nondestructive Testing (ASNT), as well as representatives of pipe manufacturers and individuals associated with related industries.

The purpose of this standard is to present methods for the production of high quality welds through the use of qualified welders using approved welding procedures, materials, and equipment. Its purpose is also to present inspection methods to ensure the proper analysis of welding quality through the use of qualified technicians and approved methods and equipment. It applies to both new construction and in-service welding.

The use of this standard is entirely voluntary and is intended to apply to welding of piping used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, and nitrogen and, where applicable, to distribution systems.

This standard represents the combined efforts of many engineers who are responsible for the design, construction, and operation of oil and gas pipelines, and the committee appreciatively acknowledges their wholehearted and valuable assistance.

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Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the standard.

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, standards@api.org.

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Welding of Pipelines and Related Facilities

1 Scope

This standard covers the gas and arc welding of butt, branch, and fillet welds in carbon and low-alloy steel pipe and piping components used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, nitrogen, and, where applicable, covers welding on distribution systems. It applies to both new construction and in-service welding. The welding may be done by a shielded metal arc welding, submerged arc welding, gas tungsten arc welding, gas metal arc welding, flux-cored arc welding, plasma arc welding, or oxyacetylene welding process, or by a combination of these processes using a manual, semiautomatic, or mechanized welding technique or a combination of these techniques. The welds may be produced by position or roll welding or by a combination of position and roll welding.

This standard also covers the procedures for radiographic, magnetic particle, liquid penetrant, and ultrasonic testing, as well as the acceptance standards to be applied to production welds tested to destruction or inspected by radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing methods.

The values stated in either U.S. customary units (USC) or metric units (SI) are to be regarded separately as standard. Each system is to be used independently of the other, without combining values in any way.

The figures depicted in this standard are not drawn to scale.

It is intended that all work performed in accordance with this standard meets or exceeds the requirements of this standard.

While this standard is comprehensive, it may not address all issues that may arise. The absence of guidance or requirements is not to be considered prohibitive to a particular activity or approach that is based upon sound engineering judgment. For example, other industry standards, reliable engineering tests and analyses, or established industry practices may provide useful reference to establish sound engineering judgment.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 5L, *Specification for Line Pipe*

ASNT¹ SNT-TC-1A, *Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing*

ASTM² E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E384, *Standard Test Method for Knoop and Vickers Hardness of Materials*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E747, *Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*

¹ American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, Ohio 43228-0518, www.asnt.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E1025, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography*

AWS A3.0³, *Standard Welding Terms and Definitions*

AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.2, *Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding*

AWS A5.5, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.18, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.20, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*

AWS A5.23, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.28, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.29, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*

AWS A5.32, *Welding Consumables – Gases and Gas Mixtures for Fusion Welding and Allied Processes*

AWS A5.36, *Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding*

BS EN ISO 15653⁴, *Metallic Materials. Method of Test for the Determination of Quasistatic Fracture Toughness of Welds*

ISO 19232-1⁵, *Non-destructive testing—Image quality of radiographs—Part 1: Image quality indicators (wire type)—Determination of image quality value*

NACE MR0175/ISO⁶ 15156 (all parts), *Petroleum and Natural Gas Industries—Materials for use in H₂S-containing Environments in Oil and Gas Production*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this standard, the welding terms and definitions given in AWS A3.0 and the following shall apply. When identical terms are defined in AWS A3.0 and this standard, the following definitions shall apply.

3.1.1

automated ultrasonic testing

AUT

A term that covers a wide range of ultrasonic testing systems and techniques utilizing automated mechanical scanners while recording ultrasonic results.

³ American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

⁴ British Standards Institution, Chiswick High Road, London W4 4AL, United Kingdom, www.bsi-global.com.

⁵ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

⁶ NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.

3.1.2**back weld**

A weld made at the back side of a groove weld as part of the original weld.

3.1.3**back weld repair**

A repair weld made at the back side of a groove weld to repair a defect (or defects) in a completed weld.

NOTE A back weld repair is not a back weld

3.1.4**branch weld**

A completed groove and/or fillet weld joining a set-on or set-in branch pipe or a set-on or set-in branch fitting to a run pipe.

3.1.5**burn-through****BT**

A portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe or fitting.

3.1.6**burn-through (in-service welds)**

An event that occurs during in-service welding when the welding arc causes the pipe wall to be breached.

3.1.7**company**

The owner company or the engineering agency in charge of construction.

NOTE A company may act through an inspector or another authorized representative.

3.1.8**contractor**

An entity that includes the primary contractor and any subcontractors engaged in work covered by this standard.

3.1.9**cover pass repair**

A repair to the weld face, primarily located within the external reinforcement, but that may extend into the base material and/or weld metal (e.g., including external undercut).

3.1.10**defect**

An imperfection of sufficient magnitude to warrant rejection based on the acceptance criteria in this standard.

3.1.11**double repair**

The second repair in a previously repaired area of a completed weld; typically referred to as a "repair of a repair" or a "re-repair."

3.1.12**elongated linear indication**

An indication with its greatest dimension in the weld length direction that exceeds three times its width.

3.1.13**full-thickness repair**

A repair weld originating from the weld face that penetrates completely through the weld thickness after creating an open root without backing.

3.1.14**grinding**

Mechanical means to remove material using abrasive methods.

3.1.15**half-circumference dual-welder qualification**

Activity consisting of two welders welding on opposite sides of a full circumference pipe nipple.

NOTE This is regionally known as “brother-in-law” welding.

3.1.16**half-value layer****HVL**

The thickness of an absorbing material required to reduce the intensity of a beam of incident radiation to one half of its original intensity.

3.1.17**heat input**

The measure of energy transferred during welding.

NOTE See 5.3.2.6 for equations used to calculate heat input.

3.1.18**hollow bead (porosity)****HB**

The elongated linear porosity that occurs in the root bead.

3.1.19**imperfection**

A discontinuity or irregularity that is detectable by methods outlined in this standard.

3.1.20**inadequate cross penetration****ICP**

A subsurface lack of bond imperfection between the first inside pass and the first outside pass.

3.1.21**inadequate penetration due to high-low****IPD**

The condition that exists when one edge of the root is exposed (or unbonded) because an adjacent pipe or fitting is misaligned.

3.1.22**inadequate penetration without high-low****IP**

Incomplete filling of the weld root.

3.1.23**incomplete fusion****IF**

A surface imperfection between the weld metal and the base material that is open to the surface.

3.1.24**incomplete fusion due to cold lap****IFD**

An imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface.

3.1.25**indication**

The response or evidence from nondestructive testing.

3.1.26**instantaneous energy**

Energy that is calculated at every instant in which current and voltage are sampled during arc welding prior to averaging instead of being calculated using average current and average voltage.

3.1.27**instantaneous power**

Power that is calculated at every instant in which current and voltage are sampled during arc welding prior to averaging instead of being calculated using average current and average voltage.

3.1.28**internal concavity****IC**

A root bead that is fused to and that completely penetrates the pipe wall thickness along both sides of the bevel, but whose center is below the inside surface of the pipe wall.

NOTE The magnitude of concavity is the perpendicular distance between an axial extension of the pipe wall surface and the lowest point on the weld bead surface.

3.1.29**interpass temperature**

The temperature at a location near the start position of the welding arc(s) recorded immediately before initiating the next pass or passes (multi-arc processes).

3.1.30**linear indication**

An indication with its greatest dimension in the weld length direction.

3.1.31**mechanized welding**

The process where parameters and torch guidance are controlled mechanically or electronically, but may be manually varied during welding to maintain the specified welding conditions.

3.1.32**multiple repairs**

More than one individual repair area location in a completed weld.

3.1.33**non-waveform-controlled process**

A welding process in which arc voltage and/or arc current are maintained at a stable condition (for example, constant voltage spray gas metal arc welding or constant current gas tungsten arc welding).

3.1.34**partial-thickness repair**

A repair weld that originates from the weld face or root bead surface extending into the weld but does not completely penetrate through the weld thickness.

3.1.35**porosity**

Gas trapped by solidifying weld metal before the gas has a chance to rise to the surface of the molten puddle and escape.

3.1.36**position welding**

Welding in which the pipe or assembly is not rotating while the weld is being deposited.

3.1.37**postheat**

Heating a completed weld to temperatures intended to accelerate hydrogen diffusion.

NOTE Postheat is not PWHT (see 3.1.38).

3.1.38**postweld heat treatment****PWHT**

Heating a completed weld to temperatures intended to result in stress relief, tempering, normalizing, or other metallurgical changes.

3.1.39**preheat temperature**

The minimum temperature of the base material in the volume surrounding the point of welding immediately before welding is started. In a multipass weld, it is also the minimum temperature immediately before the second and subsequent passes are started.

3.1.40**qualified welder**

A welder who has demonstrated the ability to produce welds that meet the requirements of Section 5, Section 6, Section 10, or Annex B of this standard.

3.1.41**qualified welding operator**

A welding operator who has demonstrated the ability to produce welds that meet the requirements of Section 12 of this standard.

3.1.42**qualified welding procedure specification**

A tested and proven detailed method by which sound welds with suitable mechanical properties can be produced.

3.1.43**radiographer**

A person who performs radiographic operations.

3.1.44**repair**

Any grinding or welding on a completed weld to correct an individual defect or accumulation of defects in the weld that has been rejected by visual or nondestructive testing in accordance with acceptance criteria in this standard.

3.1.45**repair area**

One individual repair location in a completed weld that may include a single defect or accumulation of defects.

3.1.46**repair procedure**

A tested and proven detailed method by which sound repairs with suitable mechanical properties can be produced.

3.1.47**repair weld**

A weld made to repair a defect (or defects) found by visual testing and/or other nondestructive testing methods in a completed weld.

NOTE A welder may check their work visually throughout the welding process and after welding has been completed, and perform rework as necessary.

3.1.48**rework**

During the welding or after the weld has been completed, the removal of an imperfection that requires grinding and/or welding that is performed prior to nondestructive testing.

NOTE Rework is not a repair. Once a weld is judged as either acceptable or unacceptable by visual testing and/or a nondestructive testing method, any modification performed to the weld is deemed a repair.

3.1.49**roll welding**

Welding in which the pipe or assembly is rotated while the weld metal is being deposited at or near the top center.

3.1.50**root bead**

The first or stringer bead that initially joins two sections of pipe, a section of pipe to a fitting, or two fittings.

3.1.51**rounded indication**

An indication where the length is three times the width or less.

3.1.52**segment**

A piece of base metal (pipe nipple or fitting) consisting of less than a full circumference section.

3.1.53**semiautomatic welding**

Arc welding with equipment that controls only the filler metal feed. The advance of the welding arc is manually controlled.

3.1.54**slag inclusion**

A nonmetallic solid entrapped in the weld metal or between the weld metal and the parent material. Slag inclusions may be elongated slag inclusions (ESIs) or isolated slag inclusions (ISIs).

3.1.55**stacked defects**

Individual imperfections aligned in the radial (through-thickness) direction, at the same circumferential location, and that exceed the acceptance criteria of this standard.

3.1.56**test joint**

Pipe nipples, segments of pipe nipples, fittings, segments of fittings, or any combination thereof joined for the purpose of qualifying welding procedures or welders and welding operators.

3.1.57**total image unsharpness**

the blurring of test object features in a radiographical image resulting from any cause(s).

3.1.58**transverse indication**

An indication with its greatest dimension across the weld.

3.1.59**undercutting**

A groove melted into the parent material adjacent to the toe or root of the weld and left unfilled by weld metal. External undercutting (EU) is adjacent to the cover pass and internal undercutting (IU) is adjacent to the root bead.

3.1.60**UT qualification**

A process carried out by the company of evaluating evidence, provided by the ultrasonic contractor, that the UT system can provide accurate detection and sizing in accordance with the requirements of 9.6 and/or Annex A.

3.1.61**UT system**

Equipment utilized for ultrasonic testing.

3.1.62**visual examination or testing**

Visual evaluation of the surface of a weld by qualified personnel (see 8.3) to evaluate the presence of surface discontinuities (see 6.4 and 9.7) and to determine the disposition of the weld (i.e., weld acceptability).

3.1.63**volumetric indication**

An indication that is three-dimensional.

3.1.64**waveform-controlled process**

A welding process in which cyclic arc voltage and/or arc current wave shapes are controlled (for example, pulsed spray gas metal arc welding or controlled short-circuit gas metal arc welding).

3.1.65**weld**

A remelted and metallurgically altered area where two parts (for the purposes of this standard, typically two sections of pipe, a section of pipe to a fitting, or two fittings) are joined by melting a portion of each part by heating with an electric arc or flame source.

3.1.66**welder**

A person who makes a weld.

3.1.67**weld face**

An exposed surface of a weld on the side from which welding was done.

3.2 Acronyms and Abbreviations

For the purposes of this standard, the following acronyms and abbreviations apply.

<i>A</i>	welding current (amp)
AC	alternating current
AUT	automated ultrasonic testing
BT	burn-through

C	carbon
CCD	charge coupled device
CE	carbon equivalent
CMOS	complimentary metal-oxide semiconductor
CO ₂	carbon dioxide
Cr	chromium
CTOD	crack tip opening displacement
Cu	copper
CVN	Charpy V-Notch
<i>D</i>	pipe outer diameter (in. or mm)
DAC	distance amplitude correction
DC	direct current
DDA	digital detector array
DWE	double-wall exposure
DWV	double-wall viewing
<i>D/t</i>	pipe diameter-to-wall thickness ratio
ECA	engineering critical assessment
E _I	instantaneous energy measurement (kilojoules)
ESI	elongated slag inclusion
EU	external undercut
EW	electric resistance or electric induction weld
FAC	failure assessment curve
FAD	failure assessment diagram
FCAW-S	self-shielded flux-cored arc welding
FPD	flat panel detector
GMAW-S	short-circuiting gas metal arc welding
HAZ	heat-affected zone
HB	hollow bead porosity
HI	heat input

H ₂ S	hydrogen sulfide
HVL	half-value layer
IC	internal concavity
ICP	inadequate cross penetration
ID	inside diameter
IF	incomplete fusion
IFD	incomplete fusion due to cold lap
IP	inadequate penetration without high-low
IPD	inadequate penetration due to high-low
IQI	image quality indicator
ISI	isolated slag inclusion
IU	internal undercut
L	weld length (in. or mm)
LB	linear buried
LDA	linear diode array
LS	linear surface
Mn	manganese
Mo	molybdenum
MPS	manufacturing procedure specification
MUT	manual ultrasonic testing
NDT	nondestructive testing
Ni	nickel
OD	outside diameter
OFW	oxy-fuel welding
P _i	instantaneous power measurement (watts or joules per second)
PIP	phosphor imaging plate
PWHT	postweld heat treatment
RTR	real-time radiography
S	welding arc speed (in. per minute or mm per minute)

SAWH	submerged-arc helical weld
SAWL	submerged-arc longitudinal weld
SCC	stress corrosion cracking
SMTS	specified minimum tensile strength
SMYS	specified minimum yield strength
SWE	single-wall exposure
SWV	single-wall viewing
t	specified pipe wall thickness (in. or mm)
T	transverse
TCG	time-corrected gain
T_s	arc time (seconds)
UT	ultrasonic testing
V	vanadium
V	welding arc voltage (volt)
VC	volumetric cluster
VI	volumetric individual
VR	volumetric root
WPS	welding procedure specification
Y/T	yield-to-tensile ratio
σ_t	ultimate tensile strength of the pipe material (ksi or MPa)
σ_y	specified minimum yield strength of the pipe material, or SMYS (ksi or MPa)

4 Specifications

4.1 Equipment

Welding equipment, both gas and arc, shall be of a size and type suitable for the work and shall be maintained in a condition that ensures acceptable welds, continuity of operation, and safety of personnel. Arc welding equipment shall be operated within the amperage and voltage ranges given in the qualified welding procedure specification. Gas welding equipment shall be operated with the flame characteristics and tip sizes given in the qualified welding procedure specification. Equipment that does not meet these requirements shall be repaired or replaced.

4.2 Materials

4.2.1 Pipe and Piping Components

This standard applies to the welding of pipe and piping components that conform to material and product specifications including, but not limited to:

- a) API specifications,
- b) ASME international specifications,
- c) ASTM international specifications,
- d) Manufacturers Standardization Society (MSS) specifications,
- e) American National Standards Institute (ANSI) specifications.

This standard also applies to materials with chemical and mechanical properties that comply with one of the specifications listed in items a) through e) above, even though the material is not manufactured in accordance with the specification.

4.2.2 Filler Metals and Fluxes

4.2.2.1 Types

All filler metals and fluxes shall conform to one of the following, except as provided below:

- a) AWS A5.1;
- b) AWS A5.2;
- c) AWS A5.5;
- d) AWS A5.17;
- e) AWS A5.18;
- f) AWS A5.20;
- g) AWS A5.23;
- h) AWS A5.28;
- i) AWS A5.29;
- j) AWS A5.36.

Filler metals and fluxes that do not conform to the specifications listed may be used, provided they have been utilized during welding procedure qualification.

4.2.2.2 Storage and Handling

Filler metals and fluxes shall be stored and handled to avoid damage to them and to the containers in which they are shipped. Filler metals and fluxes in opened containers shall be protected from deterioration, and filler metals that are coated shall be protected from excessive changes in moisture. Filler metals and fluxes that show signs of damage or deterioration shall not be used.

4.2.3 Shielding Gases

4.2.3.1 Types

The purity and dryness of these atmospheres influence resulting weldments and should be of values suitable for the process and the materials to be welded. The shielding atmosphere to be used shall be qualified for the material and the welding process.

Atmospheres for shielding an arc are of several types and should consist of inert gases, active gases, or mixtures of inert and active gases.

4.2.3.2 Storage and Handling

Shielding gases shall be kept in the containers in which they are supplied, and the containers shall be stored in a manner compliant with the applicable safety regulations and manufacturer's recommendations. Gases shall not be field intermixed in their containers. Gases of questionable purity and those in containers that show signs of damage shall not be used.

5 Qualification of Welding Procedures with Filler Metal Additions

5.1 Procedure Qualification

This section shall apply to the qualification of welding procedures using manual welding and semiautomatic welding processes with filler metal additions.

When a welding procedure specification uses a combination of manual/semiautomatic and mechanized welding, the requirements of Section 5 and Section 12 shall apply to their portions of the welding procedure specification.

NOTE 1 Section 12 applies to the qualification of welding procedures using mechanized welding with filler metal additions.

Before production welding is started, a detailed welding procedure specification shall be established and qualified to demonstrate that sound welds with suitable mechanical properties (such as strength, ductility, and hardness) can be made by the procedure. The acceptance of the procedure qualification welds shall be determined by destructive testing in accordance with 5.6 or 5.8 as applicable.

NOTE 2 Multiple qualification welds may be combined to qualify a range of essential variables within one welding procedure specification.

5.2 Record

The details of each procedure qualification shall be recorded. The record shall document at a minimum the actual observed values for the variables to be specified per 5.3 and the complete results of the procedure qualification tests. The record shall be maintained as long as the procedure is in use.

NOTE An example of an acceptable form is shown in Figure 1.

5.3 Welding Procedure Specification

5.3.1 General

The welding procedure specification shall include the information specified in 5.3.2 where applicable.

NOTE An example of an acceptable form is shown in Figure 2.

5.3.2 Specification Information

5.3.2.1 Process

The specific process, method of application, or combination thereof shall be identified.

5.3.2.2 Materials

The SMYS range of the materials to which the procedure applies shall be specified.

5.3.2.3 Diameters and Wall Thicknesses

The ranges of specified outside diameters (ODs) and specified wall thicknesses over which the procedure is applicable shall be specified.

5.3.2.4 Joint Design and Weld Shape and Size

The specification shall include a sketch or sketches of the joint that show tolerances for the angle of bevel, the size of the root face, and the root opening or the space between abutting members. The tolerance ranges for cap height and width shall be specified for groove welds. The shape and size tolerance ranges of fillet welds shall be shown. If a backing is used, the type shall be specified.

5.3.2.5 Filler Metal, Flux, and Number of Beads

The sizes and classification of the filler metal and flux and the minimum number and sequence of beads shall be specified. When different numbers of beads and sequences of beads apply to different thickness ranges within the specified thickness range on the WPS, the number of beads and sequences shall be designated for company-defined subsets of the thickness range.

QUALIFICATION WELD REPORT													
Date _____		Test No. _____			Test Type: ____ Procedure ____ Welder _____								
Location _____		Welder(s) _____											
Material Grade 1 _____													
Material Grade 2 _____													
Outside Diameter _____					Wall Thickness _____								
Joint Type _____					Bevel Angle _____								
Backing Type (if applicable) _____					Roll or Fixed Position _____								
RECORDED WELDING PARAMETERS													
Pass	Process and Direction of Welding	Filler Metal Classification and Diameter	Shielding Gas type and flow rate or Shielding Flux	Preheat / Interpass Temperature	Voltage	Amperage	Travel Speed	Heat Input					
Root Bead													
Second Bead													
Note: Number of weld beads are not intended to be limited by this table and the table should be adjusted to present all required passes. Time Between Passes: Root bead to 2 nd bead: _____, 2 nd bead to 3 rd bead: _____ Cooling Method (if applicable) _____ PWHT _____													
MECHANICAL TEST RESULTS													
TENSILE TESTS Report Number: _____					NICK BREAK TESTS Report Number: _____								
Specimen Number	Tensile 1	Tensile 2	Tensile 3	Tensile 4	Specimen Number	Nick 1	Nick 2	Nick 3	Nick 4	Nick 5	Nick 6	Nick 7	Nick 8
Location					Location								
Original specimen dimensions					Result								
Original specimen area					BEND TESTS Report Number: _____								
Maximum load					Specimen Type and Number								
Tensile strength					Location								
Fracture location					Result								
Remarks													
Test made at _____ Date _____ Tested by _____ Supervised by _____													

NOTE See 5.2; the use of this sample form does not exclude adding other details.

Figure 1—Sample Qualification Weld Report Form

WELDING PROCEDURE SPECIFICATION								
								WPS Number _____
Process(es)/Method of Application _____								
Material grade(s) _____								
Outside diameter _____				Wall thickness _____				
Joint type _____				Bevel angle _____				
Backing type (if applicable) _____				Roll or fixed position _____				
Direction of welding _____				Number of welders _____				
Preheat temperature _____				Interpass Temperature _____				
Method of Heating _____								
Filler metal(s) and Flux _____								
Flame characteristics _____				Cleaning and/or grinding tools _____				
Type and removal of lineup clamp _____				Minimum number of passes _____				
Maximum time between root pass and start of the second pass _____				Maximum time between second pass and start of third pass _____				
Method of cooling _____				PWHT procedure _____				
JOINT DESIGN								
SEQUENCE OF BEADS								
WELDING PARAMETERS								
Pass	Process / Electrical Characteristics	Filler Metal Group or Classification	Electrode Size	Shielding Gas Type and Flow Rate or Shielding Flux	Voltage Range	Amperage Range	Travel Speed Range	Heat Input Range
Root Bead								
Second Bead								
Note: Number of weld beads are not intended to be limited by this table and the table should be adjusted to present all required passes.								
Supporting qualification weld report No(s) _____								
Approved by: _____								

NOTE See 5.3.1; the use of this sample form does not exclude adding other details.

Figure 2—Sample Welding Procedure Specification Form

5.3.2.6 Electrical Characteristics

The current and polarity shall be specified, and the range of voltage and amperage for each type and size of electrode, rod, or wire shall be shown.

NOTE Consult the filler metal manufacturer's recommended ranges for guidance. The specified ranges need not replicate either the recommended ranges or the observed ranges used in welding procedure qualification.

When required by Table 1, the heat input and the method of calculating heat input shall be specified.

Heat input for non-waveform-controlled processes shall be calculated per Equation (1):

$$HI = \frac{60VA}{1000S} \quad (1)$$

where

HI = heat input (kilojoules per in. or kilojoules per mm)

V = average welding arc voltage (volt)

A = average welding current (amp)

S = average travel speed (in. per minute or mm per minute)

Heat input for waveform-controlled processes shall be calculated per Equation (2) or Equation (3):

$$HI = \frac{E_I}{L} \quad (2)$$

where

HI = average heat input (kilojoules per in. or kilojoules per mm)

E_I = average instantaneous energy measurement (kilojoules)

L = weld length (in. or mm)

$$HI = \frac{P_I T_s}{1000L} \quad (3)$$

where

HI = average heat input (kilojoules per in. or kilojoules per mm)

P_I = average instantaneous power measurement (watt)

T_s = arc time (seconds)

L = weld length (in. or mm)

5.3.2.7 Flame Characteristics

For the oxy-fuel welding process, the specification shall indicate whether the flame is neutral, carburizing, or oxidizing. The size of the orifice in the torch tip for each size of rod or wire shall be specified.

5.3.2.8 Position

The specification shall indicate roll or fixed position welding.

5.3.2.9 Direction of Welding

The specification shall indicate whether the welding is to be performed in the vertical up, vertical down, or horizontal direction.

5.3.2.10 Time Between Passes

When using EXX10 or EXX11 electrodes, the maximum time between the completion of the root bead and the start of the second bead, as well as the maximum time between the completion of the second bead and the start of the third bead, shall be specified. The time shall be expressed as minutes or hours.

5.3.2.11 Type and Removal of Lineup Clamp

The specification shall indicate whether the lineup clamp is to be internal or external, or if no clamp is required. If a clamp is used, the minimum percentage of root bead completed before the clamp is released shall be specified.

5.3.2.12 Cleaning and/or Grinding

The specification shall indicate whether power tools or hand tools are to be used for cleaning, grinding, or both.

5.3.2.13 Preheat and Interpass Temperature

The method of heating and minimum preheat temperature immediately before welding is started shall be specified. The maximum interpass temperature shall be specified.

5.3.2.14 Shielding Gas and Flow Rate

The shielding gas classification and the range of flow rates shall be specified.

5.3.2.15 Shielding Flux

When applicable, the type of shielding flux shall be specified.

5.3.2.16 Speed of Travel

The range for speed of travel, in inches or millimeters per minute, shall be specified for each pass or grouping of passes.

Specified ranges for speed of travel need not replicate, but should be representative of the speed of travel used during procedure qualification.

5.3.2.17 Method of Cooling After Welding

If forced cooling is to be used, the specification shall designate the type of cooling after welding, such as forced cooling with water, as well as the maximum weld temperature prior to deliberate cooling.

5.3.2.18 Postheating for Hydrogen Diffusion

When used during qualification, the minimum temperature and time at temperature range of any postheating for hydrogen diffusion shall be specified.

5.3.2.19 Postweld Heat Treatment (PWHT)

The details of the PWHT procedure shall be specified in the WPS. PWHT procedures shall include method of application, heating rate, temperature range, time at temperature, and cooling rate.

5.4 Essential Variables

5.4.1 General

Welding procedure specifications shall be limited by the applicable essential variables provided in Table 1. Changes to essential variables shall necessitate requalification of the welding procedure specification or establishment and qualification of a new welding procedure specification.

5.4.2 Essential Variable Categories

The variables and qualification ranges specified in Table 1 are separated into two different categories. Category I essential variables shall apply when specified hardness and/or toughness values are not required by the company. Category II essential variables shall apply when hardness and/or toughness requirements are specified by the company.

Table 1—Essential Variables for Qualification of Welding Procedure Specifications

Welding Variable Subsection ^a	Change Requiring Requalification	Category I (Standard WPS)	Category II (Hardness and/or Toughness)
5.4.2.1 Welding Process	a) A change in welding process for any given pass or pass grouping (i.e., fill passes or cap passes).	X	X
	b) A change between manual application or semiautomatic application.	X	X
5.4.2.2 Base Material	a) A change in base material "nominal SMYS" greater than that of the base material used during qualification. When a procedure qualification test uses two different "nominal SMYS" materials, the procedure shall only be qualified to weld joints where at least one of the base materials is equal to or less than the lowest "nominal SMYS" base material used during qualification and the other no greater than the maximum of the combination. ^{b,c,d}	X	X
	b) Where t is the nominal pipe wall thickness used in procedure qualification, a change that falls outside the following ranges: i. t to $2t$ when $t < 0.154$ in. (3.9 mm) ii. 0.154 in. (3.9 mm) to $2t$ when 0.154 (3.9 mm) $\leq t \leq 1.00$ in. (25.4 mm) iii. $0.5t$ to unlimited when $t > 1.00$ in. (25.4 mm)	X	
	c) A change in nominal wall thickness plus or minus 25 % of the nominal thickness used during qualification.		X
5.4.2.3 Joint Design	a) A change from fillet weld to groove weld, but not vice versa.	X	X
	b) A major change in joint type. ^e	X	X
5.4.2.4 Backing Material	The deletion or change of backing material (steel, ceramic, non-ferrous, etc.). ^f	X	X
5.4.2.5 Position	A change in position from roll welding to fixed position, but not vice versa.	X	X
5.4.2.6 Filler Metal	a) A change in filler metal grouping(s) as specified in Table 2 when base material SMYS is less than the "nominal SMYS" of Grade X65. ^b	X	
	b) A change in sequence of deposition of filler metal groups when multiple filler metal groups are used for a single weld when base material SMYS is less than the "nominal SMYS" of Grade X65. ^b	X	
	c) A change in filler metal classification when base material SMYS is greater than or equal to the "nominal SMYS" of Grade X65. ^{b,g}	X	
	d) A change in sequence of deposition of filler metal classifications when multiple filler metal classifications are used for a single weld when base material is greater than or equal to the "nominal SMYS" of Grade X65. ^b	X	
	e) When the filler metal used during qualification is from group 1 through 3 in Table 2 and the base material SMYS is less than the "nominal SMYS" of Grade X65, any change in chemical composition designator or optional supplemental designator for toughness except for the following: i. the addition of the optional supplemental designator for toughness (-1); ii. a change in chemical composition designator within the group, A1, C1, C2, C3, C1L, C2L, C3L, M, P1, P2. ^h	X	
	f) When the filler metal during qualification has a G suffix designator only, a change in the manufacturer or trade name.	X	X
	g) When the filler metal used is not identified in Table 2, a change in AWS specification, AWS classification, or, for filler metals not having an assigned AWS specification or classification, a change in the nominal composition.	X	X
	h) A change in filler metal classification. ^g		X
	i) A change in sequence of deposition of filler metal classifications when multiple filler metal classifications are used for a single weld.		X

Table 1—Essential Variables for Qualification of Welding Procedure Specifications (continued)

Welding Variable Subsection ^a	Change Requiring Requalification	Category I (Standard WPS)	Category II (Hardness and/or Toughness)
5.4.2.7 Shielding Gas	a) A change in shielding gas classification in accordance with AWS A5.32.	X	X
	b) A change in shielding gas flow rate greater than 20 % below the nominal flow rate recorded during procedure qualification.	X	X
	c) The deletion of or change in nominal composition of backing gas when backing gas is used during qualification.	X	X
5.4.2.8 Electrical Characteristics ⁱ	a) A change in current/polarity type (DCSP/DCEN, DCRP/DCEP, AC).	X	X
	b) A change to or from a waveform-controlled process.	X	X
	c) A change in heat input exceeding ± 20 % of that recorded during qualification. ^j		X
5.4.2.9 Preheat Temperature	a) Any decrease in minimum base material preheat temperature below the base material preheat temperature recorded during qualification. ^k	X	X
	b) When preheat is not applied to the qualification test weld, the minimum temperature specified on the procedure shall be no less than the lesser of 60 °F (16 °C) or the actual base material temperature recorded prior to qualification welding.	X	X
5.4.2.10 Interpass Temperature	a) An increase in base material interpass temperature to greater than 500 °F (260 °C). ^{k,l,m}	X	X
	b) An increase in base material interpass temperature greater than 100 °F (55 °C) above the maximum base material interpass temperature recorded during procedure qualification. ^{k,l,m}		X
5.4.2.11 Pass Sequence	When using a temper bead technique, a change in bead deposition sequence.	X	X
5.4.2.12 Cooling	a) The addition or deletion of deliberate cooling methods.	X	X
	b) A change in the method of deliberate cooling after welding, resulting in a higher rate of cooling.	X	X
	c) An increase in the maximum weld temperature prior to deliberate cooling.	X	X
5.4.2.13 Postheating	a) The elimination of postheating for the purpose of promoting hydrogen diffusion.	X	X
	b) A reduction in postheating temperature greater than 60 °F (33 °C) from that used during qualification.	X	X
	c) Any reduction in postheating time at temperature from that used during qualification.	X	X
5.4.2.14 Postweld Heat Treatment	a) The addition or deletion of PWHT.	X	X
	b) When applied, a change in PWHT procedure.	X	X

^a The subsection numbers in this column are provided for referencing purposes.

^b "Nominal SMYS" is in reference to the material grade and intended to negate the slight differences in actual SMYS between material type of the same grade. For example, an API 5L X60 pipe and an ASTM A860 WPHY 60 fitting shall both be considered to have a "nominal SMYS" of 60 ksi.

^c In addition to SMYS, base material manufacturing process, heat treating process, carbon equivalent, and chemical composition should be considered for impact to mechanical properties and weld crack susceptibility.

^d When base material used during qualification has multiple grade markings, prior to qualification the company should designate the material as one single grade.

^e Major joint types are square, closed square, single-bevel, single-J, double-bevel, double-J, single-V, single-U, double-V, double-U. A change to or from a compound bevel within a major joint type is not considered a major change in joint type.

^f This requirement applies to the root pass only. Weld metal is not considered weld backing.

^g The chemical composition designator is part of the AWS classification.

^h For example, a change in suffix designator from A1 to B3, or vice versa, constitutes an essential variable. A change from A1 to C3, or vice versa, does not constitute an essential variable.

ⁱ Unless otherwise specified by company requirements, the above noted parameters should be recorded as averages representative of a weld pass or specific segment of a weld pass. Sampling of parameters for waveform-controlled processes should be at a sampling frequency no less than 10 kHz. The method used for recording and calculating heat input during production monitoring should be the same as that used during procedure qualification.

^j As defined and calculated in 5.3.2.6.

^k Procedures may be qualified with different interpass temperatures throughout the weld sequence.

^l When procedures are qualified with different interpass temperatures throughout the weld sequence, the interpass temperatures shall be specified accordingly.

^m Interpass temperatures shall be measured immediately prior to the start of subsequent weld passes.

Table 2—Filler Metal Groups

Group	AWS Specification	AWS Classification
1	A5.1	E6010, E6011
	A5.5	E7010-A1, E7010-P1, E7011-A1
2	A5.5	E8010-P1
3	A5.1	E6018, E7015, E7016, E7018, E7018M, E7016-1, E7018-1
	A5.5	E7015-C1L, E7016-C1L, E7018-C1L, E7015-C2L, E7016-C2L, E7018-C2L, E7018-C3L, E8016-C1, E8018-C1, E8016-C2, E8018-C2, E8016-C3, E8018-C3, E8018-P2, E8045-P2
5 ^a	A5.18	ER70S-2, ER70S-3, ER70S-6
	A5.28	ER70S-A1, ER80S-D2, ER80S-Ni1, ER80S-Ni2, ER80S-Ni3
6	A5.2	RG60, RG65
7	A5.20	E71T-1C, E71T-1M, E71T-9C, E71T-9M, E71T-12C, E71T-12M, E71T-12M-J
	A5.36	E71T-1C, E71T-1M, E71T-9C, E71T-9M, E71T-12C, E71T-12M, E71T-12M-J
8	A5.29	E81T-1Ni1C, E81T-1Ni1M, E81T1-1Ni2C, E81T-1Ni2M, E81T-1K2C, E81T-1K2M
^a A shielding gas (see 5.4.2.7) is required for use with the electrodes in Group 5.		

5.5 Welding of Test Joints—Butt Welds

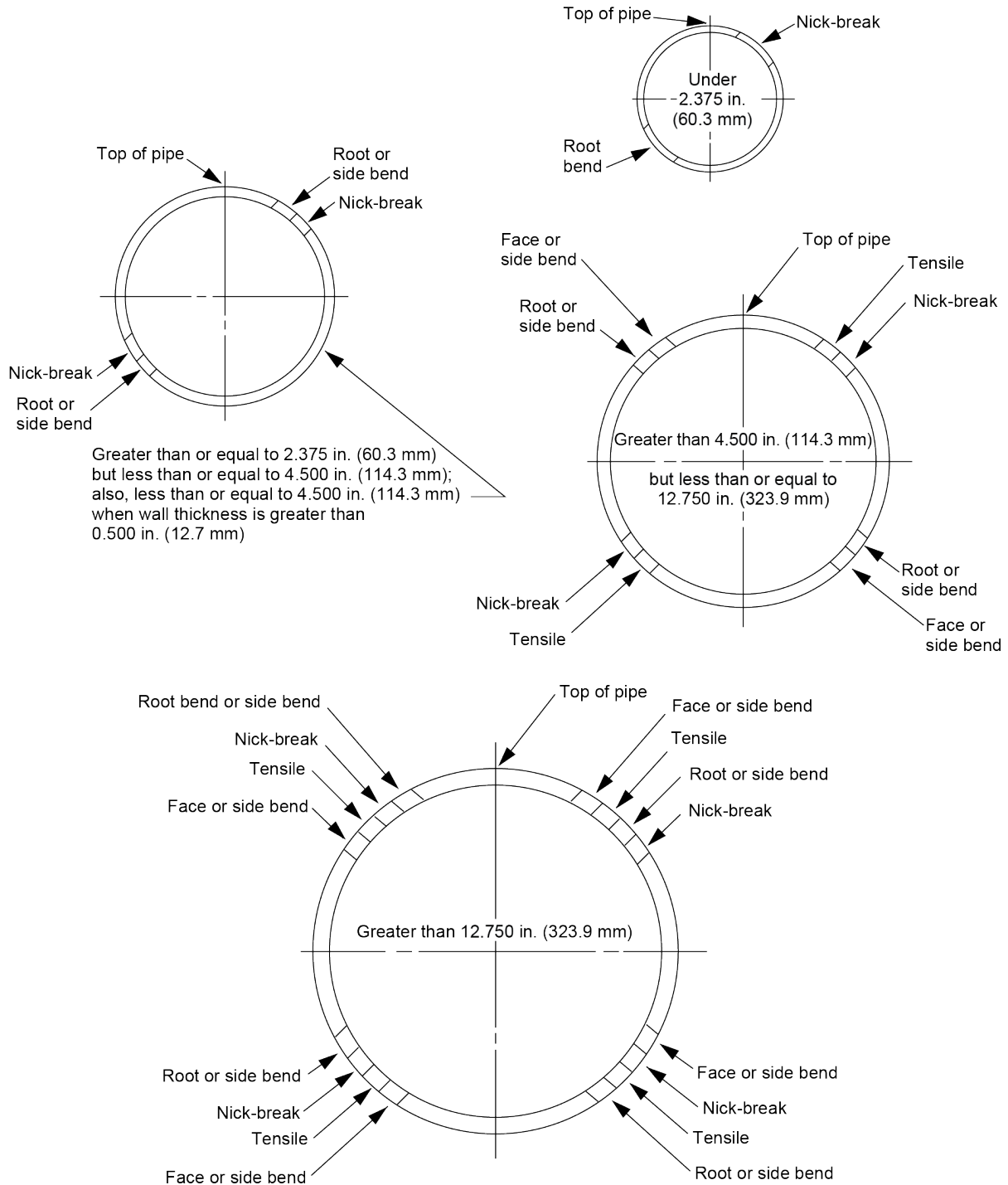
To weld the test joint for butt welds, two pipe nipples shall be joined.

5.6 Testing of Welded Joints—Butt Welds

5.6.1 Preparation

To test the butt-welded joint, test specimens shall be cut from the locations shown in Figure 3. The minimum number of test specimens and the tests to which they shall be subjected are given in Table 3. For pipe less than 2.375 in. (60.3 mm) in OD, two test joints shall be made to obtain the required number of test specimens. For pipe less than or equal to 1.315 in. (33.4 mm) in diameter, one full-section tensile strength specimen shall be tested. The full-section specimen shall be tested in accordance with 5.6.2.2 and shall meet the requirements of 5.6.2.3. All specimens shall be air cooled to ambient temperature prior to being tested.

When required by the company, the company shall specify the details of specimen preparation, testing, and acceptance criteria for measurement of hardness or toughness.



NOTE At the company's option, the locations may be rotated, provided they are equally spaced around the pipe; however, specimens do not include the longitudinal weld.

Figure 3—Location of Test Butt Weld Specimens for Procedure Qualification Test

Table 3—Type and Number of Test Specimens for Procedure Qualification Test

Outside Diameter of Pipe		Number of Specimens					
in.	mm	Tensile Strength	Nick Break	Root Bend	Face Bend	Side Bend	Total
Wall Thickness ≤ 0.500 in. (12.7 mm)							
< 2.375	< 60.3	0 ^a	2 ^b	2	0	0	4 ^c
2.375 to 4.500	60.3 to 114.3	0 ^a	2 ^b	2	0	0	4
> 4.500 to 12.750	> 114.3 to 323.9	2	2 ^b	2	2	0	8
> 12.750	> 323.9	4	4 ^b	4	4	0	16
Wall Thickness > 0.500 in. (12.7 mm)							
≤ 4.500	≤ 114.3	0 ^b	2 ^b	0	0	2	4
> 4.500 to 12.750	> 114.3 to 323.9	2	2 ^b	0	0	4	8
> 12.750	> 323.9	4	4 ^b	0	0	8	16
^a For materials with nominal SMYS greater than Grade X42, a minimum of one tensile test is required. ^b Nick break tests are not required for procedure qualification butt welds, provided procedure welds are examined by radiography or ultrasonic testing (UT) and are found acceptable per Section 9. When radiography or UT results are unacceptable, the procedure is rejected. ^c One nick break and one root bend specimen are taken from each of two test welds, or for pipe less than or equal to 1.315 in. (33.4 mm) in diameter, one full-section tensile strength specimen is taken.							

5.6.2 Tensile Strength Test

5.6.2.1 Preparation

The full-thickness tensile strength test specimens shall be either of the types shown in Figure 4.

- a) The sides of the full section specimen shown in Figure 4 a) shall be smooth and parallel.

NOTE 1 A specimen may be cut using any method, and no other preparation is needed unless the sides are notched or are not parallel.

- b) The reduced section specimens shall be prepared as shown in Figure 4 b).

NOTE 2 The weld metal reinforcement may be removed.

5.6.2.2 Method

The tensile strength test specimens shall be broken under tensile load using equipment capable of measuring the load at which failure occurs. The tensile strength shall be computed by dividing the maximum load at failure by the smallest cross-sectional area of the specimen, as measured before the load is applied.

5.6.2.3 Requirements

The tensile strength of the weld shall be greater than or equal to the specified minimum tensile strength (SMTS) of the pipe material, but need not be greater than or equal to the actual tensile strength of the material. If the specimen breaks outside the weld (i.e., in the parent metal) at a tensile strength not less than 95 % of that of the SMTS of the pipe material, the weld shall be accepted as meeting the requirements.

If the specimen breaks in the weld and the observed strength is greater than or equal to the SMTS of the pipe material and meets the soundness requirements of 5.6.3.3, the weld shall be accepted as meeting the requirements.

If the specimen breaks in the weld and below the SMTS of the pipe material, the weld shall be set aside, and a new test weld shall be made.

When welding material of different grades, the SMTS of the lower grade shall be used as the acceptance criteria.

NOTE Any specimen that fails due to improper specimen preparation or testing may be replaced and retested.

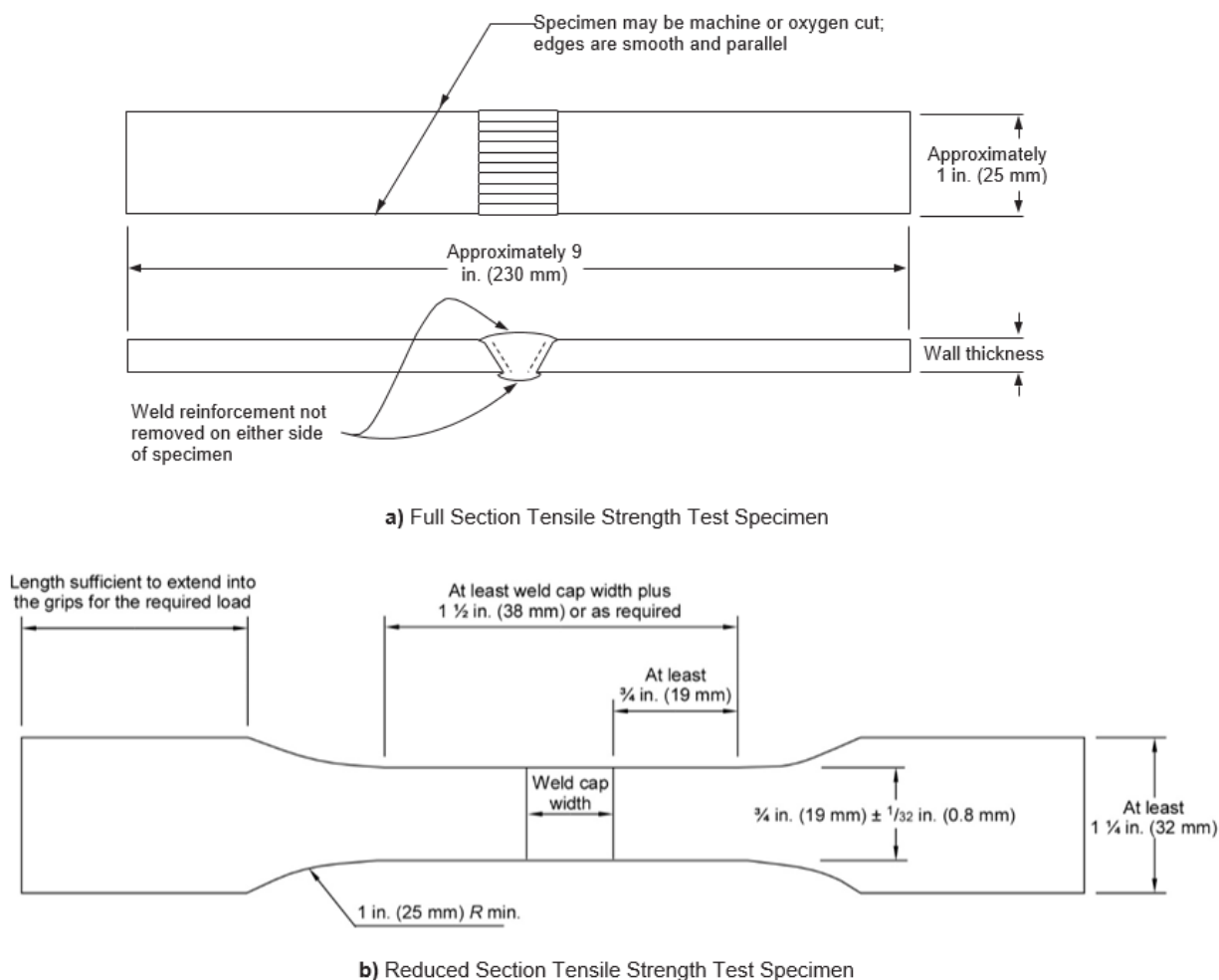


Figure 4—Tension Test Specimen

5.6.3 Nick Break Test

5.6.3.1 Preparation

The nick break test specimens (see Figure 5, top) shall be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide, and may be cut by any means. They shall be notched on each side at the center of the weld metal, and each notch shall be approximately $\frac{1}{8}$ in. (3 mm) deep, and the edges shall be smooth and parallel.

NOTE 1 Nick break specimens prepared in this manner from welds made with certain mechanized and semiautomatic processes may fail through the pipe instead of the weld. When previous testing experience indicates that failures through the pipe can be expected, the external reinforcement may be notched to a depth of not more than $\frac{1}{16}$ in. (1.6 mm), measured from the original weld surface (see Figure 5, bottom).

NOTE 2 At the company's option, nick break specimens for qualification of a procedure using a semiautomatic or mechanized welding process may be macroetched prior to being nicked.

5.6.3.2 Method

The nick break specimens shall be broken through the weld by any convenient method (i.e., pulling, bending, or striking). This does not exclude other testing methods. The exposed area of the fracture shall be at least $\frac{3}{4}$ in. (19 mm) wide.

5.6.3.3 Requirements

The exposed surfaces of each nick break specimen shall show complete penetration and fusion. The greatest dimension of any gas pocket shall not exceed $\frac{1}{16}$ in. (1.6 mm), and the combined area of all gas pockets shall not exceed 2 % of the exposed surface area. Slag inclusions shall not be more than $\frac{1}{32}$ in. (0.8 mm) in depth and shall not be more than $\frac{1}{8}$ in. (3 mm) or one-half the specified wall thickness in length, whichever is smaller. There shall be at least $\frac{1}{2}$ in. (13 mm) separation between adjacent slag inclusions of any size. The dimensions should be measured as shown in Figure 6. Fisheyes, as defined in AWS A3.0, are not cause for rejection.

For a test weld diameter greater than 12 $\frac{3}{4}$ in. (323.9 mm), if only one nick break specimen fails, the company shall have the discretion to either consider the weld unacceptable or to replace the specimen with two additional nick break specimens from locations as close as possible to the failed specimen. If either of the replacement nick break specimens fail, the weld shall be considered unacceptable.

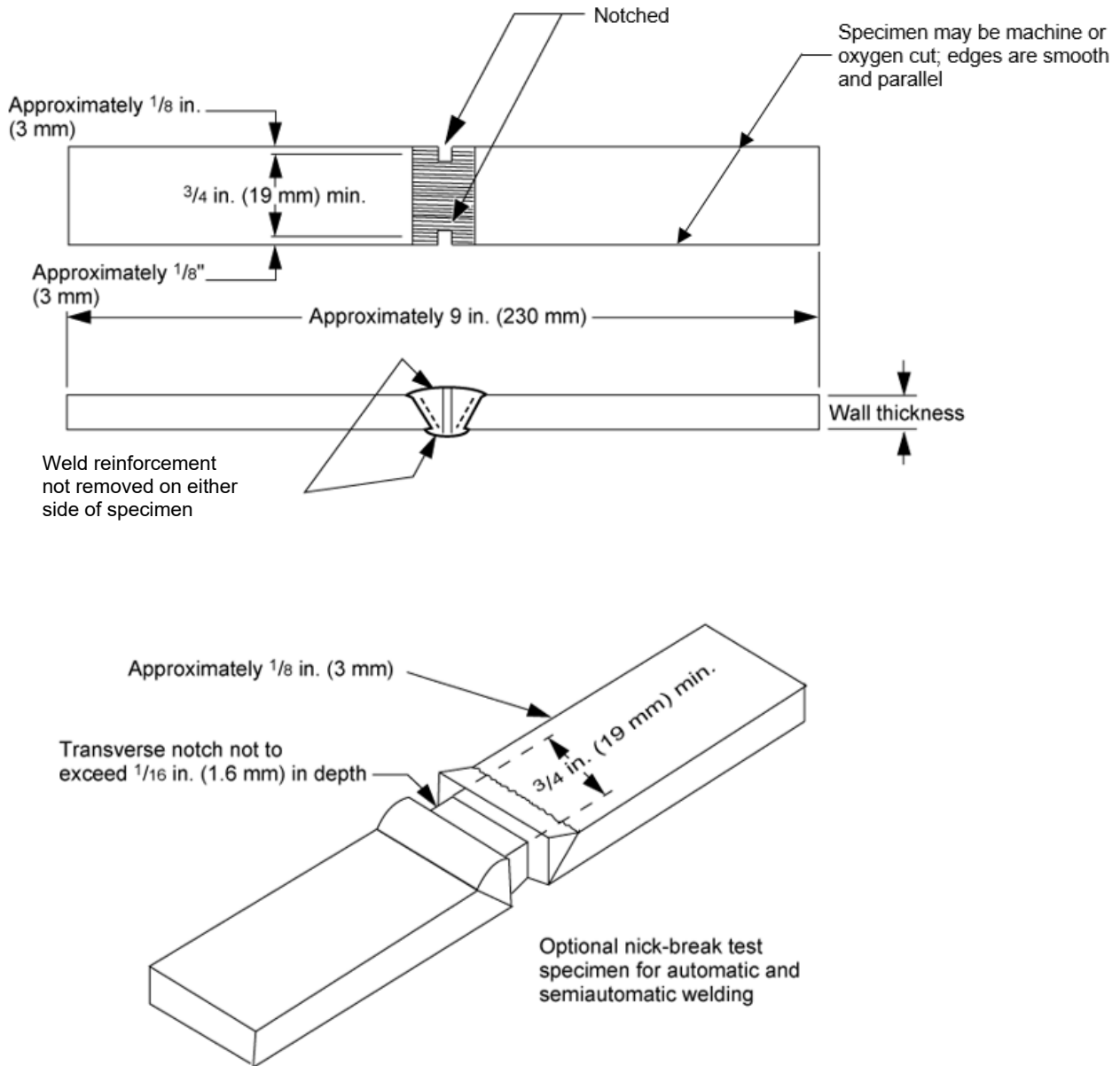
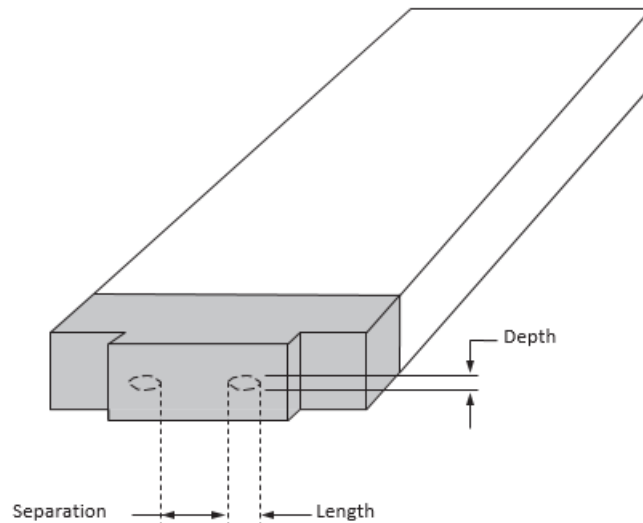


Figure 5—Nick Break Test Specimen



NOTE A broken nick break test specimen is shown; however, this method of dimensioning applies also to broken tensile and fillet weld test specimens.

Figure 6—Dimensioning of Imperfections in Exposed Weld Surfaces

5.6.4 Root and Face Bend Test

5.6.4.1 Preparation

The root and face bend test specimens (see Figure 7) shall be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide, and their long edges shall be rounded. They may be cut by any means. The cover and root bead reinforcements shall be removed flush with the surfaces of the specimen. These surfaces shall be smooth, and any scratches that exist shall be light and transverse to the weld. The specimen shall not be flattened prior to testing.

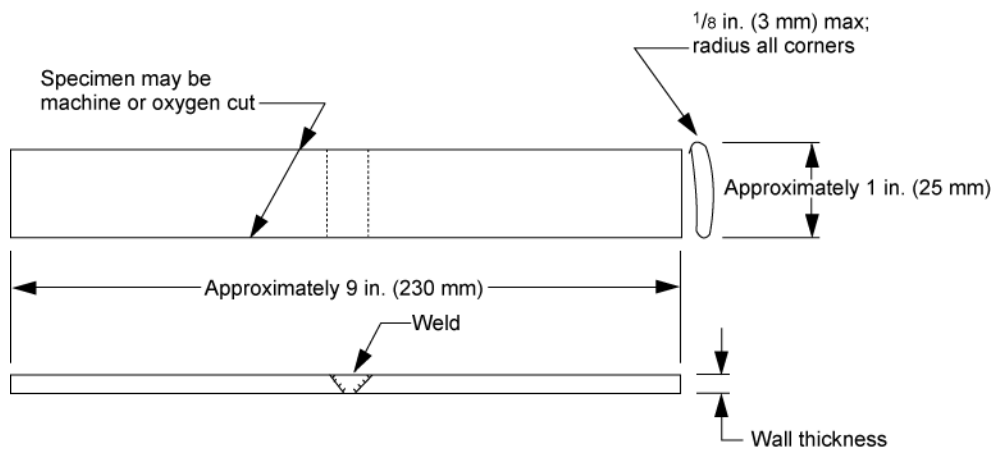
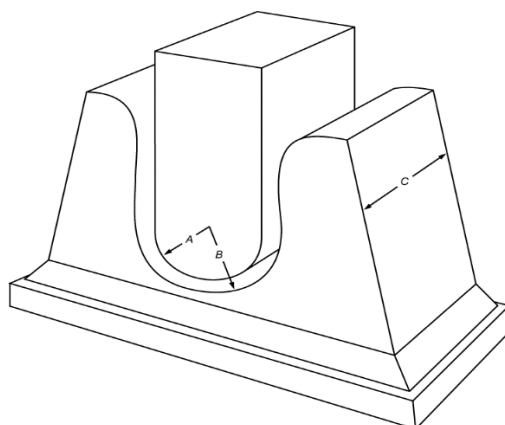


**Figure 7—Root and Face Bend Test Specimen:
Wall Thicknesses Less than or Equal to 0.500 in. (12.7 mm)**

5.6.4.2 Method

The root and face bend specimens shall be bent with the weld transverse to the longitudinal axis of the specimen. Face bend specimens shall be bent so that the face is centered on the bend radius and becomes the convex surface of the bend specimen. Root bend specimens shall be bent so that the root is centered on

the bend radius and becomes the convex surface of the bend specimen. The company shall specify the bend test fixture and bend radii. The radii shall not be greater than the radii specified in Figure 8.



NOTE This figure is not drawn to scale. Radius of plunger, $A = 1 \frac{3}{4}$ in. (45 mm); radius of die, $B = 2 \frac{5}{16}$ in. (60 mm); width of die, $C = 2$ in. (50 mm).

Figure 8—Jig for Guided-bend Tests

5.6.4.3 Requirements

The bend test shall be considered acceptable if no crack or other imperfection exceeding $\frac{1}{8}$ in. (3 mm) or one-half the specified wall thickness, whichever is smaller, in any direction is present in the weld or between the weld and the fusion zone after bending. Cracks that originate on the outer radius of the bend along the edges of the specimen during testing and that are less than $\frac{1}{4}$ in. (6 mm), measured in any direction, shall not be considered unless obvious imperfections are observed.

For a test weld diameter greater than $12 \frac{3}{4}$ in. (323.9 mm), if only one bend specimen fails, the company shall have the discretion to consider the weld unacceptable or to replace the failed specimen with two additional specimens from locations adjacent to the failed specimen. If either of the replacement bend test specimens fails, the weld shall be considered unacceptable.

5.6.5 Side Bend Test

5.6.5.1 Preparation

The side bend test specimens (see Figure 9) shall be approximately 9 in. (230 mm) long and approximately $\frac{1}{2}$ in. (13 mm) wide, and their long edges shall be rounded. They shall be machine cut, or they may be cut by other means to approximately a $\frac{3}{4}$ -in. (19-mm) width and then machined or ground to the $\frac{1}{2}$ -in. (13-mm) width. The sides shall be smooth and parallel. The cover and root bead reinforcements shall be removed flush with the surfaces of the specimen.

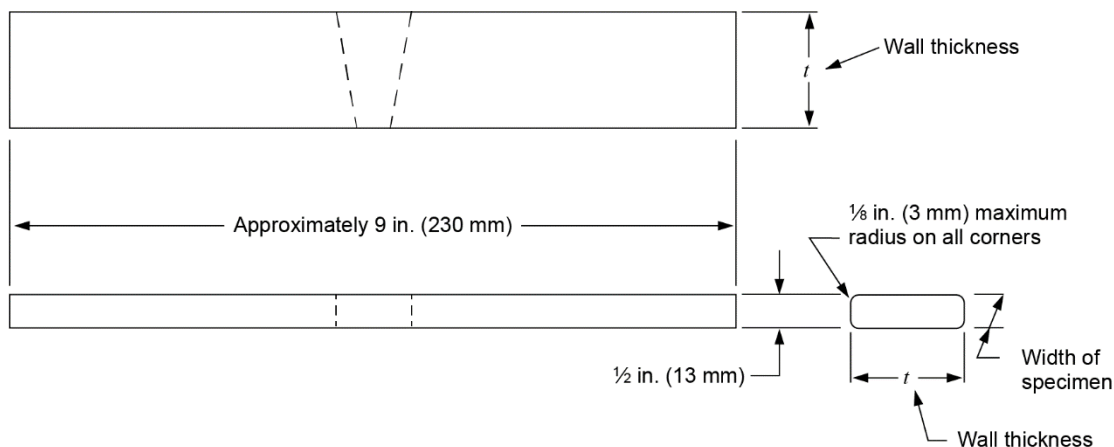
5.6.5.2 Method

The side bend specimens shall be bent with the weld transverse to the longitudinal axis of the specimen. Side bend specimens shall be bent so that one of the side surfaces is centered on the bend radius and becomes the convex surface of the bend specimen. The company shall specify the bend radii. The radii shall not be greater than the radii specified in Figure 8.

5.6.5.3 Requirements

Each side bend specimen shall meet the root and face bend test requirements specified in 5.6.4.3.

For a test weld diameter greater than 12 $\frac{3}{4}$ in. (323.9 mm), if only one side bend specimen fails, the company shall have the discretion to consider the weld unacceptable or to replace the failed specimen with two additional side bend specimens from locations adjacent to the failed specimen. If either of the replacement side bend test specimens fails, the weld shall be considered unacceptable.

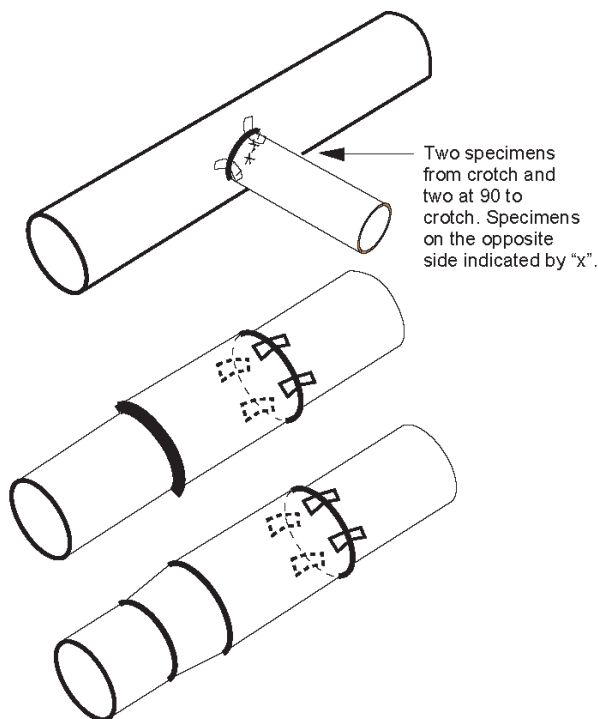


NOTE All dimensions are approximate.

Figure 9—Side Bend Test Specimen: Wall Thicknesses Greater than 0.500 in. (12.7 mm)

5.7 Welding of Test Joints—Branch and Fillet Welds

To weld the test joint for a branch or fillet weld, a weld shall be made to one of the configurations shown in Figure 10.



NOTE This figure shows the location of test specimens for joints with an OD greater than or equal to 2.375 in. (60.3 mm).

Figure 10—Location of Nick Break Test Specimens: Branch and Fillet Weld Procedure and Welder Qualification Test Welds

5.8 Testing of Welded Joints—Branch and Fillet Welds

5.8.1 Preparation

To test the branch or fillet-welded joint, test specimens shall be cut from the joint at the locations shown in Figure 10. At least four specimens shall be taken and prepared as shown in Figure 11.

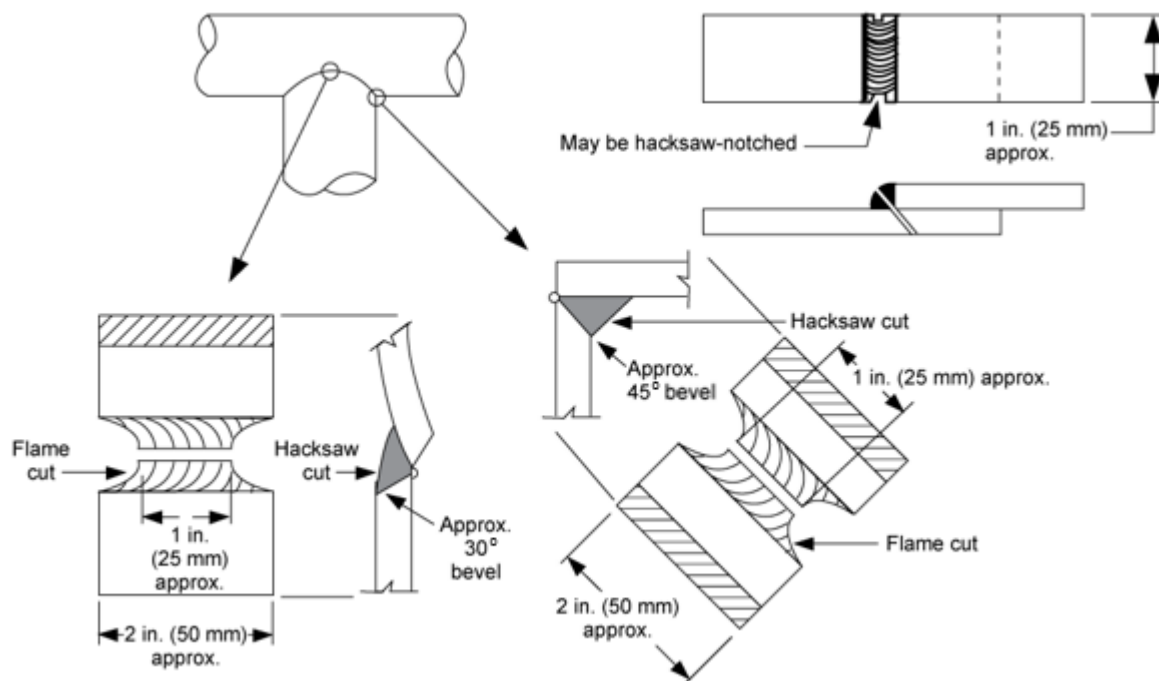
NOTE The specimens may be cut by any means.

The specimens should be at least 1 in. (25 mm) wide and long enough so that they can be broken in the weld. For pipes less than 2.375 in. (60.3 mm) in OD, specimens shall be cut from the same general location. It may be necessary to make two test welds to obtain the required number of test specimens; two specimens shall be removed from each of the two test welds. The specimens shall be air cooled to ambient temperature prior to testing.

When required by the company, the company shall specify the details of specimen preparation, testing, and acceptance criteria for measurement of hardness or toughness.

5.8.2 Method

The branch or fillet weld specimens shall be broken in the weld by any convenient method.



NOTE The methods of notching and cutting the specimens shown in the figure are not intended to preclude the use of other methods approved by the company.

Figure 11—Location of Nick Break Test Specimens: Branch and Fillet Weld Procedure and Welder Qualification Test Welds, Including Size-to-size Branch Connection Welder Qualification Test

5.8.3 Requirements

The exposed surfaces of each specimen shall show:

- a) complete penetration and fusion;

- b) the greatest dimension of any gas pocket shall not exceed $\frac{1}{16}$ in. (1.6 mm);
- c) the combined area of all gas pockets shall not exceed 2 % of the exposed surface area;
- d) slag inclusions shall not be more than $\frac{1}{32}$ in. (0.8 mm) in depth and shall not be more than $\frac{1}{8}$ in. (3 mm) or one half the specified wall thickness in length, whichever is smaller; and
- e) there shall be at least $\frac{1}{2}$ in. (13 mm) separation between adjacent slag inclusions. The dimensions should be measured as shown in Figure 6.

6 Qualification of Welders

6.1 General

The purpose of the welder qualification test shall be to determine the ability of welders to make sound welds. Each welder shall be qualified according to the applicable requirements of 6.2 through 6.8 before making a production weld. It is possible to qualify a WPS and a welder with one test joint. It is the intent of this standard that a welder who satisfactorily completes the procedure qualification test shall be a qualified welder, provided the number of test specimens required by 6.5 has been removed, tested, and meet the acceptance criteria of 5.6, for each welder. In such cases, verified compliance to a WPS is not required as the welder will be establishing the WPS parameters as part of the qualification process. Replacement shall be allowed for the welding procedure qualification testing, even though the welder(s) was disqualified.

NOTE The essential variables associated with procedure and welder qualifications are not identical. The essential variables for welder qualification are specified in 6.2.2 and 6.3.2.

Prior to starting the qualification tests, the welder shall be allowed reasonable time to adjust the welding equipment to be used. The welder shall follow the requirements of the applicable qualified welding procedure specification unless the welder is welding a procedure qualification test joint. The qualification of welders shall be conducted in the presence of a representative acceptable to the company.

A welder shall qualify for welding by performing a test joint.

When segments of pipe nipples are used for a test joint, they shall be supported so that typical flat, vertical, and overhead welds are produced. Segments of pipe nipples or fittings shall not be used for test joints of diameters equal to or less than $12 \frac{3}{4}$ in. (323.9 mm) OD.

When test joints are completed using full circumference pipe nipples or fittings with an OD greater than $12 \frac{3}{4}$ in. (323.9 mm), a welder qualification test shall be performed by either:

- 1) welding the full circumference when it is permitted by the WPS used for qualification, or
- 2) a single welder welding at least one half of the circumference of a test joint, or
- 3) using two welders to complete the full circumference weld, during which each welder shall complete one half ($\frac{1}{2}$) the circumference from 12 o'clock to 6 o'clock position. In this "half-circumference dual-welder qualification" (see 3.1.15), the full circumference shall be welded using two welders, with each welder welding one half ($\frac{1}{2}$) the circumference that includes a top, side, and bottom portion of the test joint. Test specimens shall be removed from each welder's portion of the completed weld. Specimens shall not be removed from locations where weld beads deposited by one welder overlap weld beads deposited by the other welder.

For options 2) and 3), all the required test specimens required by 6.5 shall be removed from the half welded by each welder.

Welders shall fit-up the test joint in addition to making the test welds. Templates may be used to assist in the preparation of test joints.

The joint thickness shall be completed by one welder unless different processes, direction of travel, or filler metal groups (in accordance with Table 4) are used to complete the joint.

Table 4—Filler Metal Groups for Welder Qualification

Filler Metal Group	Welding Process	AWS Specification	AWS Classification ^a
WF-1 ^b	SMAW	A5.1 or A5.5	EXX10-X(X), EXX11-X(X) electrodes
WF-2 ^c	SMAW	A5.1 or A5.5	Any EXX15-XX(X), EXX16-XX(X), EXX18-XX(X), EXXX18-XX(X) electrodes
WF-3 ^d	SMAW	A5.5	E8045-XX, E9045-XX, E10045-XX
WF-4 ^e	GMAW or GTAW	A5.18	ERXXS-X
		A5.28	Any ERXX(X)S-XX(X) filler metals
WF-5	OFW	A5.2	RG60, RG65
WF-6 ^e	FCAW	A5.20 or A5.36	Any EXXT-1C, EXXT-1M, EXXT-9C, EXXT-9M, EXXT-12C, or EXXT-12M
		A5.29	Any E(X)XX-1XX(X)M

^a The system for identifying the electrode classifications in this standard follows the AWS filler metal specifications. The “X” is a designator in the AWS filler metal classification and can include any letter, number, or combination thereof, and when applicable, may be omitted (e.g., E6010 electrode is listed as WF-1).

^b Cellulosic-coated electrodes

^c Low hydrogen electrodes

^d Low hydrogen vertical down electrodes

^e A shielding gas (see 5.4.2.7) is required for use with the filler metals in Group WF-4 and WF-6.

When two welders are used to fill the joint thickness, each welder shall have a weld on one surface (i.e., one welder root surface, other welder cap surface). A defect(s) shall disqualify both welders regardless of the location of the defect(s).

For half-circumference dual-welder qualification, the failure of a test joint from one half of the weld circumference shall not impact the qualification of the other welder who welded the other half of the weld circumference.

A welder who qualifies as an in-service branch welder in accordance with Annex B shall be considered qualified to make non-in-service branch and fillet welds unless prohibited by the company. A welder who qualifies as an in-service fillet welder in accordance with Annex B shall be considered qualified to make non-in-service fillet welds unless prohibited by the company. A branch or fillet welder who is qualified in this manner shall be limited to the applicable range of essential variables described in 6.2.2 and not by the essential variables described in Annex B.

Welders shall not be considered to have a Section 6 multiple qualification by combining welds made in accordance with Section 6 and welds made in accordance with Annex B.

6.2 Single Qualification

6.2.1 General

For single qualification, a welder shall weld a test joint joining pipe nipples or segments of pipe nipples. For qualifications to make butt welds, the welder shall make a butt weld in either the rolled or the fixed position.

When the welder is qualifying in the fixed position, the axis of the pipe shall be horizontal, vertical, or inclined from horizontal at an angle of not more than 45°.

For the purpose of single qualification, the company shall decide if the welder is allowed to use pre-beveled fittings as branches. The company shall decide if welders are required to cut weld bevels for butt welds or for pipe nipples used as branches.

For single qualification tests, segments of pipe nipples representing a main line or "run pipe" (which the branch is welded to) may be used to qualify the welder to make branch attachments. The segments shall be approximately one half ($1/2$) the pipe circumference or greater.

Changes in the essential variables described in 6.2.2 shall require requalification of the welder. The welder shall not be restricted to welding only with the welding procedure followed during qualification testing, but is limited by the essential variables of the welder qualification.

The weld shall be acceptable if it meets the requirements of 6.4 and either 6.5 or 6.6.

6.2.2 Scope

A welder who has successfully completed the qualification test described in 6.2.1 shall be qualified within the limits of the essential variables described in 6.2.2. The welder shall be requalified if any of the following essential variables are changed:

- a) A change from one welding process to another welding process or combination of processes, as follows:
 - 1) a change from one welding process to a different welding process; or
 - 2) a change in the combination of welding processes, unless the welder has qualified on separate qualification tests, using each of the welding processes that are to be used for the combination of welding processes.
- b) A change in the direction of welding from vertical up to vertical down or vice versa, or a change from vertical progression to horizontal progression or vice versa. The specified direction of vertical progression is not intended to prevent welders from welding across the 12 o'clock or 6 o'clock of a horizontal pipe to avoid stacking starts and stops. A welder who has successfully completed the qualification test with the pipe fixed and axis inclined 45° from horizontal shall be qualified to also weld in horizontal position.
- c) A change of filler metal, as follows:
 - 1) a change of filler metal grouping in Table 4; or
 - 2) a change of filler metal classification not listed in Table 4 to any other filler metal classification or vice versa.
- d) A change from one specified OD group to another; however, for branch connection welds, the run pipe diameter is not an essential variable. These groups are defined as follows:
 - 1) specified OD less than 2.375 in. (60.3 mm);
 - 2) specified OD from 2.375 in. (60.3 mm) through 12.750 in. (323.9 mm);
 - 3) specified OD greater than 12.750 in. (323.9 mm).
- e) A change from one specified wall thickness group to another; however, for branch connection welds and lap fillet welds, the run pipe thickness is not an essential variable. These groups are defined in Table 5.

- f) A change from rolled to fixed position. A welder who qualifies in the fixed position shall also be qualified to perform rolled welds within the essential variables qualified.
- g) A change in welding position. A welder who successfully passes a butt weld qualification test in the fixed position with the axis inclined 45° from horizontal shall be qualified to do butt welds and lap fillet welds in all positions.

NOTE Refer to AWS A3.0, Figure B.16C for position definitions.

- h) A change in the joint design [see Note e) of Table 1]. A welder who qualifies on a butt weld shall also be qualified to make fillet welds within the essential variables qualified.
- i) Elimination of a backing strip or weld metal.
- j) Welders who qualify by welding a full penetration groove branch connection with fillet reinforcement with the axis of the header run pipe either horizontal or inclined from horizontal at an angle of not more than 45° shall be qualified to make the same production weld in the following positions:
 - 1) all positions if the qualification test weld was made with the branch on the side of the pipe;
 - 2) top and bottom if the qualification test weld was made with the branch on the bottom of the run pipe;
 - 3) top, if the qualification test weld was made with the branch on the top of the run pipe.

NOTE The weld positions qualified by various branch orientations and branch-to-header size ratios are summarized in Table 6.

- k) A change in the passes welded with a single process when more than one process is used to complete the joint. However, the welder may make production welds using only the process or processes used for fill and cap passes even if the test weld used a combination of processes. When the process used for fill passes in testing is used to make a complete production weld, the process shall have been used for three or more passes in the testing. Processes used for less than three passes in testing shall not be used for more than two passes in a production weld. For short circuiting transfer mode of gas metal arc welding (GMAW-S), the welder shall only use GMAW-S in production for the same passes that the welder used GMAW-S in qualification testing.

Table 5—Qualified Thickness Range for Single Qualification Test

Qualified Thickness Range	Thickness Tested (t)
t to the greater of 0.154 in. (3.9 mm) or $1.5t$	when $t < 0.154$ in. (3.9 mm)
0.154 in. (3.9 mm) to the greater of 0.75 in. (19 mm) or $1.5t$	when 0.154 in. (3.9 mm) $\leq t < 0.75$ in. (19 mm)
0.75 in. (19 mm) to unlimited	when $t \geq 0.75$ in. (19 mm)

Table 6—Qualification Scope for Single Qualification Test Using a Branch Connection ¹

Branch Test Position	Branch Diameter/Run Pipe Diameter Ratio in Test	Qualified Welding Position of Production Weld for Branch ^a	Qualified Pipe Angle for Full Circumference Lap Fillet Weld ^b
Top	< 0.75 ≥ 0.75	Flat Flat, Vertical	75°–90° (horizontal weld) 0°–90°
Side	All	Flat, Vertical, Overhead	0°–90°
Bottom	< 0.75 ≥ 0.75	Overhead, Flat Flat, Vertical, Overhead	75°–90° (horizontal weld) 0°–90°

NOTE This table does not negate or supersede the limitations of the diameter groupings for pipe girth welds or for branch diameters.

^a Flat = 0° to approximately 15° (approximately 12 o'clock to 12:30 o'clock), Vertical = Approximately 15° to approximately 105° (approximately 12:30 o'clock to 3:30 o'clock), Overhead = Approximately 105° to 180° (approximately 3:30 o'clock to 6 o'clock)

^b 0° = horizontal, 90° = vertical pipe

6.3 Multiple Qualification

6.3.1 General

For multiple qualification, a welder shall successfully complete the two tests described below. Both test welds shall be welded using the same process or combination of processes and the same filler metal group or groups in Table 4.

NOTE 1 The two tests may be given in any order.

For one test, the welder shall make a butt weld in the fixed position with the axis of the pipe either horizontal or inclined from horizontal at an angle of not more than 45°. This butt weld shall be made on pipe with an OD of at least 6.625 in. (168.3 mm) and with a wall thickness of at least 0.250 in. (6.4 mm) without a backing strip. The weld shall be acceptable if it meets the requirements of 6.4 and either 6.5 or 6.6. Specimens shall be removed either from the test weld at the locations shown in Figure 12, at the relative locations shown in Figure 12 but without reference to the top of the pipe, or from locations that are spaced equidistantly around the entire pipe circumference. The sequence of adjacent specimen types shall be identical to that shown in Figure 12 for the various pipe diameters. Specimens shall not include the longitudinal weld.

When test joints are completed using full circumference pipe nipples or fittings with an OD greater than 12 ¾ in. (323.9 mm), a welder qualification test shall be performed by either of the following methods:

- 1) The full circumference shall be welded by a welder when it is allowed by the WPS used for qualification, or
- 2) A single welder welds at least one half (1/2) of the circumference of a test joint, or
- 3) By using two welders to complete the full circumference weld, during which each welder shall complete one half (1/2) the circumference from the 12 o'clock to 6 o'clock position. In this "half-circumference dual-welder qualification" (see 3.1.15), the full circumference shall be welded using two welders, with each welder welding one half (1/2) the circumference that includes a top, side, and bottom portion of the test joint. Test specimens shall be removed from each welder's portion of the completed weld. Specimens shall not be removed from locations where weld beads deposited by one welder overlap weld beads deposited by the other welder.

For options 2) and 3), all the required test specimens required by 6.5 shall be removed from the half welded by each welder. See Figure 13.

NOTE 2 When only one half ($\frac{1}{2}$) of a pipe circumference is welded during testing or when a pipe segment is welded during testing, precautions to minimize distortion of the test joint may be necessary to allow removal and testing of the required test specimens. Examples of precautions include use of tack welds or fixturing.

For the other test, the welder shall lay out, cut, fit, and weld a branch-on-pipe connection in which the specified diameters of the run and the branch pipes are equal. This test shall be performed with a pipe diameter of at least 2.375 in. (60.3 mm) and with a specified wall thickness of at least 0.250 in. (6.4 mm). When small-diameter pipe is used for testing, more than one test weld may be required to obtain the required number of test specimens.

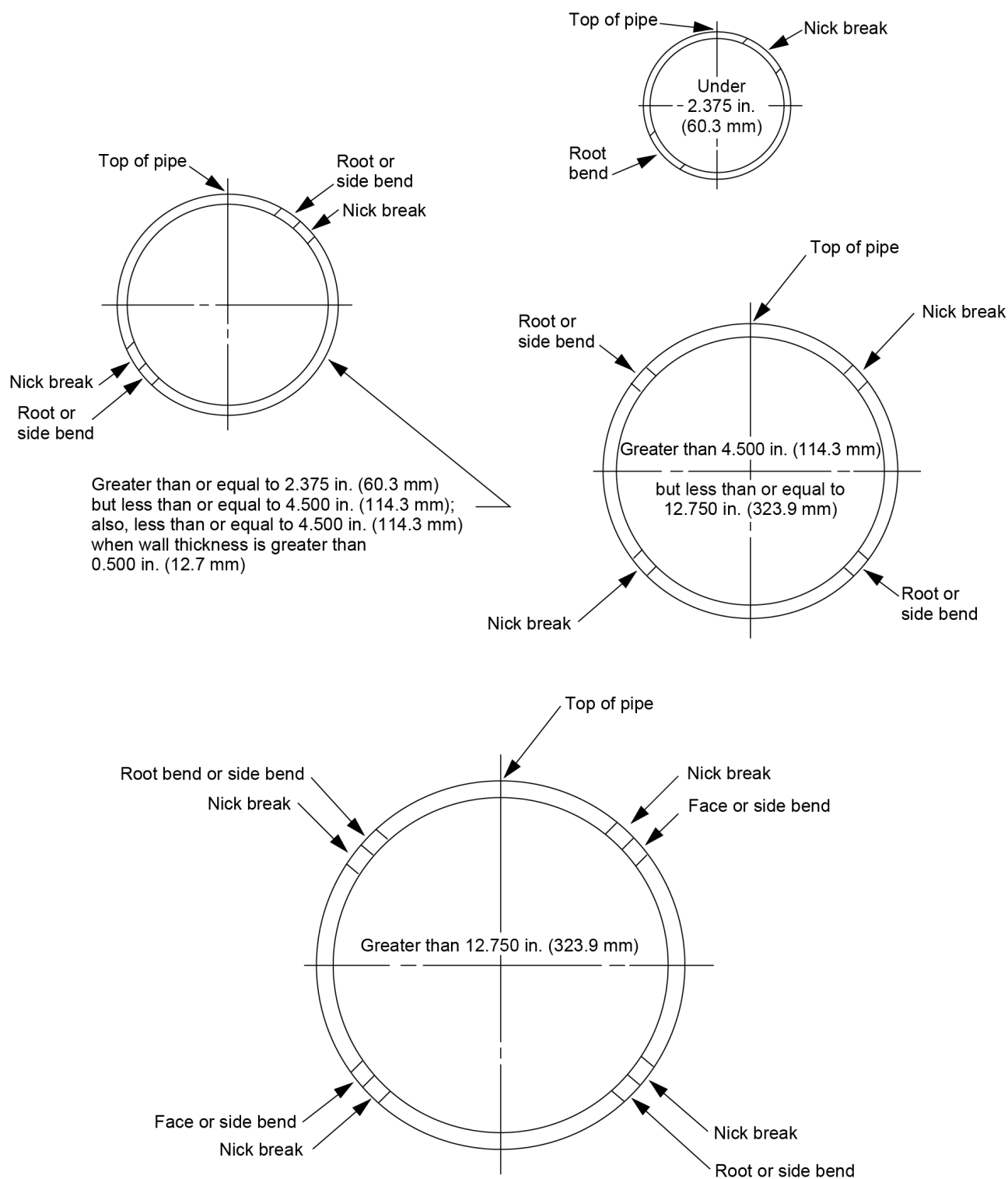
A hole with a specified diameter approximately equal to the inside diameter (ID) of the branch pipe shall be cut in the run. The company shall decide if the welder shall cut the hole in preparation of the branch assembly.

Use of templates to assist in layout shall be at the discretion of the company. Use of manually operated mechanisms that assist in accurate cutting of the hole or to prepare the branch bevel shall be at the discretion of the company.

The weld shall be made with the run pipe in the fixed horizontal position, with the branch pipe axis extending either vertically downward from the run pipe or projecting from the side of the run pipe.

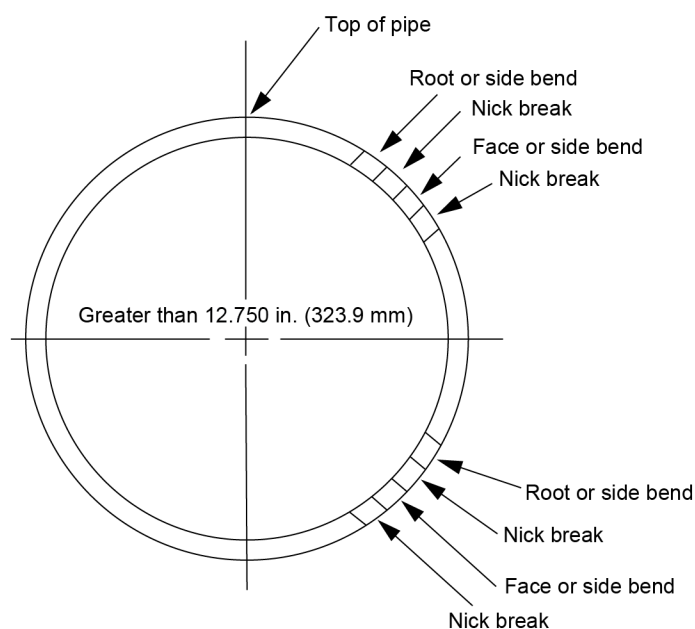
If the welder fails either the butt or the branch test weld, the welder shall be required to retest only for the failed weld. The welder shall not be required to repeat both the butt and the branch test weld unless required by the company.

The welds shall be acceptable if they meet the requirements of 6.4 and either 6.5 or 6.6.



NOTE At the company's option, the locations may be rotated, provided they are equally spaced around the pipe; however, specimens do not include the longitudinal weld.

Figure 12—Location of Test Butt Weld Specimens for Welder Qualification Test (Full Circumference)



NOTE 1 At the company's option, this setup may be used for qualifying welders using the half-circumference dual-welder technique or when the test weld consists of a segment or a weld on only one half (1/2) of a full circumference.

NOTE 2 The illustration shows samples for one welder who welded half of the circumference.

Figure 13—Location of Test Butt Weld Specimens for Welder Qualification Test (Half Circumference)

6.3.2 Scope

A welder who has successfully completed the butt weld qualification test described in 6.3.1 on pipe with an OD greater than or equal to 12.750 in. (323.9 mm) and a branch weld with pipe and branch having specified OD greater than or equal to 12.750 in. (323.9 mm) in which the specified diameters of the run and branch pipes are equal shall be qualified to weld in all positions; on all wall thicknesses, joint designs, and fittings; and on all pipe diameters using the same process or combination of processes and same filler metal groups (see Table 4) used for the two test welds. A welder who has successfully completed the butt weld and branch weld requirements of 6.3.1 on pipe with an OD less than 12.750 in. (323.9 mm) shall be qualified to weld in all positions; on all wall thicknesses, joint designs, and fittings; and on all pipe diameters less than or equal to the OD used by the welder in the qualification tests.

If any of the following essential variables are changed in a welding procedure specification, the welder using the new procedure shall be requalified:

- a) A change from one welding process to another welding process or combination of processes, as follows:
 - 1) a change from one welding process to a different welding process; or
 - 2) a change in the combination of welding processes, unless the welder has qualified on separate qualification tests, each using the same welding process that is used for the combination of welding processes.
 - 3) a change in the passes welded with a single process when more than one process is used to complete the joint. However, the welder shall also be qualified to make production welds using only the process or processes used for fill and cap passes even if the test weld used a combination of processes. When the process used for fill passes in testing is used to make a complete production

weld, the process shall have been used for three or more passes in the testing. Processes used for less than three passes in testing shall not be used for more than two passes in a production weld.

- b) A change in the direction of welding from vertical up to vertical down or vice versa.
- c) A change of filler metal grouping in Table 4. A change of filler metal classification not listed in Table 4 to any other filler metal classification or vice versa.

6.4 Visual Examination

For a qualification test weld to meet the requirements for visual examination, the weld shall be free from cracks and inadequate penetration, and shall present a neat workmanlike appearance that is acceptable to the company.

For a butt weld, no burn-through (BT) shall be allowed. Branch connections shall not contain any BT having a length more than $\frac{1}{4}$ in. (6 mm). The sum of the maximum dimensions of separate unrepaired BTs in any continuous 12-in. (300-mm) length of branch connection weld shall not exceed $\frac{1}{2}$ in. (13 mm).

External undercut (and internal undercut, when practical) shall be evaluated to the requirements of 9.7, and if any portion of the welder's qualification weld exceeds the undercut allowed by Table 8, the welder shall be disqualified.

All dimensional requirements specified in the WPS shall be met.

When semiautomatic or mechanized welding is used, filler wire protruding into the inside of the pipe shall be kept to a minimum. The company shall determine the acceptance criteria for the number of protruding wires.

Failure to meet the requirements of this section shall be adequate cause to eliminate additional testing.

6.5 Destructive Testing

6.5.1 Sampling of Test Butt Welds

To test butt welds, samples shall be cut from each test weld. Figure 12 shows the locations from which the specimens shall be removed if the test weld is a full circumference. Figure 13 shows the locations from which the specimens shall be removed if the test weld is completed as a half circumference. If the test weld consists of segments of pipe nipples, an approximately equal number of specimens shall be removed from each segment. The total number of specimens and the tests to which each shall be submitted are shown in Table 7. The specimens shall not include the longitudinal weld. The specimens shall be air cooled to ambient temperature prior to testing. For pipe with an OD less than or equal to 1.315 in. (33.4 mm), the company shall select qualification by testing either one full-section tensile specimen or testing root bend and nick break specimens. If a full-section tensile is used and the specimen breaks in the weld or at the junction of the weld and the parent material and fails to meet the soundness requirements of 5.6.3.3, the welder shall be disqualified.

Table 7—Type and Number of Butt Weld Test Specimens per Welder for Welder Qualification Test and Destructive Testing of Production Welds

Outside Diameter of Pipe		Number of Specimens				
in.	mm	Nick Break	Root Bend	Face Bend	Side Bend	Total
Wall Thickness ≤ 0.500 in. (12.7 mm)						
< 2.375	< 60.3	2	2	0	0	4 ^a
2.375 to 4.500	60.3 to 114.3	2	2	0	0	4
> 4.500 to 12.750	> 114.3 to 323.9	2	2	0	0	4
>12.750	>323.9	4	2	2	0	8
Wall Thickness > 0.500 in. (12.7 mm)						
≤4.500	≤114.3	2	0	0	2	4
> 4.500 to 12.750	>114.3 to 323.9	2	0	0	2	4
> 12.750	>323.9	4	0	0	4	8

^a For pipe less than or equal to 1.315 in. (33.4 mm) in outside diameter, nick break and root bend specimens from two welds or one full-section tensile strength specimen is taken.

6.5.2 Nick Break Test Requirements for Butt Welds

For the nick break test, if any specimen shows imperfections that exceed those allowed by 5.6.3.3, the welder shall be disqualified. Replacement of a nick break specimen is not permitted for welder qualifications.

6.5.3 Bend Test Requirements for Butt Welds

For the bend tests, if any specimen shows imperfections that exceed those allowed by 5.6.4.3 or 5.6.5.3, the welder shall be disqualified. Welds shall not be rejected solely for failure of the specimen to bend to the full U shape. These welds shall be considered acceptable if the specimens that crack are broken apart and their exposed surfaces meet the requirements of 5.6.3.3.

If one of the bend test specimens fails to meet these requirements and, in the company's opinion, the imperfection observed is not representative of the weld, the test specimen shall be replaced by an additional specimen cut adjacent to the one that failed, or the welder shall be disqualified.

The welder shall be disqualified if the additional specimen also shows imperfections that exceed the specified limits.

6.5.4 Branch and Fillet Weld Test Requirements

Four nick break specimens shall be removed from the weld at the locations shown in Figure 10. They shall be prepared and tested in accordance with 5.8.1 and 5.8.2. The exposed surfaces shall meet the requirements of 5.8.3. If the test weld consists of segments of pipe nipples, an approximately equal number of specimens shall be removed from each segment. The specimens shall be air cooled to ambient temperature prior to testing.

6.6 Nondestructive Testing (NDT)—Butt Welds Only

6.6.1 General

If requested by the company, the qualification butt weld shall be examined by radiography or automated ultrasonic testing (AUT) using a qualified NDT procedure instead of or in addition to the tests specified in 6.5.