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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The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the standard.

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*

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

ASTM[2] 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*

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[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 A3.0[3], *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 A5.28, *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 15653[4], *Metallic Materials. Method of Test for the Determination of Quasistatic Fracture Toughness of Welds*

ISO 19232-1[5], *Non-destructive testing—Image quality of radiographs—Part 1: Image quality indicators (wire type)—Determination of image quality value*

NACE MR0175/ISO[6] 15156 (all parts), *Petroleum and Natural Gas Industries—Materials for use in H_2S-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.

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[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 dscontinuity 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 edxposed 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.

A 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
D	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
D/t	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_2S	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 2nd bead: ______________ , 2nd bead to 3rd bead:
____

Cooling Method (if applicable) ____________________________
PWHT____

MECHANICAL TEST RESULTS

TENSILE TESTS Report Number: __________

Specimen Number	Tensile 1	Tensile 2	Tensile 3	Tensile 4
Location				
Original specimen dimensions				
Original specimen area				
Maximum load				
Tensile strength				
Fracture location				

NICK BREAK TESTS Report Number:

Specimen Number	Nick 1	Nick 2	Nick 3	Nick 4	Nick 5	Nick 6	Nick 7	Nick 8
Location								
Result								

BEND TESTS Report Number:

Specimen Type and Number								
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

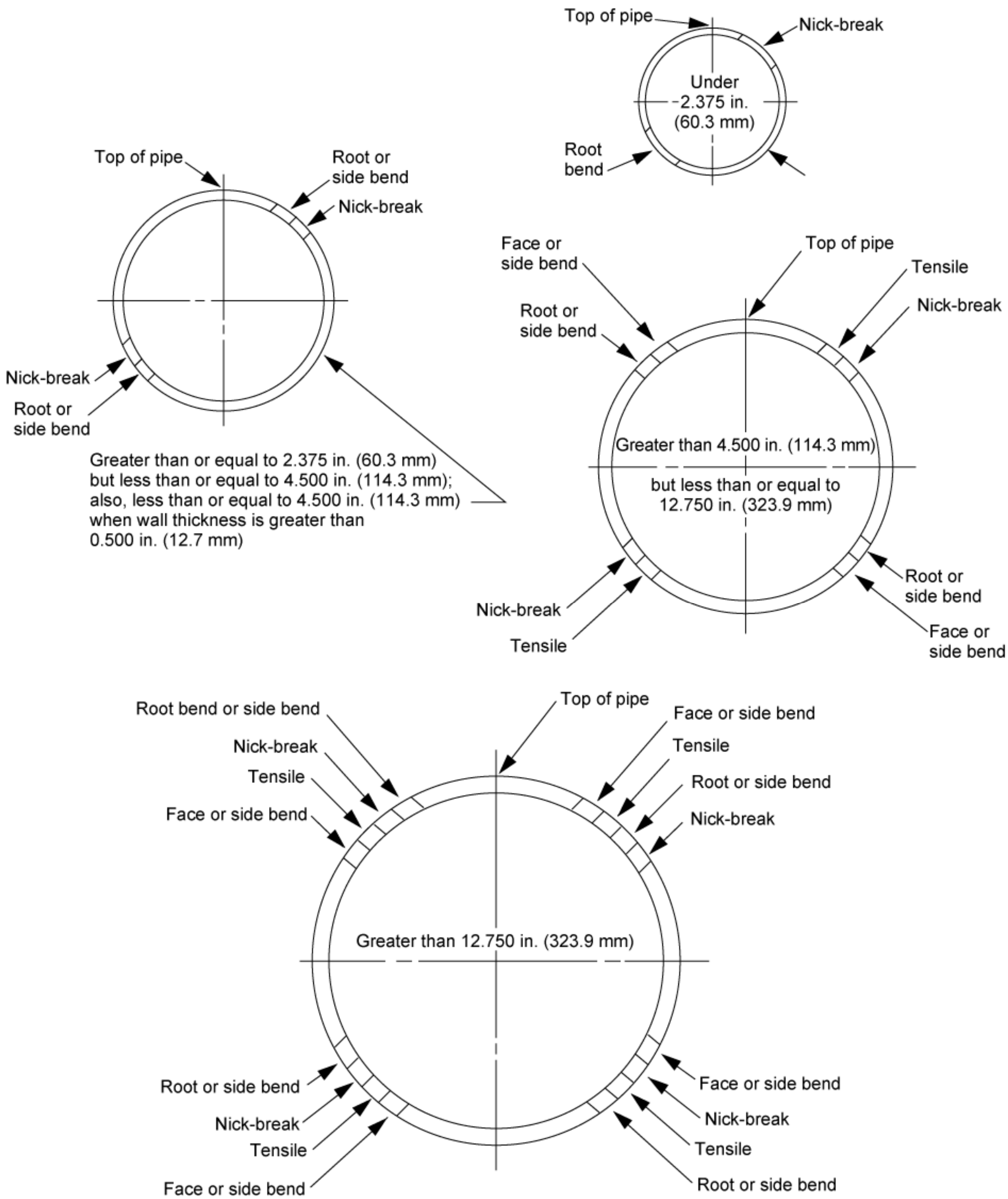
To weld the test joint for butt welds, two pipe nipples shall be joined.

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 take.

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.

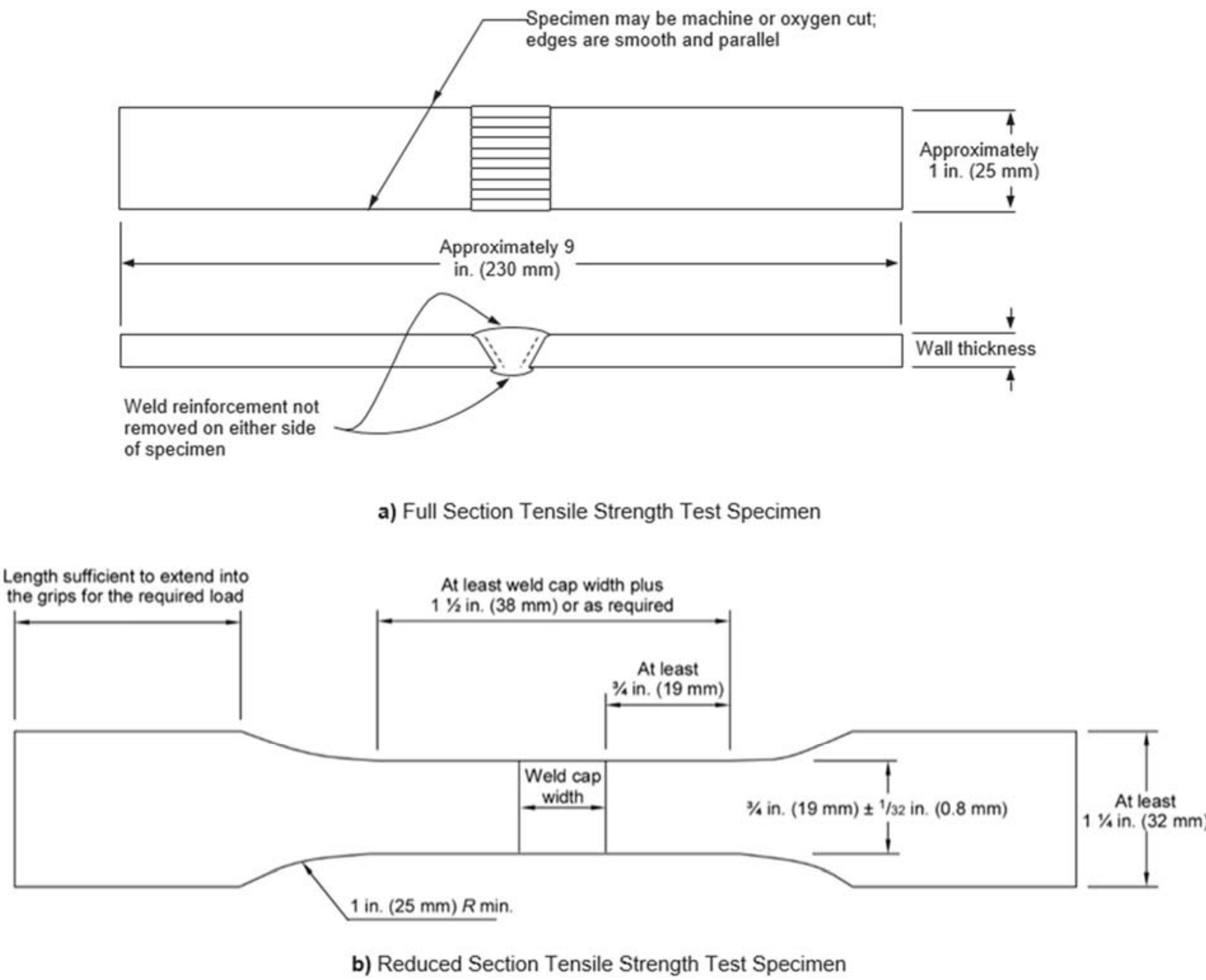


Figure 4—Tension Test Specimen

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 $^{1}/_{8}$ 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 $^{1}/_{16}$ 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 ¾ 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 $^{1}/_{16}$ 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 $^{1}/_{32}$ in. (0.8 mm) in depth and shall not be more than $^{1}/_{8}$ in. (3 mm) or one-half the specified wall thickness in length, whichever is smaller. There shall be at least ½ 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 ¾ 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.

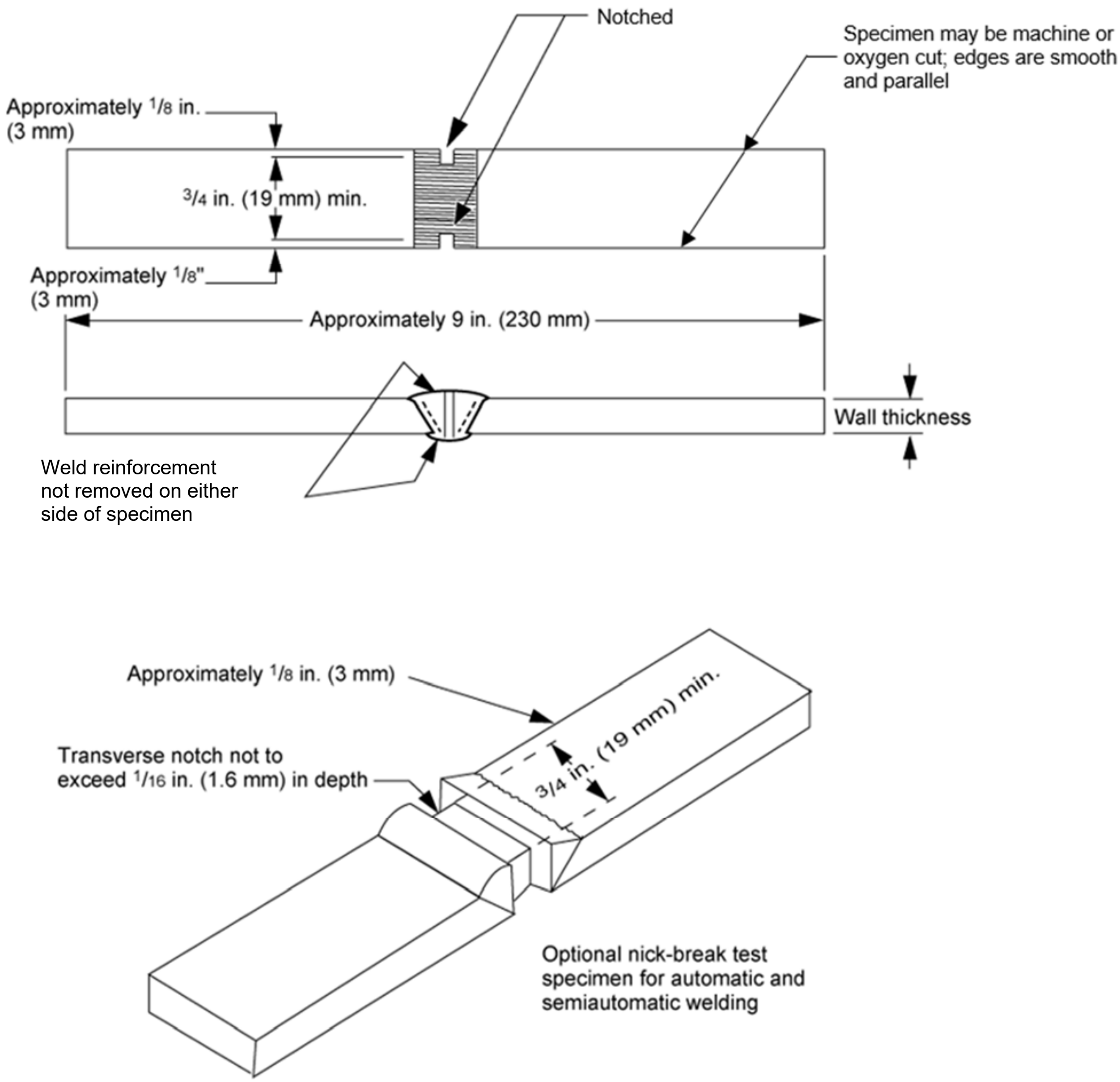
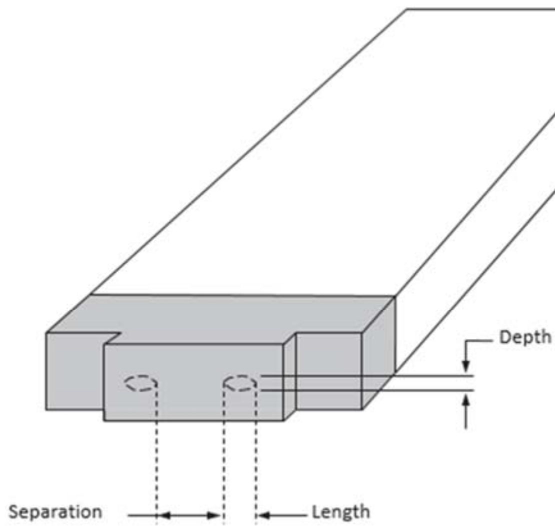


Figure 5—Nick Break Test Specimen



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.

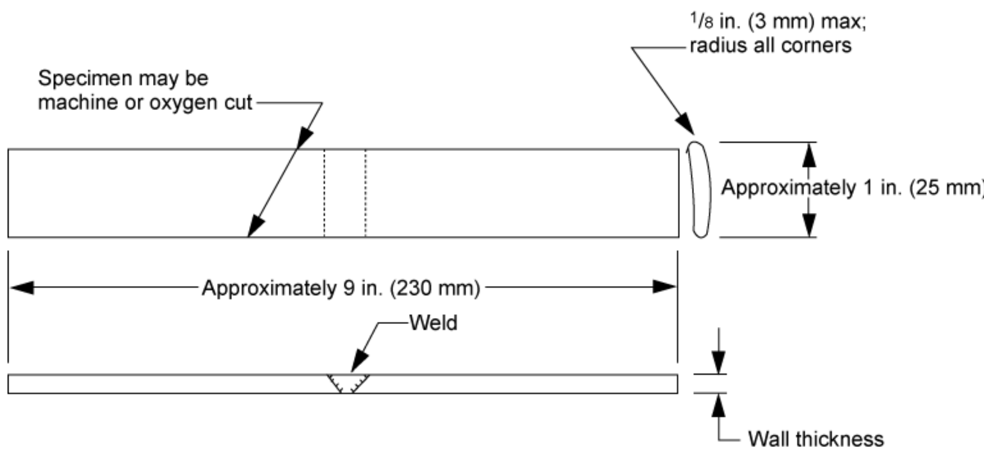
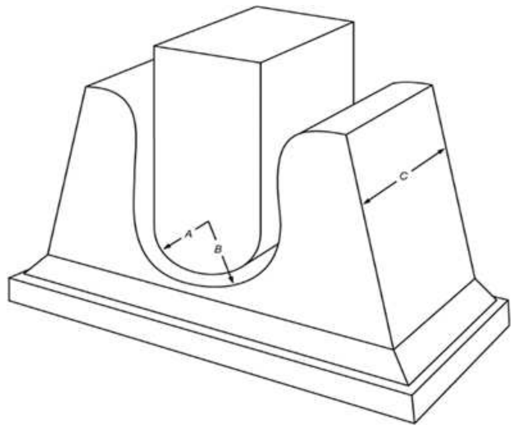


Figure 7—Root and Face Bend Test Specimen:
Wall Thicknesses Less than or Equal to 0.500 in. (12.7 mm)

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 ¾ in. (45 mm); radius of die, B = 2 $^{5}/_{16}$ 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 $^{1}/_{8}$ 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 ¼ in. (6 mm), measured in any direction, shall not be considered unless obvious imperfections are observed.

For a test weld diameter greater than 12 ¾ 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 ½ 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 ¾-in. (19-mm) width and then machined or ground to the ½-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.

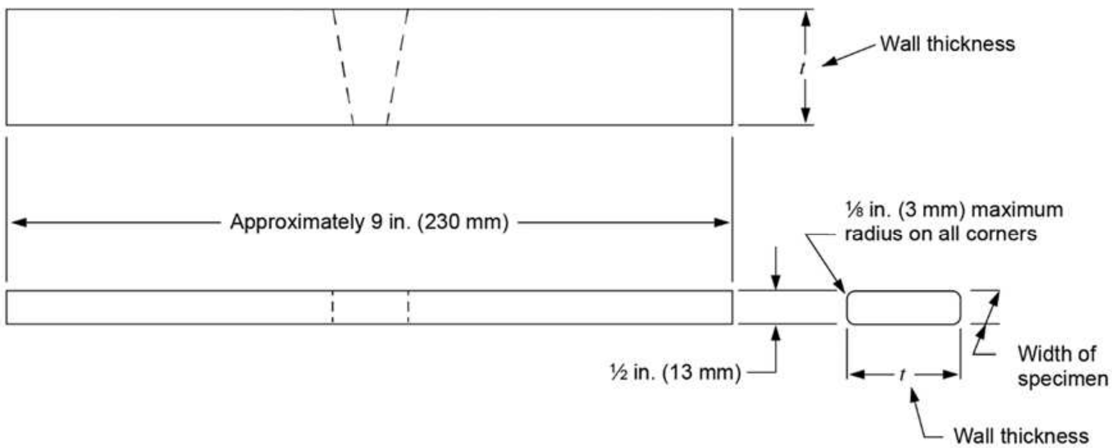
5.6.5.2 Method

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 ¾ 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.

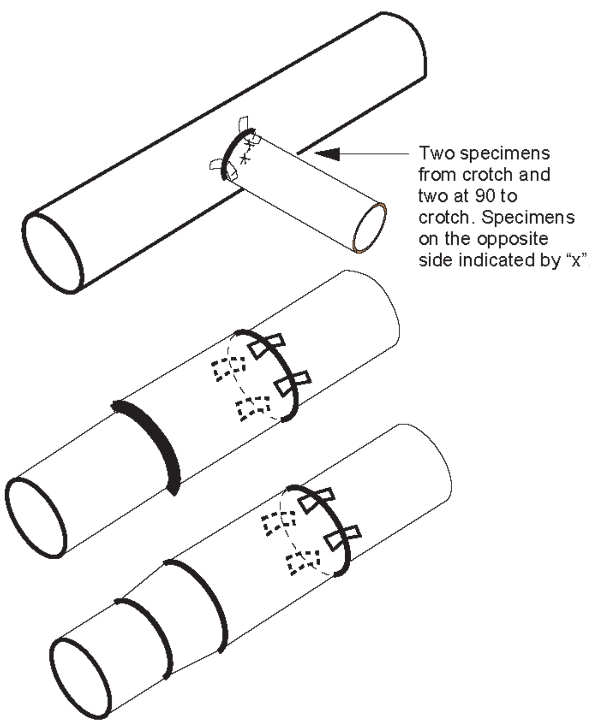


NOTE All dimensions are approximate.

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.

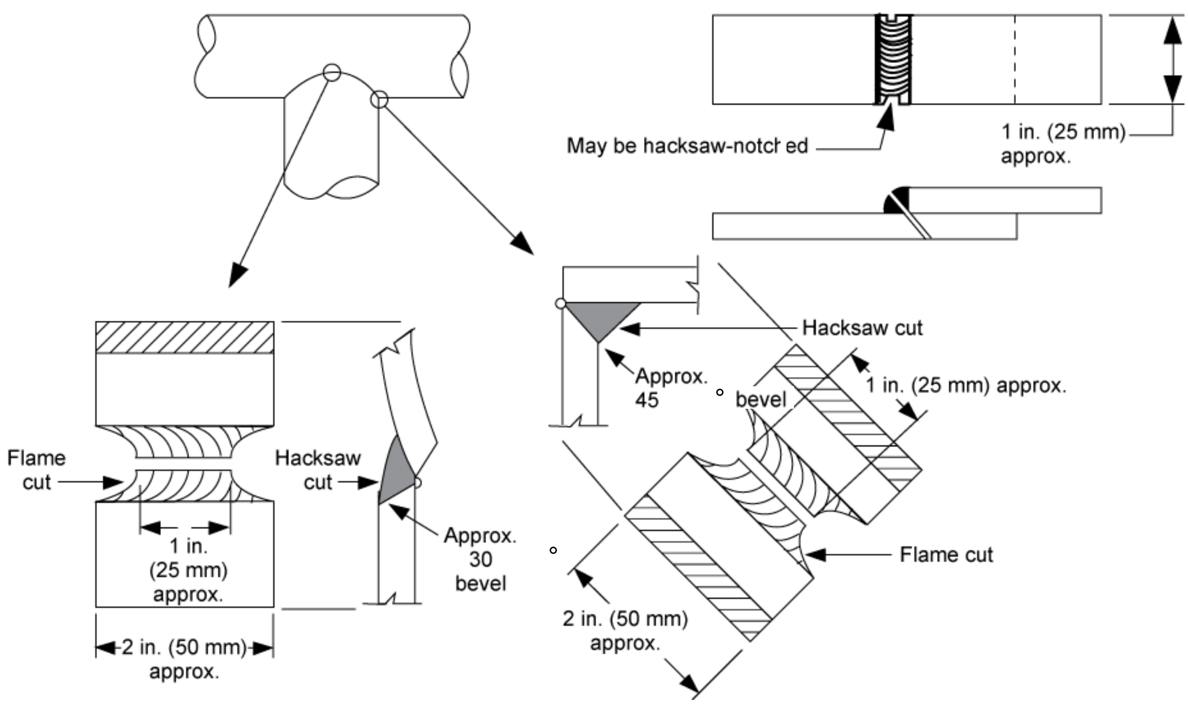
NOTE The specimens may be cut by any means.

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 $^1/_{16}$ 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 $^1/_{32}$ in. (0.8 mm) in depth and shall not be more than $^1/_8$ in. (3 mm) or one half the specified wall thickness in length, whichever is smaller; and

e) there shall be at least $^1/_2$ 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 ¾ in. (323.9 mm) OD.

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:

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 ($^1/_2$) 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 ($^1/_2$) 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 d) 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) ≤ t < 0.75 in. (19 mm)
0.75 in. (19 mm) to unlimited	when t ≥ 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), Vertica l= 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 (½) 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.

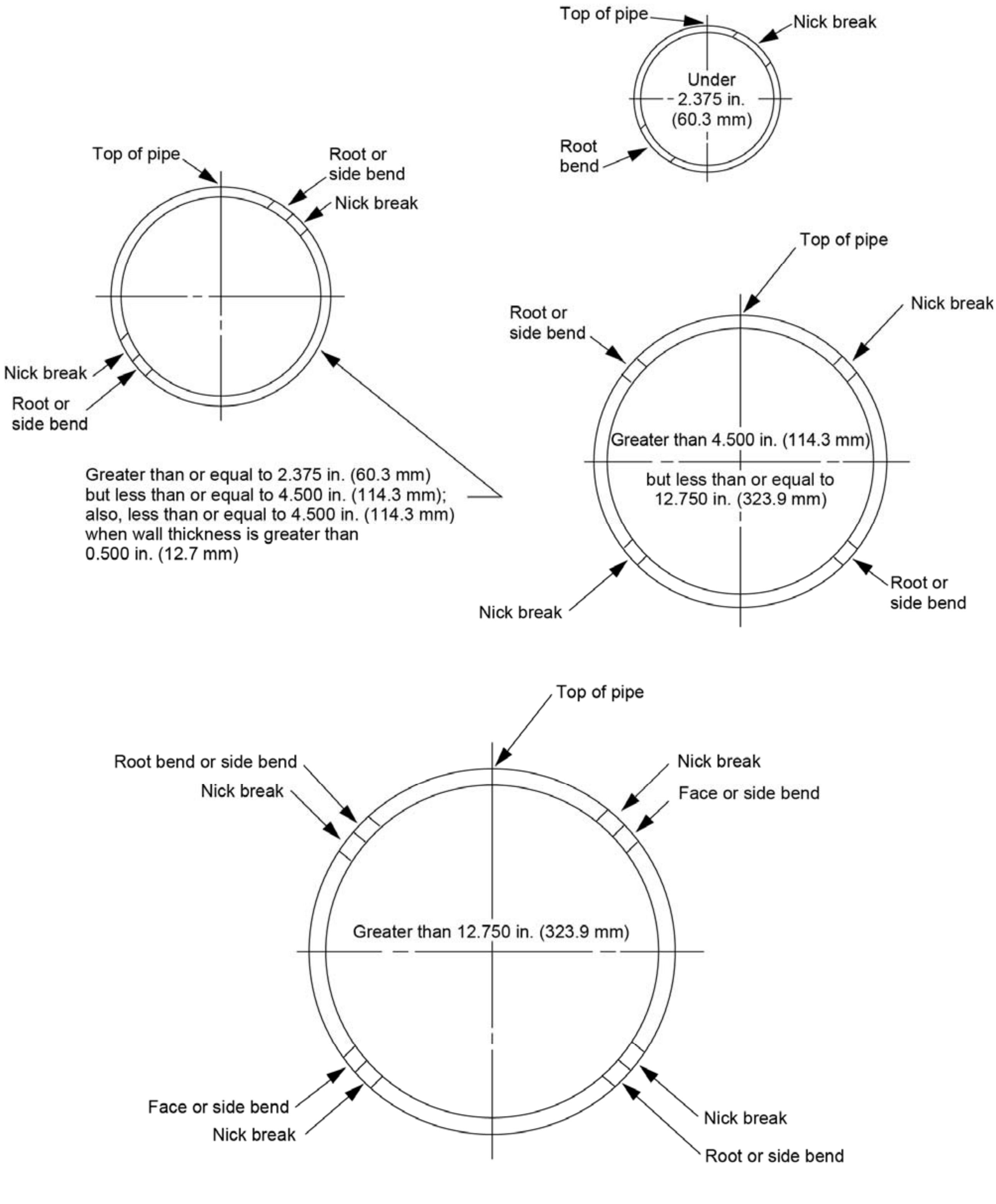
A hole with a specified diameter approximately equal to the inside diameter (ID) of the branch pipe shall be cut in the run. The company shall decide if the welder shall cut the hole in preparation of the branch assembly.

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.

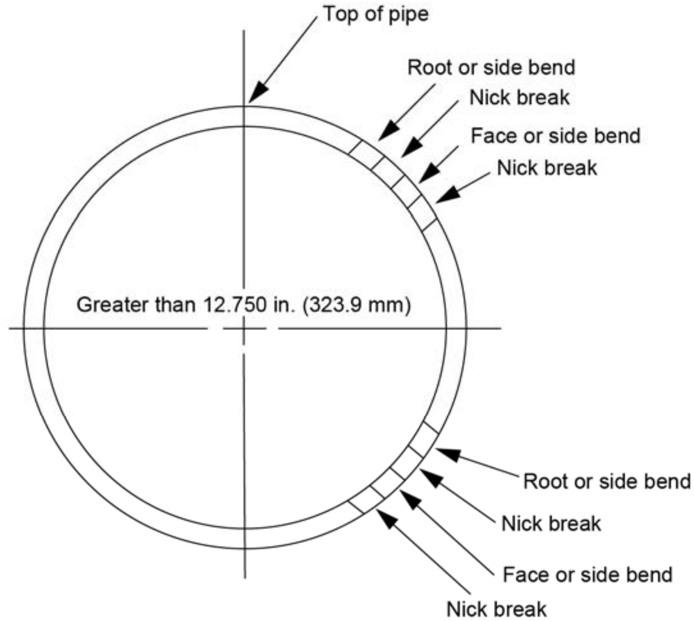
If the welder fails either the butt or the branch test weld, the welder shall be required to retest only for the failed weld. The welder shall not be required to repeat both the butt and the branch test weld unless required by the company.

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 ¼ 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 ½ 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.

6.6.2 Inspection Requirements

When radiography is used, radiographs shall be made of each of the test welds. The welder shall be disqualified if any of the test welds do not meet the requirements of 9.3.

When AUT is utilized, each test weld shall be fully examined. The welder shall be disqualified if any of the test welds do not meet the requirements of 9.6.

Radiographic testing or AUT shall not be used for the purpose of locating sound areas or areas that contain imperfections and subsequently destructively testing such areas to qualify or disqualify a welder.

6.7 Retesting and Disposition of Test Results

If, in the mutual opinion of the company and the contractor's representatives, a welder fails to pass the qualification test because of unavoidable conditions or conditions beyond the welder's control, the welder should be given a second opportunity to qualify. No further retests shall be given until the welder has submitted proof of subsequent welder training that is acceptable to the company.

If the company elects to use both nondestructive tests and destructive tests to evaluate a welder test joint, failure to meet the acceptance criteria of either test shall result in failure of the test weld.

6.8 Records

A record shall be maintained of the tests given to each welder and of the detailed results of each test. In addition to the results of NDT or destructive test results, Figure 1—or a similar form developed to suit the needs of the individual company—should be used. Forms should be sufficiently detailed to demonstrate that the qualification test met the workmanship requirements of this standard and that the welder welded within the parameter ranges specified on the applicable WPS during the qualification test. A list of qualified welders and the procedures for which they are qualified shall be maintained.

If requested by the company, a welder shall requalify if a question arises about the welder's competence.

7 Design and Preparation of a Joint for Production Welding

7.1 General

Piping shall be welded by qualified welders using qualified procedures. The surfaces to be welded shall be smooth, uniform, and free from laminations, tears, scale, slag, grease, paint, and other deleterious material that might adversely affect the welding.

For production welding of materials with two separate strength levels, a procedure that is qualified for the higher-strength material should be used.

NOTE While it is acceptable (according to 5.6.2.3) for the measured tensile strength across the weld to be less than the actual tensile strength of the pipe material, some pipeline designs (e.g., high longitudinal strains due to geotechnical reasons) require matching or overmatching strength girth welds. The use of filler metal with yield strength that matches or overmatches the actual yield strength of the pipe material prevents longitudinal strains from accumulating in the weld region, which is more likely to contain imperfections than the pipe material.

7.2 Alignment

The root opening, or spacing between abutting members, shall be in accordance with the welding procedure specification. The alignment of abutting ends shall minimize the offset between surfaces. For pipe ends of the same OD and specified thickness, the offset at any location should not exceed $^1/_8$ in. (3 mm). Larger variations are permissible provided the variation is caused by variations of the pipe end dimensions within the pipe purchase specification tolerances, and such offset has been minimized by distributing around the circumference of the pipe. Hammering of the pipe to obtain proper lineup should be kept to a minimum and hinging of the pipe joint (i.e., the use of hinge tacks) to achieve a proper root gap should be prohibited.

7.3 Use of Lineup Clamp for Butt Welds

Use and removal of lineup clamps shall be in accordance with the welding procedure specification. If the clamp can be removed prior to root pass completion, the percentage required by the welding procedure specification shall be met and should be equally spaced around the circumference.

7.4 Bevel

The bevels shall conform to the joint design used in the welding procedure specification.

7.5 Weather Conditions

Welding shall not be done when the quality of the completed weld would be impaired by the prevailing weather conditions, including but not limited to low temperatures, airborne moisture, blowing sands, or high winds. Windshields or temporary shelters may be used when practical. The company shall decide if weather conditions are suitable for welding.

7.6 Clearance

When the pipe is welded above ground, the working clearance around the pipe at the weld should not be less than 16 in. (400 mm). When the pipe is welded in a trench, the bell hole shall be large enough to provide the welder or welders with ready access to the joint.

7.7 Cleaning Between Beads

Scale and slag should be removed from each bead and groove. Power tools shall be used when called for in the welding procedure specification; otherwise, cleaning may be performed with either hand or power tools.

When semiautomatic or mechanized welding is used, surface porosity clusters, bead starts, and high points should be removed by grinding before weld metal is deposited over them. When requested by the company, heavy glass deposits shall be removed before weld metal is deposited over them.

7.8 Position and Roll Welding

7.8.1 Procedure

All position welds shall be made with the parts to be joined secured against movement and with adequate clearance around the joint to allow the welder or welders space in which to work. At the company's option, roll welding shall be permitted using a qualified welding procedure specification, provided alignment is maintained using skids or a structural framework with an adequate number of roller dollies to prevent sag in the supported lengths of pipe.

7.8.2 Filler and Finish Beads

The number of filler and finish beads shall allow the completed weld a substantially uniform cross-section around the entire circumference of the pipe. At no point shall the crown surface fall below the outside surface of the pipe, nor should it be raised above the parent metal by more than that specified in the welding procedure specification.

Two beads shall not be started at the same location. The cap width should conform to the tolerances specified in the welding procedure specification. The completed weld shall be thoroughly brushed and cleaned.

7.9 Identification of Welds

Each welder shall identify the welder's work in the manner agreed by the company.

7.10 Preheat, Interpass Temperature, Postheat, and PWHT

Preheat, interpass temperature, postheat, and PWHT practices as listed on the qualified welding procedure specification shall be followed.

NOTE Application of postheat can be beneficial to the reduction of solute hydrogen, particularly when using cellulosic-coated (AWS EXX10-type) electrodes.

8 Inspection and Testing of Production Welds

8.1 Rights of Inspection

The company shall have the right to inspect all welds by nondestructive means or by removing welds and subjecting them to mechanical tests. The inspection may be made during the welding or after the weld has been completed. The frequency of inspection shall be as specified by the company.

8.2 Methods of Inspection

The NDT method used shall produce indications of imperfections that can be accurately interpreted and evaluated. The welds shall be evaluated on the basis of either Section 9 or, at the company's option, Annex A. In the latter case, more extensive inspection to determine the imperfection size is required.

Destructive testing shall consist of the removal of completed welds, sectioning of the welds into specimens, and the examination of the specimens. The specimens shall be prepared in accordance with and shall meet the requirements of 6.5. The company shall have the right to accept or reject any weld that does not meet the requirements for the method by which it was inspected.

NOTE 1 The welder who makes a weld that fails to comply with the requirements may be disqualified from further work.

NOTE 2 Operators of nondestructive inspection equipment may be required to demonstrate the inspection procedure's capability to detect defects and the operator's ability to properly interpret the indications given by the equipment.

Trepanning methods of testing shall not be used.

8.3 Qualification of Inspection Personnel

Welding inspection personnel shall be qualified by experience and training for the specified inspection task they perform. Their qualifications shall be acceptable to the company.

Documentation of these qualifications shall be retained by the company and shall include but is not limited to the following:

a) education and experience;

b) training;

c) results of any qualification examinations.

8.4 Certification of NDT Personnel

8.4.1 Procedures

NDT personnel shall be certified to Level I, II, or III in accordance with the recommendations of ASNT SNT-TC-1A, ASNT ACCP[7], or any other recognized national certification program that shall be acceptable to the company for the test method used. Only Level II or III personnel shall interpret test results.

8.4.2 Record

A record of certified NDT personnel shall be maintained by the company. The record shall include the results of certification tests, the agency and person granting certification, and the date of certification.

NOTE NDT personnel may be required to be recertified at the company's option or if any question arises about their ability.

All levels of NDT personnel shall be recertified at least every five years.

8.4.3 Vision Examinations

8.4.3.1 Near Distance

All NDT personnel shall be examined to ensure that they have natural or corrected near-distance acuity in at least one eye such that each individual is capable of reading a Jaeger No. 1 test chart or equivalent at a distance of not less than 12 in. (300 mm). Non-NDT personnel (i.e., welding inspectors) who perform visual inspections shall be examined to ensure that they have natural or corrected near-distance acuity in at least one eye such that each individual is capable of reading a Jaeger No. 2 test chart or equivalent at a distance of not less than 12 in. (300 mm).

8.4.3.2 Color Vision

NDT personnel for all methods shall demonstrate the ability to differentiate among the colors or shades of gray used in the method.

8.4.3.3 Frequency

Near-vision examinations shall be administered at least annually for NDT personnel and every three years for non-NDT personnel. Color differentiation examinations shall be repeated at least every five years.

9 Acceptance Standards for NDT

9.1 General

The acceptance standards presented in this section apply to imperfections located by radiographic, magnetic particle, liquid penetrant, and ultrasonic test methods. They may also be applied to visual inspection. NDT shall not be used to select welds/weld specimens that are subjected to destructive testing in accordance with 6.5.

9.2 Rights of Rejection

All nondestructive test methods are limited in the information that can be derived from the indications they produce, and the company may therefore reject any weld that appears to meet these acceptance standards if, in its opinion, the depth of an imperfection may be detrimental to the weld.

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[7] ASNT Central Certification Program, American Society for Nondestructive Testing, www.asnt.org.

9.3 Radiographic Testing

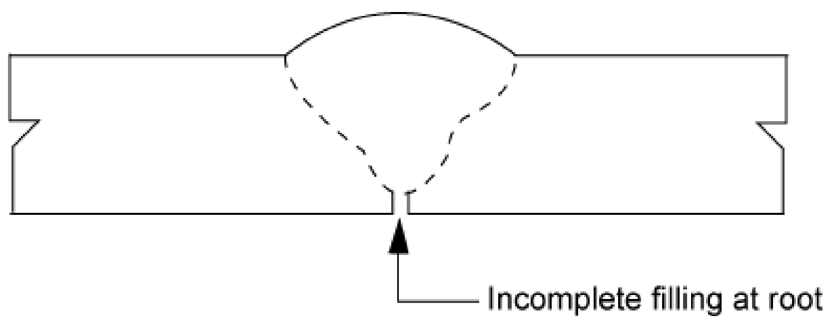
9.3.1 Inadequate Penetration Without High-low (IP)

IP, as defined in 3.1.22 and shown schematically in Figure 14, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of IP exceeds 1 in. (25 mm);

b) the aggregate length of indications of IP in any continuous 12-in. (300-mm) length of weld exceeds 1 in. (25 mm);

c) the aggregate length of indications of IP exceeds 8 % of the weld length in any weld less than 12 in. (300 mm) in length.



NOTE One or both root faces may be inadequately filled at the inside surface.

Figure 14—Inadequate Penetration Without High-low

9.3.2 Inadequate Penetration Due to High-low (IPD)

IPD, as defined in 3.1.21 and shown schematically in Figure 15, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of IPD exceeds 2 in. (50 mm);

b) the aggregate length of indications of IPD in any continuous 12-in. (300-mm) length of weld exceeds 3 in. (75 mm).

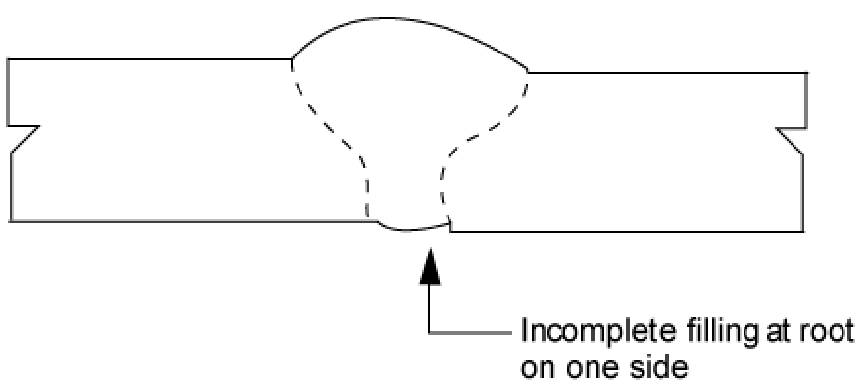


Figure 15—Inadequate Penetration Due to High-low

9.3.3 Inadequate Cross Penetration (ICP)

ICP, as defined in 3.1.20 and shown schematically in Figure 16, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of ICP exceeds 2 in. (50 mm);

b) the aggregate length of indications of ICP in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm).

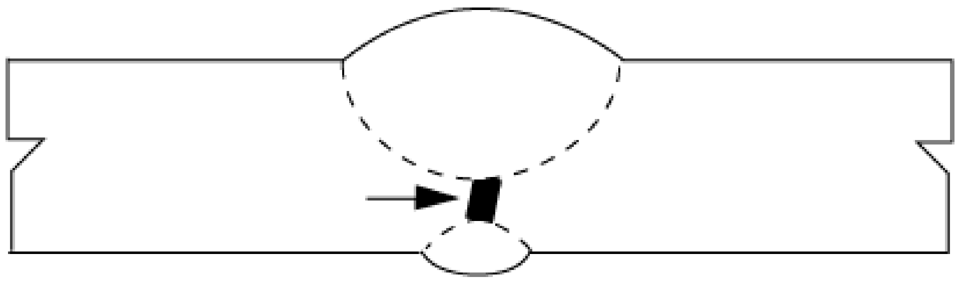


Figure 16—Inadequate Cross Penetration

9.3.4 Incomplete Fusion (IF)

IF, as defined in 3.1.23 and shown schematically in Figure 17, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of IF exceeds 1 in. (25 mm);

b) the aggregate length of indications of IF in any continuous 12-in. (300-mm) length of weld exceeds 1 in. (25 mm);

c) the aggregate length of indications of IF exceeds 8 % of the weld length in any weld less than 12 in. (300 mm) in length.

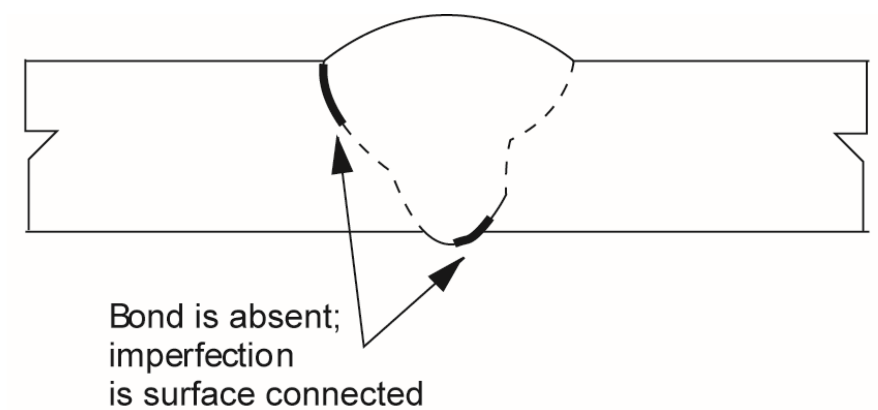


Figure 17—Incomplete Fusion at Root of Bead or Top of Joint

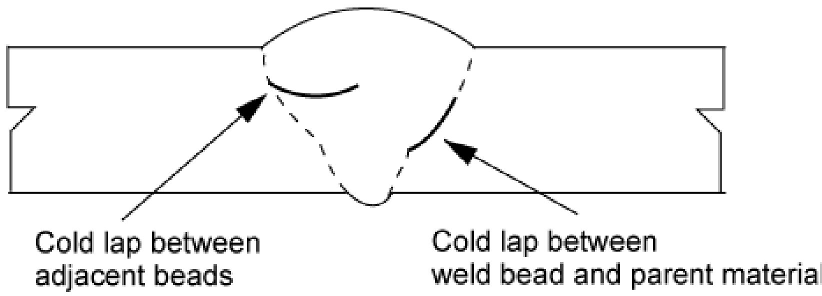
9.3.5 Incomplete Fusion Due to Cold Lap (IFD)

IFD, as defined in 3.1.24 and shown schematically in Figure 18, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of IFD exceeds 2 in. (50 mm);

b) the aggregate length of indications of IFD in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

c) the aggregate length of indications of IFD exceeds 8 % of the weld length.



NOTE The cold lap shown is not surface connected.

Figure 18—Incomplete Fusion Due to Cold Lap

9.3.6 Internal Concavity (IC)

IC, as defined in 3.1.28 and shown schematically in Figure 19, of any length shall be acceptable, provided the density of the radiographic image of the IC does not exceed that of the thinnest adjacent parent material. For any areas that exceed the density of the thinnest adjacent parent material, the IC shall be considered a defect.

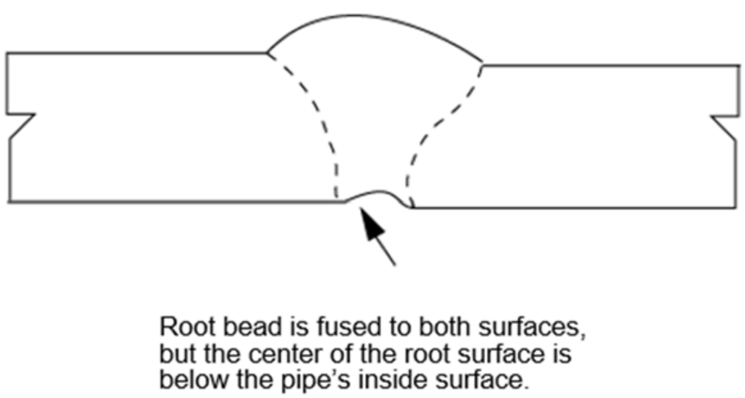


Figure 19—Internal Concavity

9.3.7 Burn-through (BT)

BT, as defined in 3.1.5, shall be considered a defect when a portion of the area is thinner than the thinnest adjacent parent material.

9.3.8 Slag Inclusions

9.3.8.1 General

Slag inclusion is defined in 3.1.54. Elongated slag inclusions (ESIs)—for example, continuous or broken slag lines or wagon tracks—are found at the fusion zones. Isolated slag inclusions (ISIs) are irregularly shaped and may be located anywhere in the weld.

For evaluation purposes, when the size of a radiographic indication of slag is measured, the indication's maximum dimension shall be considered its length.

9.3.8.2 Pipe Diameter—2.375 in. (60.3 mm) or Greater

For pipe with a specified OD greater than or equal to 2.375 in. (60.3 mm), slag inclusions shall be considered a defect should any of the following conditions exist:

a) the length of an ESI indication exceeds 2 in. (50 mm);

b) parallel ESI indications separated by approximately the width of the root bead (wagon tracks) shall be considered a single indication unless the width of either of them exceeds $^{1}/_{32}$ in. (0.8 mm). In that event, they shall be considered separate indications;

c) the aggregate length of ESI indications in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

d) the width of an ESI indication exceeds $^{1}/_{16}$ in. (1.6 mm);

e) the aggregate length of ISI indications in any continuous 12-in. (300-mm) length of weld exceeds $^{1}/_{2}$ in. (13 mm);

f) the width of an ISI indication exceeds $^{1}/_{8}$ in. (3 mm);

g) more than four ISI indications with the maximum width of $^{1}/_{8}$ in. (3 mm) are present in any continuous 12-in. (300 mm) length of weld;

h) the aggregate length of ESI and ISI indications exceeds 8 % of the weld length.

9.3.8.3 Pipe Diameter—Less than 2.375 in. (60.3 mm)

For pipe with a specified OD less than 2.375 in. (60.3 mm), slag inclusions shall be considered a defect should any of the following conditions exist:

a) the length of an ESI indication exceeds three times the thinner of the specified wall thicknesses joined;

b) parallel ESI indications separated by approximately the width of the root bead (wagon tracks) shall be considered a single indication unless the width of either of them exceeds $^{1}/_{32}$ in. (0.8 mm). In that event, they shall be considered separate indications;

c) the width of an ESI indication exceeds $^{1}/_{16}$ in. (1.6 mm);

d) the aggregate length of ISI indications exceeds two times the thinner of the specified wall thicknesses joined and the width exceeds one-half the thinner of the specified wall thicknesses joined;

e) the aggregate length of ESI and ISI indications exceeds 8 % of the weld length.

9.3.9 Porosity

9.3.9.1 General

Porosity, as defined in 3.1.35, is generally spherical but may be elongated or irregular in shape, such as wormhole porosity, and when the size of the indication produced by a pore is measured, the maximum dimension of the indication shall apply to the criteria given in 9.3.9.2 or 9.3.9.3.

9.3.9.2 Individual or Scattered Porosity

Individual or scattered porosity shall be considered a defect should any of the following conditions exist:

a) the size of an individual pore exceeds $^{1}/_{8}$ in. (3 mm) in diameter or 25 % of the specified wall thickness, whichever is less;

b) the size of an individual pore exceeds 25 % of the thinner of the two specified wall thicknesses joined, but no more than $^{1}/_{8}$ in. (3 mm) in diameter;

c) the distribution of scattered porosity exceeds the concentration permitted by Figure 20 or Figure 21.

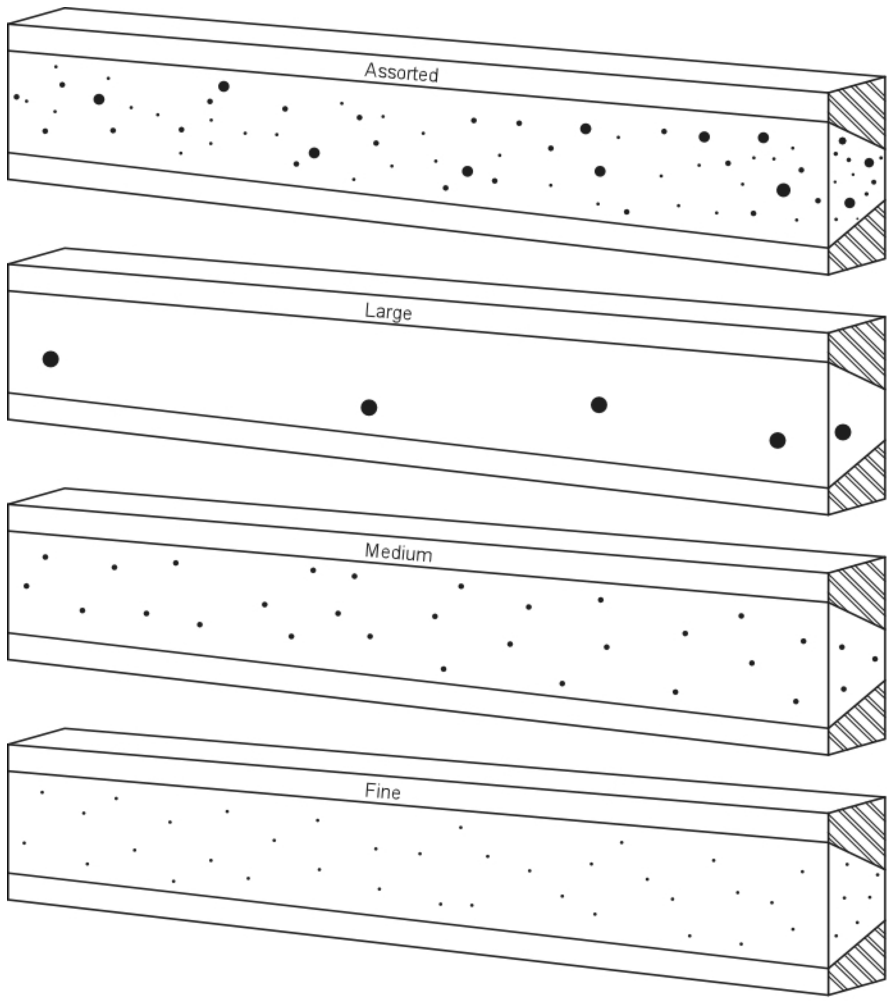


Figure 20—Maximum Distribution of Gas Pockets: Wall Thickness (*t*) less than or equal to 0.500 in. (12.7 mm)

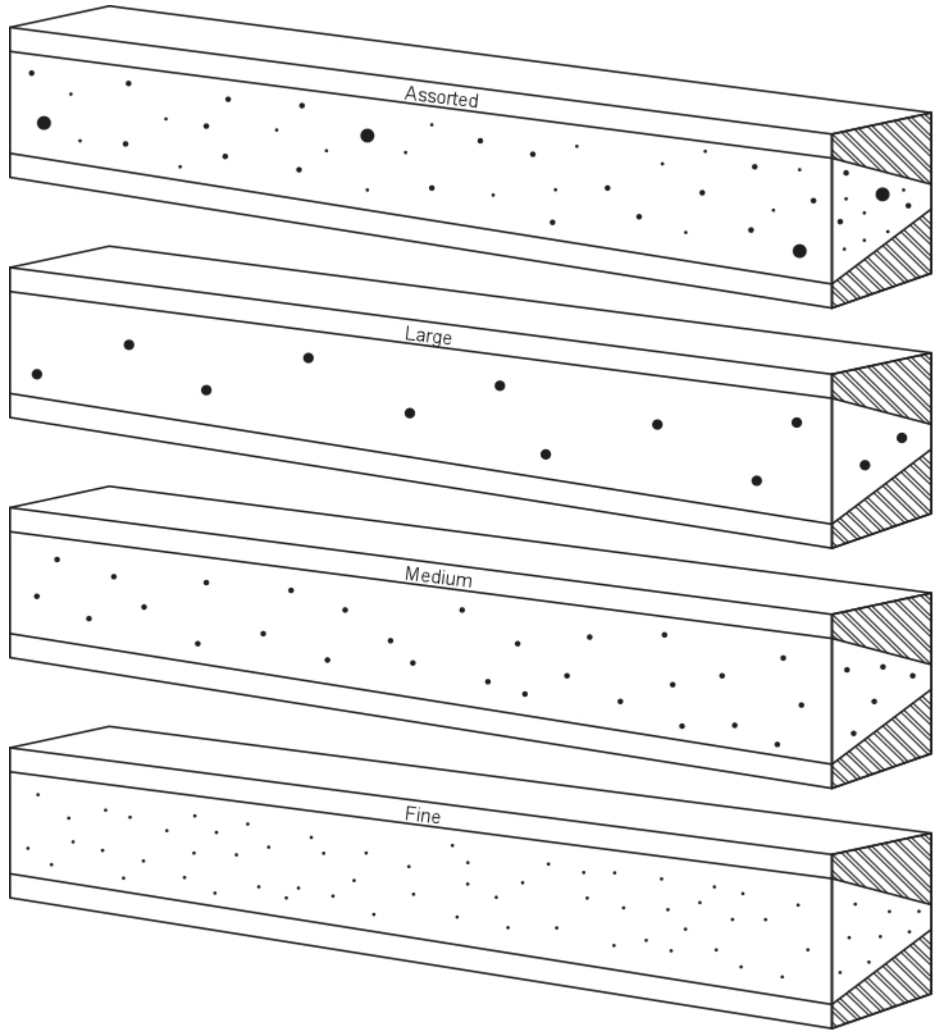


Figure 21—Maximum Distribution of Gas Pockets: Wall Thickness (*t*) Greater Than 0.500 in. (12.7 mm)

9.3.9.3 Hollow Bead (HB) Porosity

HB, as defined in 3.1.18, shall be considered a defect should any of the following conditions exist:

a) the length of an individual indication of HB exceeds 1 in. (25 mm);

b) the aggregate length of indications of HB in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

c) the aggregate length of all indications of HB exceeds 8 % of the weld length.

9.3.10 Cracks

Cracks shall be considered a defect should any of the following conditions exists:

a) the crack, of any size or location in the weld, is not a crater crack or star crack;

b) the crack is a crater crack or star crack with a length that exceeds $^{5}/_{32}$ in. (4 mm).

NOTE Crater cracks or star cracks are located at the stopping point of weld beads and are the result of weld metal contractions during solidification.

9.3.11 Undercutting

Undercutting, as defined in 3.1.59, adjacent to the cover pass (EU) or undercutting adjacent to the root bead (IU) shall be considered a defect when either of the following conditions exists:

a) the aggregate length of indications of EU and IU, in any combination, in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

b) the aggregate length of indications of EU and IU, in any combination, exceeds one-sixth of the weld length.

NOTE See 9.7 for acceptance standards for undercutting when visual and mechanical measurements are employed.

9.3.12 Accumulation of Imperfections

Excluding inadequate penetration due to high-low and undercutting, any accumulation of imperfections shall be considered a defect should any of the following conditions exist:

a) the aggregate length of indications in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

b) the aggregate length of indications exceeds 8 % of the weld length.

9.3.13 Base Material Imperfections

Imperfections in the base material and/or seam welds detected by radiographic testing shall be reported to the company. The disposition of these imperfections shall be as directed by the company.

9.4 Magnetic Particle Testing

9.4.1 Classification of Indications

Indications produced by magnetic particle testing are not necessarily imperfections. Magnetic and metallurgical variations may produce indications that are like those produced by imperfections but that are not relevant to acceptability.

The following criteria shall apply when indications are evaluated.

a) Any indication with a maximum dimension of $^{1}/_{16}$ in. (1.6 mm) or less shall be classified as nonrelevant. Any larger indication believed to be nonrelevant shall be regarded as relevant until reexamined by magnetic particle or another NDT method to determine whether or not an actual imperfection exists. The surface may be ground or otherwise conditioned before reexamination. After an indication is determined to be nonrelevant, other nonrelevant indications of the same type need not be reexamined.

b) Relevant indications are those caused by imperfections.

9.4.2 Acceptance Standards

Linear indications are defined in 3.1.30. Rounded indications are defined in 3.1.51. Transverse indications are defined in 3.1.58.

Relevant indications shall be considered defects should any of the following conditions exist:

a) indications evaluated as crater cracks or star cracks exceed $^{5}/_{32}$ in. (4 mm) in length;

b) indications evaluated as cracks other than crater cracks or star cracks;

c) linear indications evaluated as IF and exceed 1 in. (25 mm) in total length in a continuous 12-in. (300-mm) length of weld or 8 % of the weld length.

Rounded indications shall be evaluated according to the criteria of 9.3.9.2 and 9.3.9.3, as applicable. For evaluation purposes, the maximum dimension of a rounded indication shall be considered its size.

NOTE When doubt exists about the type of imperfection being disclosed by an indication, verification may be obtained by using other NDT methods.

9.4.3 Base Material Imperfections

Imperfections in base material and/or seam welds detected by magnetic particle testing shall be reported to the company. The disposition of these imperfections shall be as directed by the company.

9.5 Liquid Penetrant Testing

9.5.1 Classification of Indications

Indications produced by liquid penetrant testing are not necessarily imperfections. Machining marks, scratches, and surface conditions may produce indications that are similar to those produced by imperfections but that are not relevant to acceptability. The following criteria shall apply when indications are evaluated.

a) Any indication with a maximum dimension of $^{1}/_{16}$ in. (2 mm) or less shall be classified as nonrelevant. Any larger indication believed to be nonrelevant shall be regarded as relevant until reexamined by liquid penetrant or another NDT method to determine whether or not an actual imperfection exists. The surface may be ground or otherwise conditioned before reexamination. After an indication is determined to be nonrelevant, other nonrelevant indications of the same type need not be reexamined.

b) Relevant indications are those caused by imperfections.

9.5.2 Acceptance Standards

Linear indications are defined in 3.1.30. Rounded indications are defined in 3.1.51. Transverse indications are defined in 3.1.58.

Relevant indications shall be considered defects should any of the following conditions exist:

a) indications evaluated as crater cracks or star cracks exceed $^{5}/_{32}$ in. (4 mm) in length;

b) indications evaluated as cracks other than crater cracks or star cracks;

c) linear indications evaluated as IF and exceed 1 in. (25 mm) in total length in a continuous 12-in. (300-mm) length of weld or 8 % of the weld length.

Rounded indications shall be evaluated according to the criteria of 9.3.9.2 and 9.3.9.3, as applicable. For evaluation purposes, the maximum dimension of a rounded indication shall be considered its size.

NOTE When doubt exists about the type of imperfection being disclosed by an indication, verification may be obtained by using other NDT methods.

9.5.3 Base Material Imperfections

Imperfections in the base material and/or seam welds detected by liquid penetrant testing shall be reported to the company. The disposition of these imperfections shall be as directed by the company.

9.6 Ultrasonic Testing

9.6.1 Classification of Indications

9.6.1.1 General

Indications produced by ultrasonic testing are not necessarily imperfections. Changes in the weld geometry due to alignment offset of abutting pipe ends, changes in weld reinforcement profile of ID root and OD capping passes, internal chamfering, and ultrasonic wave mode conversion due to such conditions may cause geometric indications that are similar to those caused by weld imperfections but that are not relevant to acceptability.

9.6.1.2 Linear Indications

Typical linear indications may be caused by, but are not limited to, the following types of imperfections: IP, IPD, ICP, IF, IFD, ESI, cracks, EU, IU, and HB.

9.6.1.3 Transverse Indications

Typical transverse indications may be caused by, but are not limited, to the following types of imperfections: cracks, ISIs, and IFD at start/stops in the weld passes.

9.6.1.4 Volumetric Indications

Volumetric indications may be caused by single or multiple inclusions, voids, or pores. Partially filled voids, pores, or small inclusions at start/stops in weld passes may cause larger indications in the transverse direction than in the weld length direction. Typical volumetric indications may be caused by, but are not limited to, the following types of imperfections: IC, BT, ISIs, porosity, and CP.

9.6.1.5 Relevant Indications

Relevant indications are those caused by imperfections. Relevant indications shall be evaluated as per the requirements defined in the ultrasonic testing procedure.

NOTE When doubt exists about the type of imperfection being disclosed by an indication, verification may be obtained by using other NDT methods.

9.6.2 Acceptance Standards

9.6.2.1 General

Indications shall be considered defects should any of the following conditions exist:

a) indications determined to be cracks;

b) individual indications with a vertical height (through-wall) dimension determined to be greater than one-quarter of the wall thickness;

c) multiple indications at the same circumferential location with a summed vertical height (through-wall) dimension exceeding one-quarter the wall thickness.

9.6.2.2 Linear Surface (LS) Indications

LS indications (other than cracks) interpreted to be open to the ID or OD surface shall be considered defects should any of the following conditions exist:

a) the aggregate length of LS indications in any continuous 12-in. (300-mm) length of weld exceeds 1 in. (25 mm);

b) the aggregate length of LS indications exceeds 8 % of the weld length.

9.6.2.3 Linear Buried (LB) Indications

LB indications (other than cracks) interpreted to be subsurface within the weld and not ID or OD surface connected shall be considered defects should any of the following conditions exist:

a) the aggregate length of LB indications in any continuous 12-in. (300-mm) length of weld exceeds 2 in. (50 mm);

b) the aggregate length of LB indications exceeds 8 % of the weld length.

9.6.2.4 Transverse (T) Indications

T indications (other than cracks) shall be considered volumetric and evaluated using the criteria for volumetric indications. The letter T shall be used to designate all reported transverse indications.

9.6.2.5 Volumetric Cluster (VC) Indications

VC indications shall be considered defects when the maximum dimension of VC indications exceeds ½ in. (13 mm).

9.6.2.6 Volumetric Individual (VI) Indications

VI indications shall be considered defects when the maximum dimension of VI indications exceeds $^1/_8$ in. (3 mm).

9.6.2.7 Volumetric Root (VR) Indications

VR indications interpreted to be open to the ID surface shall be considered defects should any of the following conditions exist:

a) the maximum dimension of VR indications exceeds $^1/_4$ in. (6 mm) or the specified wall thickness, whichever is less;

b) the total length of VR indications exceeds $^1/_2$ in. (13 mm) in any continuous 12-in. (300-mm) length.

9.6.2.8 Accumulation

Any accumulation of relevant indications shall be considered a defect when any of the following conditions exist:

a) the aggregate length of indications above evaluation level exceeds 2 in. (50 mm) in any 12-in. (300-mm) length of weld;

b) the aggregate length of indications above evaluation level exceeds 8 % of the weld length.

9.6.3 Base Material Imperfections

Imperfections in the base material and/or seam weld detected by ultrasonic testing shall be reported to the company. The disposition of these imperfections shall be as directed by the company.

9.7 Visual Acceptance Standards for Undercutting

9.7.1 General

Undercutting is defined in 3.1.59. The acceptance standards in 9.7.2 supplement but do not replace visual inspection requirements found elsewhere in this standard.

9.7.2 Acceptance Standards

When visual and mechanical means are used to determine depth, undercutting adjacent to the cover or root bead shall not exceed the dimensions given in Table 8. When both mechanical and radiographic measurements are available, the mechanical measurements shall govern.

Table 8—Maximum Dimensions of Undercutting

Depth	Length
> $^{1}/_{32}$ in. (0.8 mm) or > 12.5 % of pipe wall thickness, whichever is smaller	Not acceptable
> $^{1}/_{64}$ in. (0.4 mm) but ≤ $^{1}/_{32}$ in. (0.8 mm) or > 6 % but ≤ 12.5 % of pipe wall thickness, whichever is smaller	2 in. (50 mm) in a continuous 12-in. (300-mm) weld length or one-sixth the weld length, whichever is smaller
≤ $^{1}/_{64}$ in. (0.4 mm) or ≤ 6 % of pipe wall thickness, whichever is smaller	Acceptable, regardless of length

9.8 Visual Acceptance Standards for Internal Concavity

9.8.1 General

Internal concavity (IC) is defined in 3.1.28. The acceptance standards in 9.8.2 supplement but do not replace visual inspection requirements found elsewhere in this standard.

9.8.2 Acceptance Standards

When IC is detected by visual examination, any length of IC shall be considered a defect should the depth of the concavity be greater than the cap height at the same location relative to the length of the weld.

10 Repair and Removal of Weld Defects

10.1 General

Weld defects identified during visual inspection, nondestructive testing, or during the company's review of nondestructive testing results shall be repaired.

The full length of the defect being repaired in a single repair area shall be removed and repaired as part of the repair weld process; intentional partial repair of a defect is prohibited. However, if part of the original defect remains after repair and the repair weld meets the acceptance criteria of Section 9, the repair weld shall be considered acceptable. New indications introduced by the repair weld shall be acceptable if the acceptance criteria is satisfied. Defects rejected by Annex A shall be repaired along the full length of the identified defect.

10.2 Repair Requirements

10.2.1 Company Authorization Requirements

Company authorization shall not be required for any repairs that do not involve the application of heat or weld metal, such as grinding, filing, etc.

Company authorization shall be required for the following:

a) crack repair;

b) back weld repair;

c) double repair; and

d) repair of a weld in pipe with a specified OD less than 2.375 in. (60.3 mm).

Unless mandated by the company, authorization is not required for any other type of repair.

10.2.2 Repair Procedure Application Requirements

A qualified repair procedure shall be required whenever a repair is made by welding when:

a) using a welding procedure different from that used to make the original weld;

b) repairs are made in a previously repaired area (double repair);

c) a crack(s) is repaired;

d) a back weld repair when a back weld was not part of the original welding procedure; or

e) required by the company.

A repair procedure qualified for a double repair shall be acceptable to use for a single repair. A repair procedure that is qualified for a repair of a weld with a crack shall be acceptable to use to repair other defect types.

10.2.3 Crack Repairs

A weld containing a crack defect(s) shall either be repaired or cut out. Crater or star crack defect(s) found and contained completely in internal or external weld reinforcement may be repaired by grinding (i.e., abrasive methods) without a qualified repair procedure. If grinding to remove a crater or star crack defect(s) exceeds the internal or external reinforcement, the reinforcement shall be replaced using a qualified welding procedure. A cut-out is required when either of the following conditions exist.

a) A weld with a crack defect, as defined by 9.3.10, shall be cut out when the length of a single crack or the aggregate length of more than one crack is greater than 8 % of the weld length. The length of a crack is the longest dimension regardless of orientation.

b) A double repair of a crack is not permitted. Additional cracking in the weld area after repair shall require a cut-out.

10.2.4 Multiple Repairs in a Repair Area

Only two repairs to the same repair area (i.e., double repair) shall be allowed unless authorized by the company and repaired with a qualified repair procedure appropriate for the number of thermal cycles subjected to the weld and base metal.

NOTE A grinding repair is not considered to be one of the thermal cycles.

10.2.5 Repairs by Grinding

Repairs made only by grinding shall only be used to remove defects provided that:

a) pipe surface contour and minimum design wall/weld thickness requirements are not violated; and

b) defect removal is restricted to the reinforcement height of root bead and cover passes when the minimum design wall/weld thickness value is not known.

NOTE Grinding repair lengths and the number of grinding repair areas are not limited. Grinding repairs do not require use of a qualified repair procedure.

10.2.6 Repair Area Length

10.2.6.1 Maximum Deposited Repair Area Length

The maximum deposited repair area length shall be measured at the base metal surface.

The length of any individual repair area or total length of all accumulated repair areas within a completed weld shall not exceed a percentage of weld length specified by the company.

10.2.6.2 Minimum Deposited Repair Area Length

The minimum deposited repair area length shall be measured at the deepest part of the repair area.

All repair areas shall have a length of at least 2 in. (50 mm) or as otherwise specified by the company.

10.3 Repair Procedure

10.3.1 General

When a repair procedure is required, the procedure shall be established and qualified to demonstrate that a repair weld with suitable mechanical properties and soundness can be produced. The repair weld shall meet the minimum requirements of the production weld or as otherwise specified by the company.

10.3.2 Types of Repair Procedures

Types of repair procedures include but are not limited to the following:

a) full-thickness repair;

b) internal partial-thickness repair;

c) external partial-thickness repair;

d) cover pass repair;

e) back weld repair.

10.3.3 Specification Information

Repair weld procedures shall be revised to show any changes and shall include the following.

a) welding processes and other specification information contained in 5.3.2, to include with the following addition:

When one repair type is used to qualify another (e.g., full-thickness to qualify partial or cover pass repair in accordance with Table 10), initial welding process(es) or filler metal classification(s) may be eliminated when the welding procedure is used to apply another repair type. When this is applicable, the welding procedure shall specify the welding process and filler metal classifications to be used for each repair type;

b) when the application of the repair procedure requires company approval;

c) repair type;

d) location; identify excavation location at weld centerline and/or fusion line;

e) method of defect removal (i.e., grinding, arc-gouging, filing, etc.);

f) method of inspection by which the repair groove shall be examined;

g) requirements for preheat and interpass temperature (minimum/maximum), method of application, and location or area;

h) requirement, if any, for interpass NDT;

i) methods (i.e., storage, handling, usage) to control filler metals, fluxes, and shielding gases when hydrogen control is required;

j) maximum and minimum repair area length;

k) minimum time delay, if any, before final inspection;

l) revision identifier.

10.3.4 Essential Variables

A repair procedure shall be reestablished as a new repair procedure and shall be requalified when any of the essential variables listed in Table 1 or those shown in Table 9 are changed. Essential variables as listed in Table 9 supersede those listed in Table 1 when any conflict exists. Essential variables in Table 1 and Table 9 shall apply to the repair weld only, not the original production weld.

The variables and qualification ranges specified in Table 9 are classified as two categories. Category I essential variables shall apply for all repair welding procedures. Category II essential variables shall apply when the system design requires hardness and/or toughness limits.

Table 9—Essential Variables for Qualification of Repair Welding Procedure Specifications

Welding Variable Subsection[a]	Change Requiring Requalification	Category I (Standard WPSs)	Category II (Hardness and/or Toughness)
10.3.4.1 Welding Process or Filler Metal [b]	A change from the repair welding process or method of application (e.g., manual or semiautomatic) established in the welding procedure specification constitutes an essential variable. If a specific welding process or consumable for a pass or pass grouping is not used as allowed by 10.3.3 a), this process or consumable shall not be used in the repair weld.	X	X
10.3.4.2 Type of Repair [c, d]	Any change from a repair type listed in 10.3.2 to another, except as provided in Table 10.	X	X
10.3.4.3 Repair with Multiple or Single Beads	A change from multiple bead repair to single weld bead repair.		X
10.3.4.4 Location of Excavation	a) A change from centerline to fusion line location for excavation of partial-thickness repairs.		X
	b) A change from centerline to fusion line location for cover pass repairs.		X
10.3.4.5 Bevel Angle	A change in bevel geometry by more than ± 25 % from that qualified.	X	X

NOTE Welding into or over self-shielded flux-cored arc welding (FCAW-S) weld metal with a process other than FCAW-S may result in reduced weld metal toughness or other issues. Some FCAW-S consumables are only meant for single pass welding (e.g., AWS usability designator 3, 10, 13, 14, GS).

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

[b] For example, a full-thickness repair welding procedure qualified using E6010 for the root and second (hot) pass, and E7018 for the remaining passes, may be used to make a partial-thickness repair only using E7018 filler metal.

[c] Repair types qualified on a butt joint qualify branch and fillet weld joint designs in addition to a butt joint design.

[d] See Table 10 for 10.3.4.2.

Table 10—Repair Type Qualification Matrix

Repair Type Performed During Qualification	Repair Type Qualified				
	Full-Thickness	External Partial-thickness	Internal Partial-thickness	Cover Pass	Back Weld
Full-thickness	X	X	X	X	X[a]
External partial-thickness		X	X[a]	X	X[a]
Internal partial-thickness		X[a]	X	X[a]	X
Back weld				X[a]	X
Cover pass				X	X[a]

NOTE Repair types are independent of joint type (i.e., butt weld repair qualifications can be applied to fillet and branch joint designs); all tests shall be carried out on butt welds.

[a] For Category II per Table 9, this option is not permitted.

10.3.5 Welding of Test Joints

Repair procedures shall be qualified on a test weld completed following the details of a production welding procedure specification. A full circumferential butt weld shall be used to qualify a repair procedure. Multiple repair procedures may be qualified on a single production weld in location(s) specified by the company provided each repair weld is a minimum of 8 in. (203 mm) in length, measured at the bottom of the repair groove. Length shall be sufficient for all test specimens.

NOTE A single full-circumference test weld joint may be used to qualify more than one type of repair procedure (i.e., more than one repair weld can be made in a single butt weld to qualify multiple repair procedures provided all required test specimens are taken from each repair type).

Details for each repair procedure shall be recorded with the complete results in the procedure qualification record.

At a minimum, the data and information documenting the observed values of essential variables for the repair weld used during qualification testing shall be recorded. A form similar to that shown in Figure 1 should be used. The record shall be maintained as long as the procedure is in use.

10.3.6 Testing of Repair Welds

10.3.6.1 General

Repair procedures shall be qualified by visual and destructive testing. For repair procedure qualification, sample preparation and destructive and visual testing shall not commence until the repair weld has been allowed to cool to ambient temperature. Accelerated cooling may not be used to reduce the time for the weld to cool to ambient temperature unless deliberate cooling is a requirement of the WPS.

The minimum total number of specimens and the types of destructive tests to which each repair procedure shall be submitted are shown in Table 11. At the discretion of the company, additional types and number of tests may be required. The repair welder and repair welding procedure may be qualified simultaneously, provided two nick breaks are added in the locations as specified by Table 14.

When the production weld that is to be repaired has toughness requirements, the repair procedure shall demonstrate the ability to meet those same requirements. This may be demonstrated through Charpy impact testing or other testing as specified by the company. This requirement applies to partial-thickness and full-thickness repair procedures only.

When the production weld that is to be repaired has hardness requirements, the repair procedure should demonstrate the ability to meet those same requirements.

NOTE 1 Dependent on pipe material and/or welding process, the company may require additional cooling time or a delay prior to destructive and visual testing.

NOTE 2 Thermal cycles can affect base material properties, particularly yield and tensile strength in the HAZ, which may differ between materials that were manufactured differently and/or have different chemical compositions.

Table 11—Type and Number of Butt Weld Test Specimens per Repair Type for Repair Procedure Qualification

Repair Type	Tensile Strength	Root Bend	Face Bend	Side Bend	Total (Minimum)
Nominal Wall Thickness ≤ 0.500 in. (12.7 mm)					
Full-thickness	1	1	1	0	3
Internal partial-thickness	1	0	1 [a]	0	2
External partial-thickness	1	0	1	0	2
Cover pass	0	0	1	0	1
Back weld	0	0	1 [a]	0	1
Nominal Wall Thickness > 0.500 in. (12.7 mm)					
Full-thickness	1	0	0	2	3
Internal partial-thickness	1	0	0	1	2
External partial-thickness	1	0	0	1	2
Cover pass	0	0	0	1	1
Back weld	0	0	0	1	1

NOTE 1 Hardness testing is required when performed for the original weld procedure.

NOTE 2 Charpy impact testing is required when performed for the original weld procedure.

[a] The weld face is located on the inside (concave side) of the pipe.

10.3.6.2 Tensile and Bend Tests

The test specimen preparation, test method, and acceptance requirements in 5.6 for tensile and bend tests shall be used for repair welds, except that test specimens shall be cut from the joint at each of the repair area locations.

The test specimens may be taken from the repair weld in any order; a specific sequence is not specified.

10.3.6.3 Charpy Impact Tests

10.3.6.3.1 General

When required by 10.3.6.1, Charpy impact testing shall be performed at locations in the weld as specified by the company.

10.3.6.3.2 Preparation

When Charpy impact testing is required by Table 11, both the weld metal and the HAZ shall be tested. Each test (of weld metal or HAZ) shall consist of at least three valid specimens. The exact size of the specimens depends on the weld thickness, but the largest possible size shall be selected. The thickness of subsized specimens should have at least 80 % of the wall thickness of the test coupon. The specimens shall be machined and notched in accordance with ASTM E23. The notch shall be oriented in the through-thickness direction as shown in Figure A.2 in Annex A or as specified by the company.

10.3.6.3.3 Testing

All specimens for each notch location (weld metal or HAZ) shall be tested at or below the minimum design temperature in accordance with the requirements of ASTM E23 or as otherwise directed by the company.

NOTE When a minimum fracture surface shear area percentage is specified, test temperatures lower than the design temperature may be necessary when the Charpy specimen size is significantly smaller than the pipe wall thickness.

10.3.6.3.4 Requirements

The minimum average value of a set and minimum individual value of impact energy for each set of three specimens shall not be less than the minimum values specified for qualification of the production weld or as otherwise specified by the company. Retesting is permitted when no more than one specimen fails and when approved by the company. When retesting is performed a new set of three test specimens shall be extracted from a location as close as possible to the location of the specimens that generated the low result. The absorbed energy of all three retest specimens shall meet or exceed the average absorbed energy requirement of the original specimens.

10.3.6.4 Hardness Tests

10.3.6.4.1 General

This section shall only apply when hardness testing is required by 10.3.6.1.

10.3.6.4.2 Preparation

Transverse sections shall be cut suitable for visual examination of the repair weld and adjacent base metal, and for a hardness survey. The specimen for the hardness test should have a thickness of at least ½ in. (13 mm). The specimen may be machine cut, or cut oversized using a thermal process and machined by a nonthermal process to remove at least ¼ in. (6 mm) from the side(s) that will be prepared. At least one face should be ground and polished to at least a 600 grit finish and etched with a suitable etchant such as Nital, ammonium persulfate, or dilute hydrochloric acid to give a clear definition of the weld structure.

10.3.6.4.3 Visual Examination

The macrosection shall be visually examined with lighting that will sufficiently reveal details of the weld soundness.

For the repair welding procedure to be considered acceptable, a visual examination of the macrosection shall show that the repair weld portion of the completed weld is completely fused to the adjacent base metal and/or weld metal at the root and between weld passes, and is free of cracks. Any other defects associated with the repair weld shall be within the applicable individual size limits specified in Section 9. A cross-section showing defects that are not associated with the repair weld portion of the completed weld shall not disqualify the test.

10.3.6.4.4 Testing

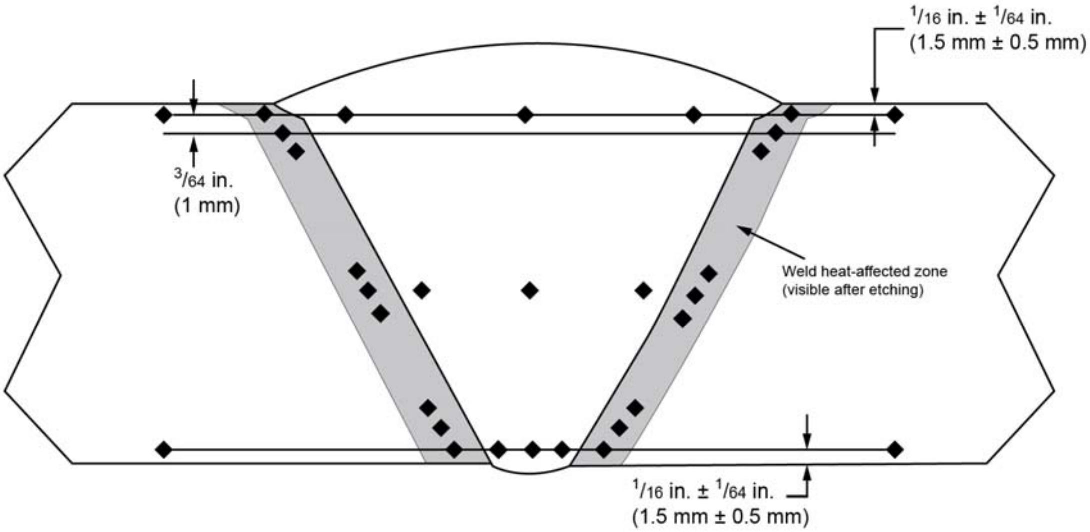
The macrosection test specimen shall be prepared for hardness testing in accordance with ASTM E384 or as otherwise directed by the company. The required number of indentations shall be made using a Vickers indenter using a 10-kg load or less. Locations shall be as shown in Figures 22 through 27, or at locations otherwise specified by the company. HAZ hardness impressions shall be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ).

If subsequent repairs (e.g., double repair) are qualified, the company may use the hardness test location provided here or specify other locations.

The wall thickness of the test coupon may restrict the total number of indents that are specified in the figures below. The number of indents should be reduced as needed to maintain indent spacing.

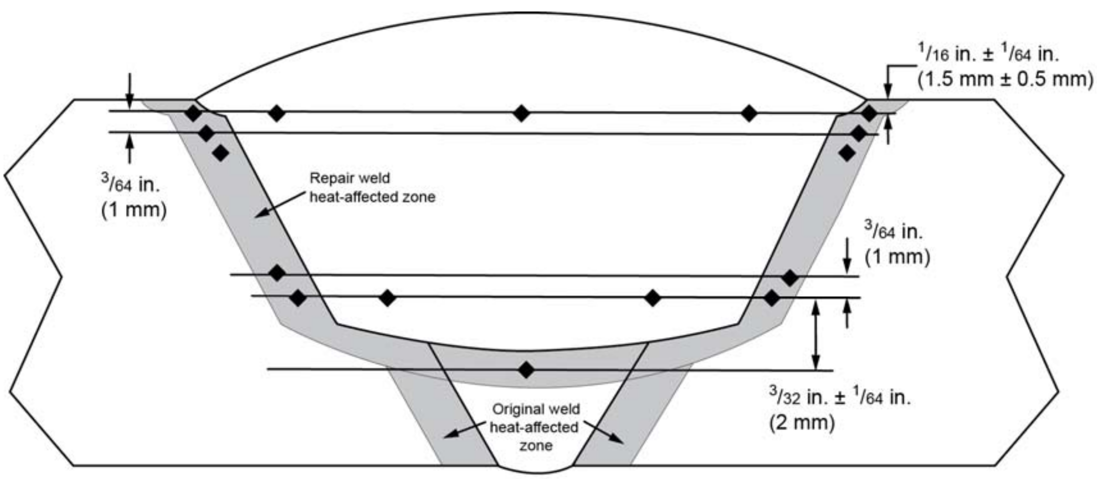
Maximum hardness values for repair welds should not exceed those given in Table 12 unless otherwise specified by the company.

Chemical composition should be used to determine the carbon equivalent of the base materials, to provide context for hardness measurements. Multiple thermal cycles from repair welding may widen the heat-affected zone and/or have adverse effects on the hardness and strength of the heat-affected zone.



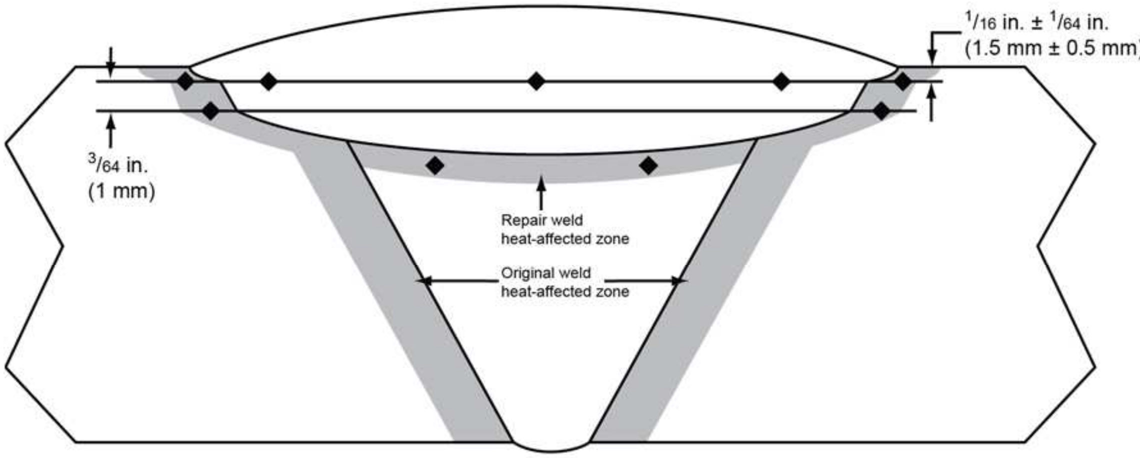
NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ). The wall thickness of the specimen may prevent all the indents as shown from being made, particularly along the mid-point of the specimen.

Figure 22—Hardness Locations for Full-thickness Repair Procedure Qualification



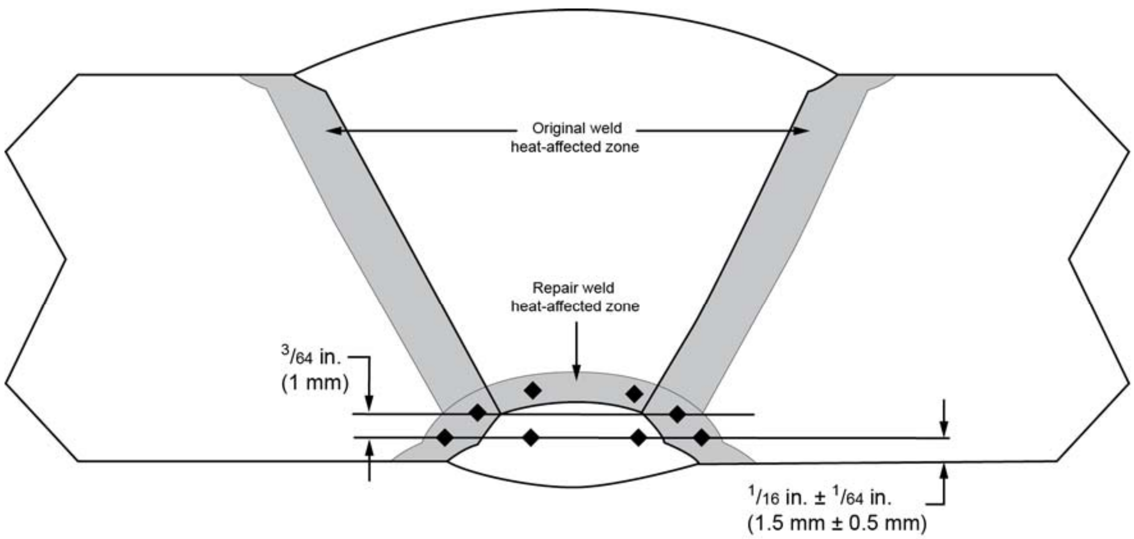
NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ). The wall thickness of the specimen may prevent all the indents as shown from being made.

Figure 23—Hardness Locations for External Partial-thickness Repair Procedure Qualification at Weld



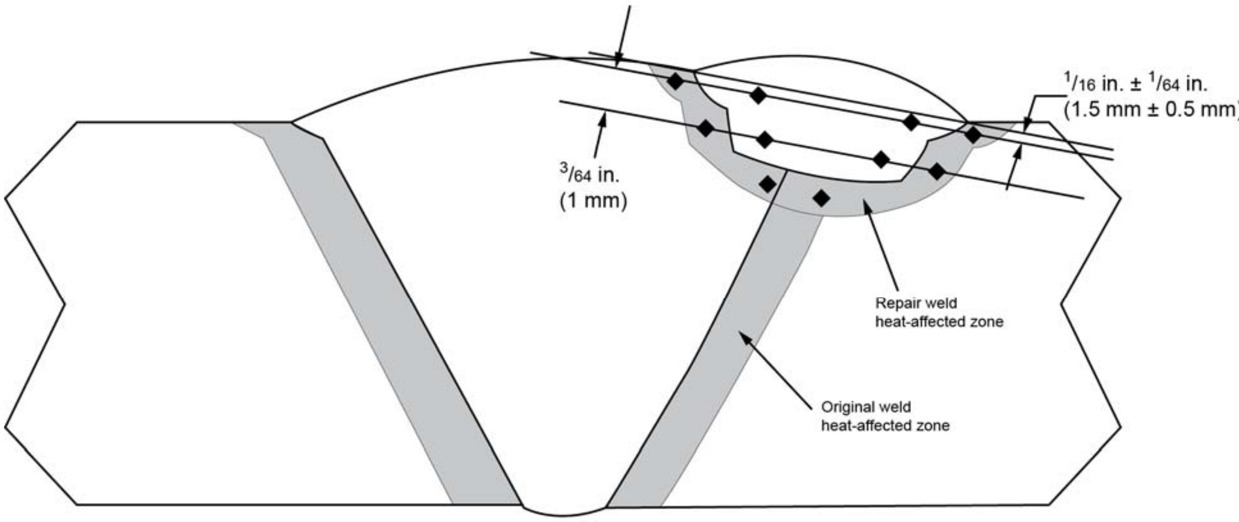
NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ).

Figure 24—Hardness Locations for Cover Pass Repair Procedure at Weld Centerline



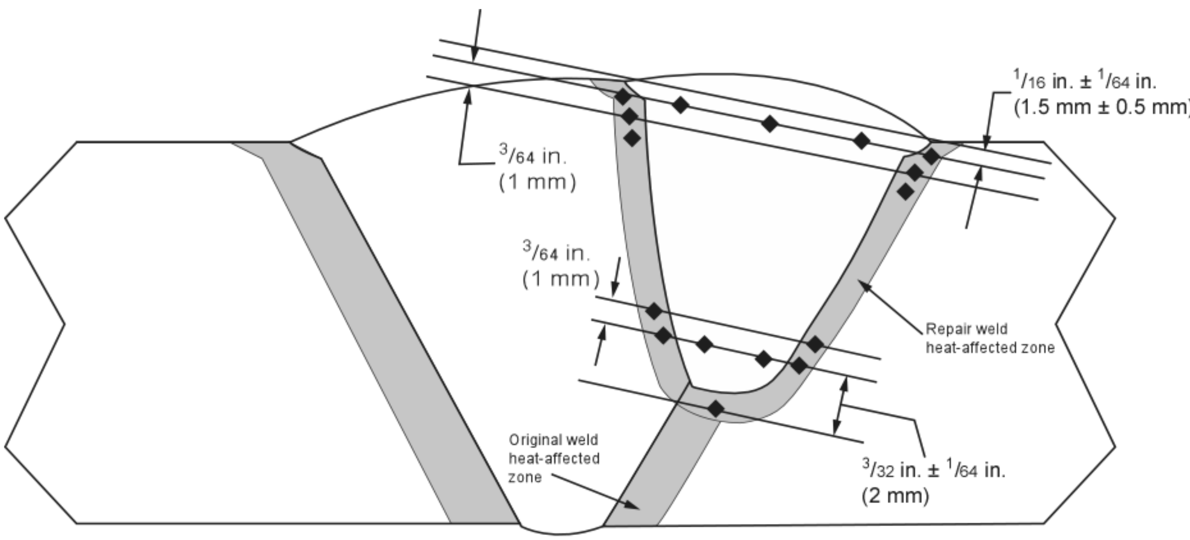
NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ).

Figure 25—Hardness Location for Back Weld Repair or Internal Partial-Thickness Repair Procedure at Weld Centerline



NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ).

Figure 26—Hardness Locations for Cover Pass Repair Procedure at Fusion Line



NOTE Heat-affected zone (HAZ) hardness impressions must be entirely within the HAZ and located as close as possible to the fusion boundary (between the weld metal and HAZ).

Figure 27—Hardness Locations for External Partial-Thickness Repair at Fusion Line

Table 12—Repair Weld Maximum Hardness Values, Non-Sour Service, HV10 [a]

Hardness Location	Weld Metal		Heat-affected Zone	
	Root and Mid-thickness	Cap	Root and Mid-thickness	Cap
Low-hydrogen welding process	275	275	350	350
Any welding process	275 [b]	275	275	325

NOTE 1 The company may specify other maximum hardness values.

NOTE 2 For sour service, see applicable governing standard or specification document.

[a] A lower load may be used for the narrow heat-affected zones in some welds made by mechanized or automatic processes.

[b] 300 HV10 when base metal thickness is 0.375 in. (9.5 mm) and above.

10.4 Repair Welder Qualification

10.4.1 General

When a repair procedure is required by 10.2, a qualified repair welder shall be required. A qualified repair welder shall be also required when making a full-thickness repair using the original production welding procedure. The repair welder and repair welding procedure may be qualified simultaneously, provided a tensile specimen is added (when required) per Table 11. The purpose of the repair welder qualification test is to determine the ability of welders to make sound repair welds. A single welder shall deposit the entire repair thickness for the qualification test weld; qualification may not be split between two or more welders. The welder shall be qualified per the requirements of this section.

The welder shall qualify by depositing a repair weld, following all details of a repair procedure, into a fully completed circumferential butt weld. The welder performing the qualification test shall not be required to weld the original weld joint that will be used during qualification. The repair welder shall prepare their own repair groove, in addition to completing the repair weld, in the position to be qualified (see 10.4.3.3). A single full-circumference test joint may be used to qualify more than one welder or a welder for more than one type of repair. The test joint can be repositioned to deposit the repair weld in the position designated by the company. The repair weld shall be deposited in the fixed position for each repair type to be qualified in the location(s) specified by the company, unless the repair weld will be rolled. The repair weld length shall be adequate for the number of specimens required by Table 14 and should be 8 in. (203 mm) minimum.

Details of the repair welder qualification shall be recorded and maintained in accordance with 6.8. In addition to the requirements of 6.8, the record shall include, at a minimum, documentation of the observed values (or actual) of welder essential variables as specified in 10.4.3. An example record of welder essential variables and other welding variables is shown in Table 13. A form should be developed to suit the needs of the individual company, and should be sufficiently detailed to demonstrate that the qualification test met the requirements of this standard. A welder may be required to requalify if a question arises regarding the welder’s competence.

Table 13—Repair Welder Qualification Scope

Essential Variables Required to be Recorded for Welder Qualification	Actual Values used During Qualification	Qualification or Qualification Range Achieved
Welding process(es)		
Filler metal group(s)		
Repair type		
Thickness of weld metal deposited per filler group number		
Position of repair groove		
Direction of welding		

10.4.2 Testing of Repair Welders

For a repair welder qualification test weld, the repair weld shall meet the visual examination requirements of 6.4.

The total number of specimens and the test to which each shall be submitted are shown in Table 14. The destructive testing requirements shall follow 6.5.2 and 6.5.3 for nick break and bend tests, respectively, except that test specimens shall be cut from the joint at each individual repair area location for each type of repair. Excluding nick break specimens, the test specimens can be taken from the repair weld in any order; a specific sequence is not specified. A failed bend test specimen may be replaced in accordance with 6.5.3.

At the company's option, the qualification repair weld may be examined by radiography, or the ultrasonic testing method as used to inspect a production weld, using a qualified NDT procedure in lieu of destructive tests. Radiography shall meet the requirements of 9.3; ultrasonic testing shall meet the requirements of 9.6. Only the repair weld area shall be inspected.

A welder who fails to pass the repair welder qualification test(s) shall be permitted to retest as described in 6.7.

Table 14—Type and Number of Butt Weld Test Specimens per Repair Type for Repair Welder Qualification

Repair Type	Nick Break [a]	Root Bend	Face Bend	Side Bend	Total (Minimum)
Nominal Wall Thickness ≤ 0.500 in. (12.7 mm)					
Full-thickness	2	1	1	0	4
Internal partial-thickness	2	0	1 [b]	0	3
External partial-thickness	2	0	1	0	3
Cover pass	2	0	1	0	3
Back weld	2	0	1 [b]	0	3
Nominal Wall Thickness > 0.500 in. (12.7 mm)					
Full-thickness	2	0	0	2	4
Internal partial-thickness	2	0	0	1	3
External partial-thickness	2	0	0	1	3
Cover pass	2	0	0	1	3
Back weld	2	0	0	1	3

[a] One nick break specimen is taken at the transition between the repair weld end and original weld bead and the second nick break specimen located at the midpoint of the repair weld deposit.

[b] The weld face is located on the inside (concave side) of the pipe.

10.4.3 Qualification Limits

A repair welder who has successfully completed the qualification test described in 10.4.1 and 10.4.2 shall be qualified within the limits of the essential variables described in Table 15. Pipe diameter shall not be an essential variable for a repair welder. If any of the following essential variables are changed, the repair welder using a repair procedure shall be requalified.

Table 15—Essential Variables for Repair Welders

Welding Variable Subsection[a]	Change Requiring Requalification
10.4.3.1 Welding Process	a) A change from one repair welding process to another repair welding process. b) A change in the combination of repair welding processes, unless the welder has qualified on separate qualification tests, using each of the repair welding processes that are to be used for the combination of repair welding processes. c) When more than one process is used to complete the joint, a change of the welding process used for the pass types (i.e., root, fill, cap). However, the welder may make repair welds using only the process or processes used for fill and cap passes even if the test weld used a combination of processes, provided 10.4.3.5 is met. d) When the process used for fill passes in testing is used to make a complete repair 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 repair weld.
10.4.3.2 Deposit Thickness	a) The welder is qualified to weld a maximum deposited thickness of two times the deposited repair weld thickness in the repair welder qualification test. b) For the GMAW short circuiting mode (GMAW-S), the welder shall only use GMAW-S during repair welding for the same passes that they deposited GMAW-S in qualification testing.
10.4.3.3 Position [b]	a) Qualification on the top of the pipe (flat) only qualifies for that position. b) Qualification on the side of the pipe (vertical) qualifies to weld on the side and top of the pipe. c) Qualification in the horizontal position (pipe oriented in 2G) qualifies to weld horizontally and on the top of the pipe. d) Qualification in the 5G in the overhead position qualifies for all positions except for horizontal welding (pipe oriented in 2G). e) A qualification scheme using c) and d) qualifies the welder for all positions. f) Qualification in the 6G, in the overhead position, qualifies the welder for all positions. g) A change from rolled to fixed position. A welder who qualifies in the fixed position shall also be qualified to perform rolled repair welds within the essential variables qualified.
10.4.3.4 Direction	For fixed position welding, a change in the direction of welding from vertical up to vertical down or vice versa or a change from vertical progression, up or down, to horizontal progression or vice versa. The specified direction of vertical progression, up or down, is not intended to prevent welders from welding across the top dead center or bottom dead center of a pipe oriented in the horizontal position to avoid stacking starts and stops. A repair welder who successfully passes a qualification test in the 6G position, as per 10.4.3.3.f, shall also be qualified for the horizontal direction.
10.4.3.5 Filler Metal	a) For the root bead of a full-thickness repair, a change of filler metal group number. b) For all other weld passes, a change of filler metal classification from Group 1 or 2 to any other group or from any Group 3 through 8 to Group 1 or 2 (see Table 2). c) A change of filler metal classification not listed in Table 2 to any other filler metal classification or vice versa.
10.4.3.6 Repair Type [c,d,e]	a) A change from external partial-thickness to full-thickness, internal partial-thickness, or back weld. b) A change from internal partial-thickness to full-thickness. c) A change from back weld to any other repair type. d) A change from cover pass to any other repair type.

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

[b] Definitions for welding positions can be found in AWS A3.0.

[c] A full-thickness repair qualification qualifies all other repair types.

[d] Repair types are independent of joint type (i.e., butt weld repair qualifications can be applied to fillet and branch joint designs); all tests shall be carried out on butt welds.

[e] See Table 16 for 10.4.3.6.

Table 16—Repair Welder Qualification Matrix

Repair Type Performed During Qualification	Repair Type Qualified				
	Full-Thickness	External Partial-Thickness	Internal Partial-Thickness	Cover Pass	Back Weld
Full-thickness	X	X	X	X	X
External partial-thickness		X		X	
Internal partial-thickness		X	X	X	X
Back weld					X
Cover pass				X	

NOTE Repair types are independent of joint type (i.e., butt weld repair qualifications can be applied to fillet and branch joint designs).

10.5 Inspection of Repair Welding

Repair welding inspection shall be performed as specified by the company. Welding inspection personnel shall meet the requirements of 8.3.

Repairs shall be documented, and the documentation maintained by the company.

10.6 NDT and Weld Repair Acceptance Criteria

When weld metal is added to make the repair, all NDT methods required on the original weld shall also be used to inspect the repair weld. NDT of a repair weld shall include, at a minimum, the total repair area plus 2 in. (50 mm) on each side of the repair area. Repairs shall be considered acceptable when the repair area meets the standards of acceptability of Section 9 or the acceptance criteria specified by Annex A, Option 3.

Visual testing shall be considered adequate when the defect is rejected by visual means and repaired by grinding without the addition of weld metal.

When in-process NDT is required, the company shall define the acceptance criteria.

11 Procedures for Nondestructive Testing (NDT)

11.1 General

11.1.1 Radiographic Testing Methods

The requirements of 11.1 shall be applicable for producing radiographic image(s) on film, phosphor imaging plate (PIP), computed radiography (CR), or with digital radiography (DR) acquisition devices [e.g., DDA, LDA, CCD, FPD, CMOS (both static and in-motion)] through the use of X-rays or gamma rays. A detailed procedure for the production of radiographic image(s) shall be established and documented. Radiographic image(s) produced by the use of this procedure shall meet the requirements of the applicable subsection as it pertains to sensitivity, resolution, radiographic image quality, intensity, or density as applicable. The following criteria shall be used to evaluate radiographic image(s):

a) an acceptable radiographic image quality that is free from artifacts, fog, or other types of processing irregularities that could mask the image of actual imperfections;

b) IQIs—The type of material, ASTM or ISO identification, and the following type of IQI used shall appear clearly in the radiographic image:

1) wire type: the essential wire across the area of interest; or

2) hole type: the essential hole and IQI outline on at least three sides;

c) a satisfactory identification system;

d) an acceptable technique and setup;

e) compatibility with acceptance standards.

All requirements that refer to the quality of the resulting radiographic image(s) shall apply equally when using X-rays and gamma rays. The use of radiographic testing and the frequency of its use shall be at the option of the company. The company and the radiographic contractor should agree on the radiographic procedure or procedures to be used prior to the performance of production radiography. The company shall require the contractor to demonstrate and use procedures that produce acceptable radiographic image(s).

11.1.2 Details of Procedure

11.1.2.1 General

The details of each radiographic procedure shall be recorded and may include a sketch. A copy of the record shall be furnished to the company for its records.

At a minimum, each procedure shall include the details listed in 11.1.2.2, 11.1.2.3, or 11.1.2.4 as applicable.

11.1.2.2 Film Radiography

At a minimum, the procedure for film radiography shall include the following details:

a) Radiation source: the type of radiation source, the size of the effective source or focal spot, and the voltage rating of the X-ray equipment;

b) Intensifying screens: the type and placement of the screens and, if lead is used, their thickness;

c) Film: the film brand or type, or both, and the number of film in the holder or cassette. For multiple-film techniques, the way in which the film is to be viewed shall be specified;

d) Exposure geometry: whether single-wall exposure for single-wall viewing (SWE/SWV), double-wall exposure for single-wall viewing (DWE/SWV), or double-wall exposure for double-wall viewing (DWE/DWV); the distance from the source or focal spot to the film; the relative positions of the film, weld, source, IQIs, and interval or reference markers; and the number of exposures required for radiography of a complete weld;

e) Exposure conditions: whether milliampere or curie minutes, the X-ray voltage or the input voltage and amperage, and the exposure time;

f) Processing: whether automated or manual; the time and temperature range for development and the time for stop bath or rinsing, fixing, and washing; and drying details;

g) Materials: the type and thickness range of material for which the procedure is suitable;

h) IQIs: the type of material, ASTM or ISO identification, and the following type of IQI used shall appear clearly in the radiographic image:

1) wire type: the essential wire across the area of interest;

2) hole type: the essential hole and IQI outline on at least three sides.

11.1.2.3 Computed Radiography (CR)

At a minimum, the procedure for radiography using computed radiography (CR) imaging shall include the following details:

a) Radiation source: the type of radiation source, the size of the effective source or focal spot, and the voltage rating of the X-ray equipment;

b) Intensifying screens: The type and placement of the screens and, if lead is used, their thickness;

c) Phosphor imaging plate (PIP): the PIP brand and type;

d) Exposure geometry: whether single-wall exposure for single-wall viewing (SWE/SWV), double-wall exposure for single-wall viewing (DWE/SWV), or double-wall exposure for double-wall viewing (DWE/DWV); the distance from the source or focal spot to the PIP; the relative positions of the PIP, weld, source, IQIs, and interval or reference markers; and the number of exposures required for radiography of a complete weld;

e) Image acquisition system manufacturer and model;

f) Materials: the type and thickness range of material for which the procedure is suitable;

g) IQIs: the type of material, ASTM or ISO identification, and the following type of IQI used shall appear clearly in the radiographic image:

    1) wire type: the essential wire across the area of interest;

    2) hole type: the essential hole and IQI outline on at least three sides of the IQI are visible in the radiographic image;

h) Software: The version and revision number used for acquisition.

11.1.2.4 Digital Radiography (DR)

At a minimum, the procedure for radiography using digital radiography (DR) imaging shall include the following details.

a) Radiation source: the type of radiation source, the size of the effective source or focal spot, and the voltage rating of the X-ray equipment;

b) Radiation filters/masking: the type and placement of the filters/masking and their thickness;

c) Detector: the detector type, manufacturer, and model;

d) Exposure geometry: whether single-wall exposure for single-wall viewing (SWE/SWV), double-wall exposure for single-wall viewing (DWE/SWV), or double-wall exposure for double-wall viewing (DWE/DWV); the distance from the source or focal spot to the detector; the relative positions of the detector, weld, source, IQIs, and interval or reference markers; and the number of exposures required for radiography of a complete weld;

e) Image acquisition system manufacturer and model;

f) Materials: the type and thickness range of material for which the procedure is suitable;

g) IQIs: the type of material, ASTM or ISO identification, and the following type of IQI used shall appear clearly in the radiographic image:

1) wire type: the essential wire across the area of interest;

2) hole type: the essential hole and the IQI outline on at least three sides of the IQI are visible in the radiographic image;

h) Software: the version and revision number used for acquisition;

i) Image display and viewing requirements;

j) The detector and source alignment validation;

k) Exposure conditions: X-ray voltage or the input voltage and amperage range, the exposure time and number of integrations, frame averaging or frame rate as applicable.

11.1.2.4.1 Digital Radiography (DR) Calibration

Calibration of digital detectors shall be addressed by the procedure and shall be required for the following:

a) at the commencement of the qualification of each examination procedure;

b) a change in material type and thickness;

c) a change in quantity and/or energy of radiation (voltage, isotope);

d) a change in equipment used;

e) a temperature variance in accordance with the manufacturer's guidelines;

f) a change in technique parameters;

g) failure to achieve the image quality requirements.

11.1.2.4.2 In-Motion Digital Radiography (RTR)

When in-motion digital radiography is performed involving movement of the source and/or detector, the following shall apply:

a) The beam width shall be controlled by using a metal diaphragm, such as lead. The diaphragm for the energy selected shall have a half-value layer (HVL) thickness of at least 10.

The beam width, as demonstrated in Figure 28, shall be determined per Equation (4):

$$w = \frac{c\left(F + a\right)}{b} + a \tag{4}$$

where

a = slit width in diaphragm in the direction of motion;

b = distance from source to the material/weld side of the diaphragm;

c = distance from material/weld side of the diaphragm to the source side of the material/weld surface;

F = source size: the maximum projected dimension of the radiating source (or focal spot) in the plane perpendicular to the distance $b + c$ from the material/weld being radiographed;

w = beam width at the source side of the material/weld measured in the direction of motion.

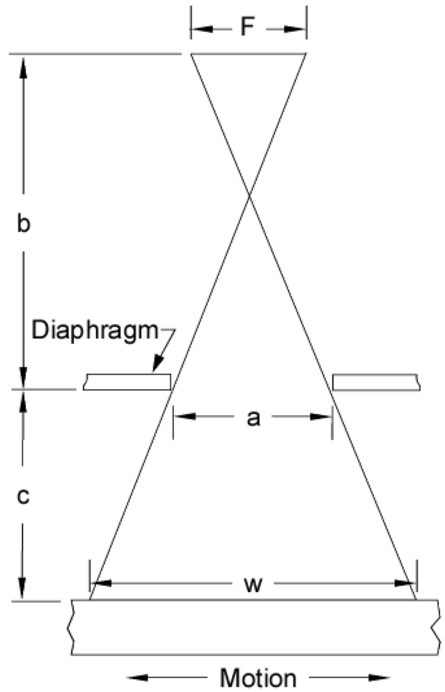


Figure 28—Calculation for Determining Beam Width

b) Alternatively, the detector's active area shall be limited so that the radiographic image produced meets the image quality requirements.

11.1.2.4.3 In-Motion Digital Radiography (RTR) Unsharpness

In-motion unsharpness or blur of the radiographic image shall be addressed by the procedure. The procedure shall clearly define the means of control and means of measuring total image unsharpness.

The procedure shall clearly identify the means for determining source-side geometric unsharpness and shall ensure that the source-side geometric unsharpness of the weld does not exceed 0.02 in. (0.5 mm) for material with a thickness of less than or equal to 2.00 in. (50.8 mm).

11.1.3 Exposure Geometry

11.1.3.1 Film and Computed Radiography (CR)

When a radiographic source is centered in the pipe for exposing a butt weld, one exposure shall be adequate for the radiographic inspection of the complete weld (SWE/SWV). When the radiographic source is outside but not more than ½ in. (13 mm) from the weld surface, at least three exposures separated by 120° shall be made for the radiographic inspection of a complete weld (DWE/SWV). When the radiographic source is outside and more than ½ in. (13 mm) from the weld surface, at least four exposures separated by 90° shall be made for the radiographic inspection of a complete weld (DWE/SWV).

When the outside diameter of the piping containing the weld is 3.500 in. (88.9 mm) or less is to be inspected with DWE/SWV, a minimum of four exposures separated by 90° shall be required to minimize the distortion of the radiographic image(s).

Alternatively, when the outside diameter of the piping containing the weld is 3.500 in. (88.9 mm) or less, a DWE/DWV procedure may be used.

When a DWE/DWV procedure is used and the radiation beam is offset so that the source-side and film or PIP-side portions of the weld do not overlap in the areas of the radiograph being evaluated, at least two exposures separated by 90° shall be made for the radiographic inspection of a complete weld. When the source-side and film or PIP-side portions of the weld are superimposed, at least three exposures separated by 60° shall be made for the radiographic inspection of a complete weld.

The minimum distance between the source or focal spot and the source side of the object being radiographed shall be determined by Equation (5) (using constant units of measurement):

$$D = \frac{St}{k} \tag{5}$$

where

D is the minimum distance, in in. (mm), between the source or focal spot and the source side of the object being radiographed;

S is the size, in in. (mm), of the effective source or focal spot;

t is the thickness of the weld, in in. (mm), including reinforcement, plus the distance between the film or PIP side of the weld and the film or PIP;

k is the geometric unsharpness factor.

When t is determined for SWE/SWV and DWE/SWV procedures, the thickness of the single wall and its weld reinforcement shall be used. When t is determined for DWE/DWV procedures, the outside diameter of the weld (that is, the outside diameter of the pipe plus twice the average height of the weld crown) shall be used. k is defined as 0.02 in. (0.5 mm) for material with a thickness of less than or equal to 2.000 in. (50.8 mm).

11.1.3.2 Digital Radiography (DR)

For static (fixed position) detector and source set-ups, the requirements of 11.1.3.1 shall apply. For in-motion imaging, the exposure geometry shall be evaluated at the maximum scanning speed to be used during the radiographic testing of the complete weld. Acquired scan lengths shall be verified to ensure full coverage of the butt weld has been obtained.

11.1.4 Type of Image Quality Indicator (IQI)

The image quality indicator (IQI) shall conform to the requirements of ASTM E747, ISO 19232-1 wire type, or ASTM E1025 hole-type IQI. The company shall define which type of IQI (ASTM or ISO) is to be used. The IQI shall be made of a material that is radiographically similar to the material being welded.

11.1.5 Selection of Image Quality Indicator (IQI)

The IQI shall consist of either a series of six wires for ASTM E747 wire type or a series of seven wires for ISO 19232-1 wire type IQI. Table 17 for ASTM E 747 wire type IQI, Table 18 for ISO 19232-1 wire type IQI, and Table 19 for ASTM E1025 hole-type IQI outline the required IQI identification, essential wire, or essential hole required based on material thickness of the thinner joining material plus applicable reinforcement.

For purposes of IQI selection, the thickness of the weld shall mean the thinner of the nominal wall thicknesses being joined plus the weld reinforcement (internal plus external combined). The IQI type of material, ASTM or ISO identification, and the following shall appear clearly in the radiographic image:

1) Wire type: the essential wire across the area of interest;

2) Hole type: the essential hole and the outline of at least three sides of the IQI are visible in the radiographic image.

Table 17—ASTM E747 Wire Type IQI Selection

Weld Thickness		Essential Wire Diameter		ASTM Set Letter
in.	mm	in.	mm	
0 to 0.250	0 to 6.4	0.008	0.20	A
> 0.250 to 0.375	> 6.4 to 9.5	0.010	0.25	A or B
> 0.375 to 0.500	> 9.5 to 12.7	0.013	0.33	B
> 0.500 to 0.750	> 12.7 to 19.1	0.016	0.41	B
> 0.750 to 1.000	> 19.1 to 25.4	0.020	0.51	B
> 1.000 to 2.000	> 25.4 to 50.8	0.025	0.64	B

Table 18—ISO Wire Type IQI Selection

Weld Thickness		Essential Wire Diameter		Wire Identity
in.	mm	in.	mm	
0 to 0.250	0 to 6.4	0.008	0.20	13
> 0.250 to 0.375	> 6.4 to 9.5	0.010	0.25	12
> 0.375 to 0.500	> 9.5 to 12.7	0.013	0.33	11
> 0.500 to 0.750	> 12.7 to 19.1	0.016	0.41	10
> 0.750 to 1.000	> 19.1 to 25.4	0.020	0.51	9
> 1.000 to 2.000	> 25.4 to 50.8	0.025	0.64	8

Table 19—ASTM E1025 Hole Type IQI Selection

Weld Thickness		Maximum IQI Thickness		Image Quality Indicator	
in.	mm	in.	mm	Identifying Number	Essential Hole
0 to 0.250	0 to 6.4	0.0125	0.317	12	2T
> 0.250 to 0.375	> 6.4 to 9.5	0.015	0.381	15	2T
> 0.375 to 0.500	> 9.5 to 12.7	0.0175	0.444	17	2T
> 0.500 to 0.750	> 12.7 to 19.1	0.020	0.508	20	2T
> 0.750 to 1.000	> 19.1 to 25.4	0.025	0.635	25	2T
> 1.000 to 2.000	> 25.4 to 50.8	0.030	0.762	30	2T

11.1.6 Placement of Image Quality Indicators (IQI)

The IQIs shall be placed as follows:

a) When a complete weld is radiographed in a single exposure using a source inside the piping (SWE/SWV), a minimum of four IQIs shall be used. Wire type shall be placed across the weld or hole type shall be placed adjacent to the weld on the film, PIP, or detector side. The IQIs shall be spaced approximately equally around the circumference of the pipe.

b) For the DWE/DWV procedure, one IQI shall be placed on the source side of the pipe and across the weld for wire type, or adjacent to the weld for hole type.

c) For the DWE/SWV or SWE/SWV procedures requiring multiple exposures for complete inspection of the weld, and where the length of film, PIP, or detector image to be interpreted is greater than 5 in. (130 mm), two IQIs placed across the weld for wire type or adjacent to the weld for hole type, and located on the film, PIP, or detector side, shall be used. One IQI shall be within 1 in. (25 mm) of the end of the film, PIP, or detector image length to be interpreted and the other IQI shall be at the center of the film, PIP, detector image for wire type or adjacent to the weld for hole type. When the film, PIP, or detector image length to be interpreted is 5 in. (130 mm) or less, one IQI shall be placed on the film, PIP, or detector side, across the weld for wire type or adjacent to the weld for hole type, and located at the center of the image length to be interpreted.

d) When multiple film or PIP cassettes are used in a single exposure, the requirements of 11.1.6 shall apply for each individual film or PIP length.

e) When a repaired weld is radiographed, it shall conform to the requirements of 11.1.6 for IQI placement.

When it is not practical to place an IQI on the weld due to weld configuration or size, the IQI may be placed on a separate block.

Separate blocks shall be made of the same or radiographically similar material, and may be used to facilitate IQI positioning. The thickness of the separate block material should be the same as the thickness of the weld and shall not be closer than the source side of the weld being inspected.

Alternatively, for DR/RTR:

— The IQI may be placed above the surface of the pipe or held in position between the surface of the pipe and the imager by a fixture attached to the imager or scanning device. Acceptability of such IQI placement shall be demonstrated during procedure qualification.

— When in-motion digital radiography (RTR) is used with an exposure of DWE/SWV and performed in one continuous exposure, at least four IQIs shall be equally spaced on the detector side of the weld.

11.1.7 Shims

For hole-type IQIs, shims of material that is radiographically similar to that of the pipe and equivalent in thickness to the average weld reinforcement shall be placed under the IQI. The shim dimensions shall exceed the IQI dimensions such that the outline of at least three sides of the IQI are visible in the radiographic image.

11.1.8 Film Densitometer Calibration

Densitometer calibrations shall be performed annually and documented with a calibrated step wedge that meets the manufacturer's requirements.

11.1.9 Production Radiography

Only Level II or III radiographers shall interpret the radiographic image(s) of production welds. Radiographers shall report to the company all defects observed in the radiographic image(s) unless the company requires that all imperfections observed be reported. The radiographer shall indicate whether the weld meets the requirements of Section 9. The company shall determine the final disposition of the weld.

11.1.10 Identification of Radiographic Image(s)

Image(s) shall be clearly identified by the use of lead numbers, lead letters, markers, or other identification so that the weld and any imperfections in it can be quickly and accurately located.

NOTE The company may specify the identification procedure to be used.

Whenever more than one image is used to inspect a weld, identification markers shall appear on each image, and adjacent image(s) shall overlap. The last reference marker on each end of the image shall appear on the appropriate adjacent image(s) in a way that establishes that no part of the weld has been omitted.

At a minimum, the weld identification and location markers shall appear as part of the radiographic image captured during exposure. All other documentation can be attached to the image as a text box, overlay, or flashed image.

Any edits or corrections needed to the identification(s) of a radiographic image shall have prior documented approval from the company before edits or corrections are to be made.

11.1.11 Storage of Film and Other Imaging Media

11.1.11.1 Film

All unexposed films shall be stored in a clean, dry place where the conditions will not detrimentally affect the emulsion. If any question arises about the condition of the unexposed film, sheets from the front and back of each package or a length of film equal to the circumference of each original roll shall be processed in the normal manner without exposure to light or radiation. If the processed film shows fog, the entire box or roll from which the test film was removed shall be discarded, unless additional tests prove that the remaining film in the box or roll is free from pre-exposure fog exceeding 0.30 H&D transmitted density.

NOTE H&D refers to the Hurter-Driffield method of defining quantitative blackening of the film [8].

11.1.11.2 Other Imaging Media

Imaging media other than film shall be stored in strict accordance with the manufacturer's recommendations.

11.1.12 Film Requirements

11.1.12.1 General

Except for small localized areas caused by irregular weld configurations, the transmitted H&D density in the area of interest shall not be less than 1.8 nor greater than 4.0. Transmitted H&D densities through small localized areas may exceed these limits; however, minimum densities shall not be less than 1.5 and maximum densities shall not exceed 4.2.

11.1.12.2 Film Viewing Equipment

The viewing equipment (illuminator) shall be of the variable high-intensity type and shall be capable of viewing film densities within the range specified in 11.1.12.1. It shall be equipped to prevent light coming from around the outer edge of the radiograph or through low-density portions of the radiograph from interfering with interpretations.

11.1.12.3 Film Viewing Facilities

Viewing facilities shall provide subdued background lighting of an intensity that will not cause troublesome reflections, shadows, or glare on the radiograph.

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[8] Ferdinand Hurter and Vero Charles Driffield, "Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates," J. Soc. Chem. Ind., May 31, 1890.

11.1.12.4 Film Processing

When requested by the company, film shall be processed, handled, and stored so that the radiographic image(s) are interpretable for at least three years after they are produced. The image processing area and all accessories shall be kept clean at all times.

11.1.12.5 Film Artifacts

The film shall be free of artifacts within the area of interest that could mask the image of actual imperfections.

11.1.12.6 Radiographic Film Review Form

The radiographer shall prepare a radiograph review form. At a minimum, the information shall be provided from 11.1.2.2 in addition to the requirements herein:

a) company, customer, or manufacturer;

b) contract or purchase order number that ties to the project;

c) project or line number;

d) a listing of material(s) or weld(s);

e) evaluation and disposition of the material(s) or weld(s) examined;

f) number of exposures for each weld;

g) name, certification ,and signature of the radiographer/interpreter;

h) date of examination;

i) procedure number and revision of that procedure;

j) acceptance criteria used for acceptance of 11.1.12.6.e.

11.1.13 Computed Radiography (CR) Requirements

11.1.13.1 General

In addition to the applicable requirements of 11.1.1 and 11.1.2, the requirements of this subsection shall apply when using phosphor imaging plates (PIP) is requested.

11.1.13.2 Image Intensity

Except for small localized areas caused by irregular weld configurations, the image intensity within the area of interest of an image shall not be less than 45 % of the system's bit depth capability (e.g., a 16-bit system has 65,536 shades of gray; therefore, no intensity shall be less than an intensity of 29,491.). The digital image shall not exceed the system's upper intensity limit (e.g., image saturation).

The image intensity throughout the area of interest shall be no less than 5 % brighter than the intensity adjacent to the essential wire or essential hole.

Alternatively, gray scales below 45 % of the system's bit depth can be utilized, provided a procedure demonstration is performed and documented for every diameter, thickness, and grade of material being inspected.

11.1.13.3 Image Processing

When requested by the company, radiographic image(s) shall be processed, handled, and stored so that the radiographic image(s) are interpretable for at least three years after they are produced. The image processing area and all accessories shall be kept clean at all times.

11.1.13.4 Dimensional Measurement

Calibration of the systems software measuring function shall be performed prior to interpretation. A verified scanned pixel size of the image is the preferred method.

Alternatively:

a) a known dimensional comparator shall be placed in direct contact with the cassette prior to exposure; or

b) a known dimensional comparator shall be inscribed on the imaging plate prior to processing; or

c) a known comparator scale shall be placed on the imaging plate prior to processing.

11.1.13.5 Image Artifacts

The radiographic image shall be free of artifacts within the area of interest that could mask the image of actual imperfections.

11.1.13.6 Image Evaluation

Prior to interpretation, the range of contrast and brightness values that demonstrate the required IQI sensitivity shall be determined. Final radiographic interpretation shall be performed on the data within this IQI sensitivity range.

The digital image may be viewed and evaluated in a negative or positive image format; however, the area of interest and IQI shall be of the same format.

Magnification may be used in the evaluation of the digital image and shall be agreed upon between the company and radiographic contractor.

11.1.13.7 Radiographic Review Form

The radiographer shall prepare a radiographic review form. At a minimum, the information shall be provided from 11.1.2.3 above in addition to the requirements herein:

a) company, customer, or manufacturer;

b) contract or purchase order number that ties to the project;

c) project or line number;

d) a listing of material(s) or weld(s);

e) evaluation and disposition of the material(s) or weld(s) examined;

f) number of exposures for each weld;

g) name, certification, and signature of the radiographer/interpreter;

h) date of examination;

i) procedure number and revision of that procedure;

j) acceptance criteria used for acceptance of item e).

11.1.14 Digital Radiography Requirements (DR/RTR)

11.1.14.1 General

In addition to the applicable requirements of 11.1.1 and 11.1.2, the requirements of this subsection shall apply when using digital radiography acquisition devices is requested

11.1.14.2 Image Intensity

Except for small localized areas caused by irregular weld configurations, the pixel intensities within the area of interest of an image shall be not less than 15 percent of the system's bit depth capability (e.g., a 16-bit system has 65,536 shades of gray potential; therefore, no intensity shall be less than an intensity of 9,831). The image pixel intensities within the area of interest shall also not exceed the system's upper grayscale limit (i.e., image saturation).

Alternatively, grayscales below 15 percent of the system's bit depth can be utilized, provided a procedure demonstration is performed and documented for every diameter, thickness, and grade of material being inspected.

11.1.14.3 Image Processing

When requested by the company, radiographic image(s) shall be processed, handled, and stored so that the radiographic image(s) are interpretable for at least three years after they are produced.

11.1.14.4 Dimensional Measurement

One of the following dimensional measurement techniques shall be performed to ensure the radiographic image is calibrated prior to interpretation.

a) The measurement scale tool shall be based upon a known dimensional comparator that is placed on or adjacent to the detector side of the weld near the area of interest during exposure.

b) Dimensional measurements shall be confirmed by verifying the measurement between two known reference points at the beginning and end of the radiographic image (0 – 0, 0 – A, etc.).

11.1.14.5 Image Artifacts

The radiographic image shall be free of artifacts within the area of interest that could mask the image of actual imperfections.

11.1.14.6 Image Evaluation

Prior to interpretation, the range of contrast and brightness values that demonstrate the required IQI sensitivity shall be determined. Final radiographic interpretation shall be performed on the data within this IQI sensitivity range.

The digital image may be viewed and evaluated in a negative or positive image format; however, the area of interest and IQI shall be of the same format.

Magnification may be used in the evaluation of the digital image and shall be agreed upon between the company and radiographic contractor.

11.1.14.7 Radiographic Review Form

The radiographer shall prepare a radiograph review form. At a minimum, the information shall be provided from 11.1.2.4 in addition to the requirements herein:

a) company, customer, or manufacturer;

b) contract or purchase order number that ties to the project;

c) project or line number;

d) a listing of material(s) or weld(s);

e) evaluation and disposition of the material(s) or weld(s) examined;

f) number of exposures for each weld;

g) name, certification, and signature of the radiographer/interpreter;

h) date of examination;

i) procedure number and revision of that procedure;

j) acceptance criteria used for acceptance of item e).

11.2 Magnetic Particle Testing Method

When magnetic particle testing is specified by the company, a detailed written procedure for magnetic particle testing shall be established that meets the requirements of ASTM E709. The company and the NDT contractor should agree on the magnetic particle testing procedure or procedures prior to the performance of production testing.

The company shall require the contractor to demonstrate that the proposed procedures will produce acceptable results, and shall require the contractor to use such procedures for production testing.

11.3 Liquid Penetrant Testing Method

When liquid penetrant testing is specified by the company, a detailed written procedure for liquid penetrant testing shall be established that meets the requirements of ASTM E165. The company and the NDT contractor should agree on the liquid penetrant testing procedure or procedures prior to the performance of production testing.

The company shall require the contractor to demonstrate that the proposed procedures will produce acceptable results and shall require the contractor to use such procedures for production testing.

11.4 Ultrasonic Testing Methods

11.4.1 General

When ultrasonic testing (UT) is specified by the company, the requirements of this section shall apply for both 9.6 (workmanship) or Annex A. The use of ultrasonic testing and the scope of its use shall be at the option of the company. The company shall require the ultrasonic system to be qualified and then demonstrated by the ultrasonic contractor. Detailed procedures for the use of the individual ultrasonic techniques (manual and automated) shall be established to cover the entire volume of the weld, including the heat-affected zone.

The qualification shall define the operational boundaries, proposed inspection (sizing) error, detectability, repeatability, reproducibility, and reliability of the UT system. Within the qualification data set, the worst cases of oversizing and undersizing shall be evaluated by the company. The methodology for the determination of the proposed inspection error shall be defined by the contractor and approved by the company.

The company shall require the ultrasonic contractor to demonstrate the UT procedure. The scope of the procedure demonstration (see 11.4.3) required to address project-specific variables shall be approved by the company.

The demonstration shall confirm the qualification results (including proposed inspection error) and that the proposed production procedure(s) produces acceptable and accurate results. In the event that the qualification results are not confirmed, the procedure shall not be approved for use by company. The company and the ultrasonic contractor shall agree and approve the ultrasonic procedures prior to ultrasonic testing of project welds in accordance with the requirements in this section.

Inside diameter and outside diameter pipe surfaces shall be suitable for ultrasonic testing (i.e., parallelism, surface roughness, uncoated, etc.). For new construction projects, the coating cutback (bare pipe length) at pipe ends necessary for ultrasonic scanning shall be specified. Pipe seam weld reinforcement (internal and external) shall be removed so that the surface of the pipe is continuous across the seam for the distance necessary and suitable for ultrasonic testing.

11.4.2 Ultrasonic Testing Personnel Requirements

An NDT Level III in the ultrasonic method shall develop the application technique and prepare and approve the testing procedure. Only NDT Ultrasonic Level II or III certified personnel shall calibrate equipment, perform the test, and interpret the test results per the acceptance/rejection criteria. Personnel used to perform ancillary activities (e.g., pipe scribing, band setting, scanner placement) related to AUT of the weld shall be trained and supervised by personnel certified in accordance with the NDT contractor's ASNT SNT-TC-1A written practice.

The ultrasonic testing personnel shall perform examinations in accordance with qualified and approved procedures (see 11.4.3). Personnel responsible for testing shall be capable of determining the acceptability of circumferential butt welds in accordance with the company approved accept/rejection criteria. The company shall approve project personnel. The company has the right, at any time, to require personnel to demonstrate their capabilities to perform to the requirements of the qualified procedure.

11.4.3 Demonstration and Acceptance of Ultrasonic Procedure

11.4.3.1 Procedure Demonstration Process

The demonstration and application of the ultrasonic procedure(s) and ultrasonic system(s) shall be performed. Project variables, including acoustic properties, diameter, wall thickness, bevel design, welding process, and repair welds, shall be considered prior to defining the scope of the procedure demonstration process. The performance demonstration process shall be documented.

The demonstration process shall be as follows:

a) Weld map(s) (applicable only to seeded defect welds) or as-built documentation depicting intended locations of the items below shall be prepared and submitted to the company prior to demonstration.

b) Weld(s) containing imperfections and defects shall be prepared from actual production pipe material utilizing the welding procedure specification approved by the company for demonstration activity. Weld development, practice, or welder qualification welds may be used if suitable imperfections and defects are present and acceptable to the company. The welds shall include:

   1) imperfections and defects inherent to the welding process;

   2) a distribution of surface (ID and OD) as well as buried imperfections and defects;

   3) multiple imperfections and defects aligned at the same circumferential location.

c) Radiographs in accordance with 11.1 or governing company specification shall be made of the welds and the results documented.

d) The UT procedure(s) shall be applied within the detailed temperature ranges, and the results shall be documented.

e) The AUT system shall demonstrate calibration consistency by positioning the calibration block in the 12 o'clock, 3 o'clock, and 6 o'clock positions.

f) The band placement offset defined in the procedure shall be demonstrated and documented.

g) A comparison of results between NDT methods shall be documented.

h) Differences in detectability and resolution between the ultrasonic and radiographic methods shall be noted.

i) Destructive testing, i.e., macrosectioning, shall be performed to confirm the sizing results. The location and number of destructive tests shall be defined by the company.

NOTE Use of alternative non-destructive testing in lieu of destructive testing of the weld sample may be used if qualified and approved by the company.

11.4.3.2 Procedure Demonstration Report

A procedure demonstration report shall document the results and be submitted to the company for approval prior to ultrasonic testing of project welds. The demonstration report shall include the following:

a) scope of the procedure demonstration process report;

b) WPS used for demonstration activity;

c) weld map(s) (applicable only to seeded defect welds);

d) RT report(s);

e) UT report(s) (manual UT and AUT);

f) destructive testing photomacrograph and report;

g) comparison report including UT (manual UT and AUT), RT, and destructive testing results;

h) technical summary of results;

i) justification of the inspection error;

j) any other requirements defined by the company.

11.4.3.3 Acceptance of Ultrasonic Testing Procedure

Acceptance of the UT procedure(s) for production weld testing shall be based on the capability of the UT operator/method/technique/system to:

a) circumferentially locate;

b) size for length;

c) size for height;

d) determine depth from OD surface; and

e) axially (weld cross-section) locate required imperfections/defects in the test samples.

In addition, the procedure shall accurately determine the acceptability of welds in accordance with the criteria listed in 9.6 and/or Annex A as defined by the company.

11.4.4 Parent Material Ultrasonic Testing

The company shall ensure a minimum length of 4 in. (101.6 mm) at each pipe end shall be free of any full or partial beam reflectors that could influence production weld inspection.

Welds completed without the use of factory ends shall require parent material inspection. All interfering partial and full beam reflectors shall be recorded on the examination report and the company shall be notified. Sensitivity applied for parent material inspection shall be defined in the ultrasonic testing procedure (11.4.6 or 11.4.7, as applicable) and approved by the company.

11.4.5 Production Ultrasonic Testing

Ultrasonic testing personnel shall report to the company all defects unless the company requires that all observed (evaluation level and above) indications and imperfections be reported. The company shall determine the final disposition of the weld.

11.4.6 Manual Ultrasonic Testing (MUT)

11.4.6.1 General

Manual ultrasonic testing (MUT) procedures shall include techniques for all ultrasonic applications for which the company defines ultrasonic inspection (i.e., wall thickness measurement, parent material inspection, production weld inspection, repair weld inspection). The company shall approve all manual ultrasonic testing procedures prior to use for project inspection.

11.4.6.2 Procedure Requirements

At a minimum, the procedure for manual ultrasonic testing shall include the following specific application details:

a) type of material or welds to be tested, joint preparation dimensions, and welding processes;

b) material type (i.e., size, grade, thickness, process of manufacturing per API 5L);

c) scanning surface preparation/condition;

d) stage at which the examination is to be performed;

e) ultrasonic instrument;

f) couplant.

g) testing technique:

— description of technique to be applied, including drawings and weld coverage;

— angle(s) inclusive of horizontal and vertical beam profiles;

— frequencies (MHz);

— temperatures and ranges;

— scanning patterns and speeds;

— reference datum and location markers (i.e., root face and circumferential location).

h) reference standards: detailed sketches showing plan view and cross-section view dimensions of production material reference standard blocks and all reference reflectors.

i) calibration requirements:

— the interval at which calibration of the instrument is required;

— the sequence of startup prior to inspecting welds;

— all calibration standards to be used;

— the reference sensitivity reflectors to be used;

— the reference sensitivity level settings;

— the requirements for verification of calibration settings;

j) scanning level: the sensitivity setting in dB to be added to the reference sensitivity for scanning;

k) evaluation level: the level or height of echoes detected during scanning at which further evaluation is required, and any sensitivity adjustment to be made before evaluating for acceptance or rejection;

l) imperfection sizing methodology;

m) record of results: type of record (e.g., sketch, image, scan, etc.);

n) reporting requirements:

— indications to be reported;

— weld status (accept/reject);

— defect type;

— defect height;

— defect length;

— defect locations (circumferential, radial, axial position);

— weld repair or cutout;

— final disposition of the weld.

o) ultrasonic examination report: an example of the examination report.

11.4.6.3 Manual UT Used with Automated UT

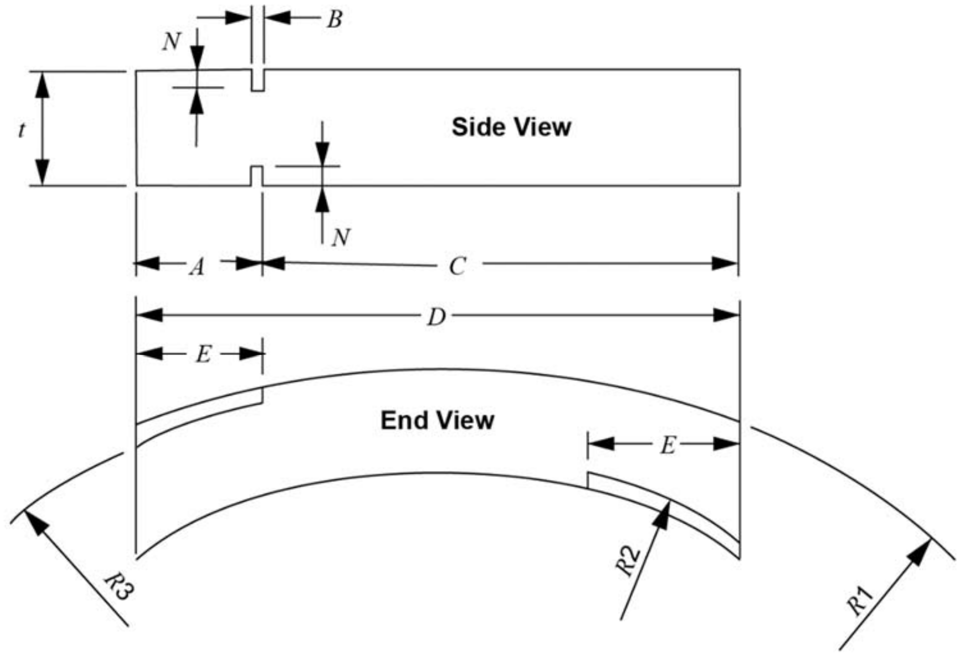
When MUT is applied in conjunction with AUT (i.e., loss of acoustic coupling, imperfection verification, repair weld inspection), the contractor shall ensure that the two techniques are equivalent in detectability. The MUT procedure shall define the process to be used to demonstrate the detectability between the AUT production weld testing technique and the MUT technique.

11.4.6.4 Reference Standards

Specific reference standards shall be designed for the purpose of manual ultrasonic testing. At a minimum, reference standards shall include inside diameter and outside diameter notches and may include side-drilled holes, flat bottom holes, or other reflectors proposed by the ultrasonic contractor and approved by the company. An example of a manual ultrasonic reference standard is included in Figure 29.

The reference standard shall also be used to determine the actual sound beam velocity, refracted angle, and sound path distance in the pipe material to be inspected. Unknown velocity and refracted angle shall be determined when welds in pipe of different chemistry specifications, wall thickness, diameter, or from more than one pipe and rolling or piercing manufacturer are to be inspected. This may be accomplished by using two probes of the same nominal angle and frequency with the probes directed toward one another (see Figure 30 and Figure 31). When a difference exceeding company-defined limits for velocity, angle, or sound path distance are reported, another reference standard shall be made from the different pipe material.

Prior to use, the reference standard shall be verified. The verification shall include mechanical and manual ultrasonic checks defined in a procedure approved by the company. These checks shall be performed and documented to ensure the reference standard’s suitability for use.



Dimensions

t	Specified pipe wall thickness
N	Notch depth = 10 % t ± 10 % of notch depth
A	2 in. (50 mm) minimum
B	0.125 in. (3.2 mm) maximum notch width
C	11.35t + 2 in. (50 mm) minimum length
D	3.1 in. (80 mm) minimum width
E	1 in. (25 mm) minimum notch length
$R1$	Outside radius of pipe
$R2$	Radius of inside notch = $R1 - 0.9t$
$R3$	Radius of outside diameter notch at depth = $R1 - 0.1t$

Figure 29—Example of Reference Standard for Manual Ultrasonic Testing

11.4.6.5 Establishing Distance, Refracted Angle, and Velocity

The procedure shall define the technique the ultrasonic contractor shall use for the determination of distance, refracted angle, and velocity.

Figure 30 defines an example of a technique to determine distance, refracted angle and velocity.

Position the transducer in line with the outside notch at double the distance used to peak up the inside notch (Position B). Verify that the outside notch echo peak is at or near zero depth reading. This will establish that refracted angle and velocity settings are sufficiently accurate.

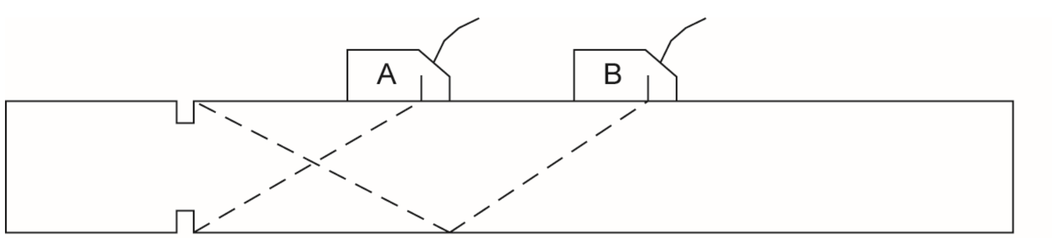


Figure 30—Example: Establishing Distance, Refracted Angle, and Velocity

11.4.6.6 Attenuation and Transfer Procedure

The procedure shall define the technique the ultrasonic contractor shall use for the attenuation and transfer procedure.

Figure 31 defines an example of a technique to determine attenuation and transfer measurements.

Using two transducers of equal angle and frequency, one transmitting and the other receiving, maximize (peak up) the echo received. Measure the surface distance between the transducer exit points. Half the surface distance divided by measured wall thickness equals the refracted angle tangent. Without changing instrument settings, repeat this process on pipe with unknown velocity, refracted angle, and attenuation to determine any differences.

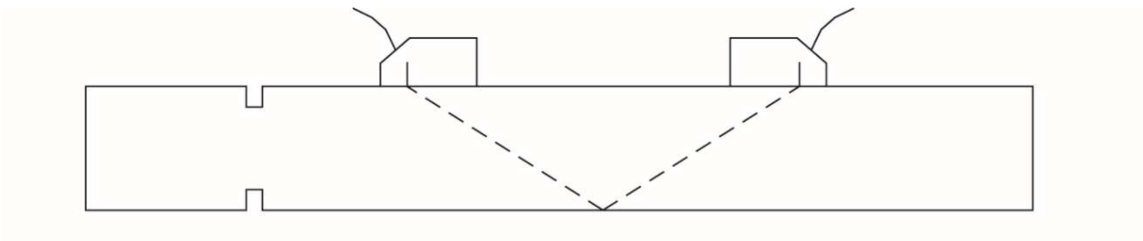


Figure 31—Example: Attenuation and Transfer Procedure

11.4.6.7 Calibration, Scanning, and Evaluation Level

Manual ultrasonic weld testing systems shall be calibrated as defined in the procedure. The minimum calibration requirements are as follows:

a) Unless alternate reflectors are specified in the MUT procedure, an N10 notch shall be used.

b) 80 % full screen height shall be used to establish the baseline sensitivity from the initial calibration reflector.

c) A DAC/TCG curve shall be established as defined by the procedure to establish reference sensitivity.

Manual ultrasonic weld testing shall be performed at a scanning sensitivity of DAC/TCG reference sensitivity, plus transfer correction with an additional 6-dB scanning gain. All indications that exceed 50 % DAC/TCG screen height shall be evaluated.

Evaluation sensitivity for manual ultrasonic weld testing should be DAC/TCG reference sensitivity, including transfer and +6dB scanning gain with an evaluation level for all imperfections at 50% of DAC/TCG screen height.

The procedure shall define the scanning and evaluation levels based on demonstration.

11.4.6.8 Inspection Error

When MUT is used for the determination of vertical height for either 9.6 or Annex A application, the inspection error of the procedure and technique shall be known. The inspection error shall be derived by a methodology agreed between contractor and company and confirmed by demonstration.

11.4.6.9 Acceptance Standards

The acceptance standards shall be defined by 9.6 or Annex A. The acceptance standards shall be incorporated into the MUT procedure and approved by the company.

11.4.7 Automated Ultrasonic Testing

11.4.7.1 General

AUT procedures shall be developed by the contractor. The company shall approve all AUT procedures prior to use for project inspection.

11.4.7.2 Procedure Requirements

At a minimum, the procedure for AUT of welds shall include the following specific application details:

a) type of welds to be tested, joint preparation dimensions, and welding processes;

b) material type (i.e., size, grade, thickness, process of manufacturing per API 5L);

c) scanning surface preparation/condition;

d) stage at which the examination is to be performed;

e) ultrasonic instrumentation;

f) software and version;

g) data management;

h) couplant and application;

i) testing technique(s):

  — description of technique to be applied, including sketches and showing weld coverage;

  — angle(s) inclusive of horizontal and vertical beam profiles;

  — transducer configuration(s);

  — frequencies (MHz);

  — temperatures and ranges;

  — scanning patterns and speeds;

  — reference datum and location markers (i.e., root face and circumferential location).

j) reference standards: detailed sketches showing plan view and cross-section view dimensions of production material reference standard blocks and all reference reflectors inclusive of machining tolerances;

k) calibration requirements:

  — the interval at which calibration of the instrument is required;

  — the sequence of startup prior to inspecting welds;

  — all calibration standards to be used;

  — the reference sensitivity reflectors to be used;

  — the reference sensitivity level settings;

— the requirements for verification of calibration settings.

l) scanning level: the sensitivity setting in dB to be added to the reference sensitivity for scanning;

m) evaluation level: the level or height of echoes detected during scanning at which further evaluation is required, and any sensitivity adjustment to be made before evaluating for acceptance or rejection;

n) imperfection sizing methodology;

o) record of results: type of record (e.g., sketch, image, scan, etc.);

p) reporting requirements:

— indications to be reported;

— weld status (accept/reject);

— defect classification;

— defect height;

— defect length;

— defect locations (circumferential, radial, axial position);

— weld repair or cutout;

— final disposition of the weld.;

q) ultrasonic examination report: an example of the examination reports;

r) example of the weld inspection scan.

11.4.7.3 Reference Standards

Reference standard(s) shall include artificial reflectors positioned to represent the orientation, shape, and location of flaws inherent to the welding process. This standard shall be used for calibration (i.e., time of flight, gating, and sensitivity) of the AUT system. The reference standard should include but is not limited to the following reference reflectors:

a) flat bottom hole(s) or notches;

b) centerline reflectors;

c) surface notches;

d) embedded notches;

e) transverse reflectors.

The reference standard shall be used in conjunction with the AUT system to ensure full volumetric coverage and detectability of the typical flaws in the weld. Reflectors should be spaced so that no two reflectors will be within the beam spread of one beam simultaneously. The reference standard shall be approved by the company.

Prior to use, the reference standard shall be verified. The verification shall include mechanical and manual ultrasonic checks defined in a procedure approved by the company. These checks shall be performed to ensure the reference standard’s suitability for use.

Examples of AUT required calibration reference blocks are show in Figure 32, Figure 33, and Figure 34. These examples are intended to provide visualization of the various required flat bottom reflectors and their role in providing weld area coverage. These examples do not represent a minimum number of reflectors required nor the types of reflectors that can be used. The design requirements for a calibration block shall be based on the location, geometry, and morphology of the indigenous weld flaws to be found in the welding process being inspected.

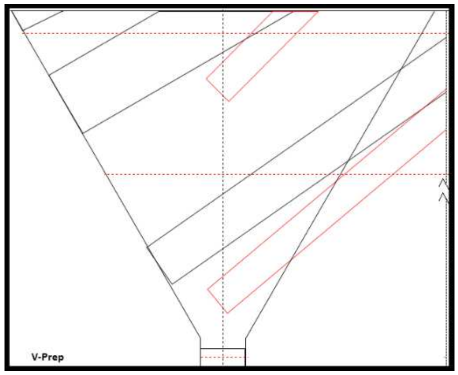


Figure 32—Example: V Prep Reference Standard—Example Reflector Positioning

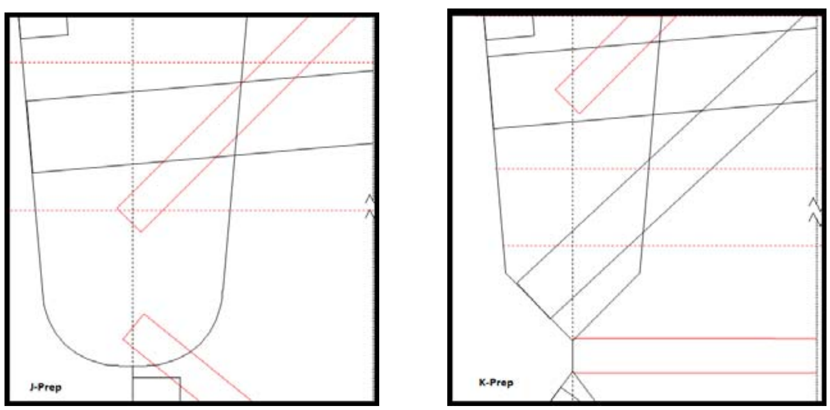


Figure 33—Example: J and K Prep Reference Standard—Reflector Positioning

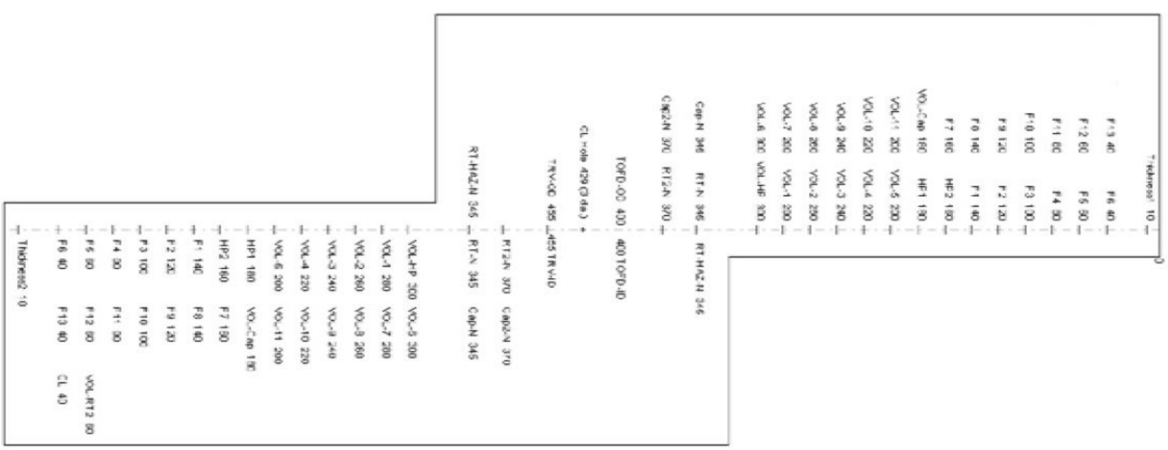


Figure 34—Example: J Prep Reference Standard—Top View

11.4.7.4 Reference Sensitivity, Scanning, and Evaluation Level

Reference sensitivity, scanning, and evaluation levels shall be proposed by the contractor. Final determination will be based on demonstration results with final approval from the company.

11.4.7.5 Inspection Error

When AUT is used for the determination of vertical height for either 9.6 or Annex A applications, the inspection error of the procedure and technique shall be known. The inspection error shall be derived by a methodology agreed between contractor and company and confirmed by demonstration.

11.4.7.6 Acceptance Standards

The acceptance standards shall be defined by 9.6 or Annex A. The acceptance standards shall be incorporated into the AUT procedure and be approved by the company.

11.4.8 Alternative Ultrasonic Techniques

Alternative ultrasonic techniques not described in this section may be proposed. The contractor shall provide sufficient development data prior to consideration for any qualification. Qualification and demonstration of the proposed procedure and technique shall be agreed between contractor and company prior to project use.

12 Mechanized Welding with Filler Metal Additions

12.1 Acceptable Processes

Mechanized welding shall be performed using one or more of the following processes:

a) submerged arc welding;

b) gas metal arc welding;

c) gas tungsten arc welding;

d) flux-cored arc welding with or without external shielding;

e) plasma arc welding;

f) the use of a manual or semiautomatic process combined with one of the mechanized processes listed in this section.

12.2 Procedure Qualification

Before production welding is started, a detailed WPS shall be established according to the requirements of 12.4 and qualified according to the requirements of 12.5 to demonstrate that welds with suitable mechanical properties (such as strength, ductility, and hardness) and soundness can be made by the procedure. Two base material lengths, full joints or nipples, shall be joined by following all the details of the WPS. The quality of the weld shall be determined by both destructive and nondestructive testing and shall meet the requirements of 12.6 and Section 9, respectively.

Should a welding procedure qualification utilize a manual or semiautomatic pass as outlined in 12.1, the nick break test in 5.6.3 shall be required as part of the procedure qualification unless procedure welds are examined by radiography or ultrasonic testing and are found acceptable per Section 9. The essential variables of Section 5 shall apply to the manual or semiautomatic portion of the weld, except that 5.4.2.2 and 5.4.2.3 shall be replaced by 12.5.2.2 and 12.5.2.3.

12.3 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 12.4 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 35.

12.4 Welding Procedure Specification

12.4.1 General

The WPS should include all the information that is pertinent to setting up and maintaining the proper operation of the equipment. At a minimum, all the variables listed in 12.4.2 shall be specified in the WPS.

NOTE An example of an acceptable form is shown in Figure 36.

12.4.2 Specification Information

12.4.2.1 Welding Process

The specific process or combination of processes used shall be specified. This shall include a description of the equipment to be used.

12.4.2.2 Materials

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

12.4.2.3 Diameters

The range of nominal ODs over which the procedure is applicable shall be specified in the WPS.

12.4.2.4 Wall Thickness and Number and Sequence of Beads

The range of nominal wall thicknesses over which the procedure is applicable shall be specified in the WPS, as shall the range of number of beads required for the thicknesses and the machine used for each bead.

PROCEDURE / WELDING OPERATOR QUALIFICATION RECORD

Date________________________________ Test No. _______________________________________ Test Type: ____WPQT ____WQT

Location ____

Welding Operator(s) Name_____________________________________ Welding Operator(s) Number_______________________________________

Material Grade 1 ____

Material Grade 2 ____

Outside Diameter____ Wall Thickness____

Joint Type_____________ Bevel Angle(s) ______________________ Root Face__________________________ Root Gap_____________________

Backing Type (if applicable) ____________________________________ Welding Position(s)____

WPS number (if applicable) ____________________________________

Method of heating ____ Width to be heated____

For Plasma Arc Welding only: orifice diameter and gas composition ____

RECORDED WELDING PARAMETERS

Pass	Process and Transfer Mode	Polarity	Filler Metal Group or Classification and Size	Shielding Gas type and flow rate or Shielding Flux	Minimum and Maximum Preheat / Interpass Temperature	Voltage Range	Amperage Range	Wire Speed 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.

Time Between Passes: Root bead to 2nd bead: _________________ , 2nd bead to 3rd bead:____

Cooling Method (if applicable) _________________________________ PWHT____

MECHANICAL TEST RESULTS

TENSILE TESTS Report Number:

Specimen Number	Tensile 1	Tensile 2	Tensile 3	Tensile 4
Location				
Original specimen dimensions				
Original specimen area				
Maximum load				
Tensile strength				
Fracture location				

BEND TESTS Report Number:

Specimen Type and Number								
Location								
Result								

If the test weld combines mechanized and manual or semiautomatic processes, a table for Nick Breaks shall be added

NDT report number			
NDT Result			

Remarks

Test made at ____ Date ____

Tested by ____ Supervised by ____

Figure 35—Sample Coupon Test Report

WELDING PROCEDURE SPECIFICATION

Date ____________________ WPS Number ____________________

Material grade qualified ____________________

Outside Diameter range qualified ____________________ Wall Thickness range qualified ____________________

Backing type (if applicable) ____________________ Welding position(s) ____________________

Direction of welding ____________________ Direction of welding qualified ____________________

Minimum preheat temperature ____________________ Maximum interpass temperature ____________________

Method of heating ____________________ Width to be heated ____________________

Filler metal(s) and Flux ____________________ Cleaning and/or grinding tools ____________________

Type and removal of lineup clamp ____________________ Minimum number of passes ____________________

Method of cooling ____________________ PWHT procedure ____________________

Purging gas composition and flow (if applicable) ____________________

For Plasma Arc Welding only: orifice diameter and gas composition ____________________

Other variables:

JOINT DESIGN
(define as a minimum joint type, bevel, angle, root face dimension, and root gap dimension and associated tolerances)

SEQUENCE OF BEADS

WELDING PARAMETERS

Pass	Process and transfer mode	Polarity	Filler Metal Group or Classification and size	Shielding Gas type and flow rate or Shielding Flux	Minimum and Maximum Interpass Temperature	Voltage Range	Amperage Range	Wire Speed Range	Travel Speed Range	Heat Input Range
Root Bead										
Second										

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.

Remarks

Supporting procedure qualification record No(s).____________________

Approved by:____________________

Figure 36—Sample Welding Procedure Specification Form

12.4.2.5 Joint Design and Weld Shape and Size

The specification shall include a sketch or sketches of the joint that show the type of joint (e.g., V, U, K, etc.), the angle of bevel, and the size of the root face and root opening (with tolerances). The cap height and width beyond the groove shall be shown (with tolerances). If a backing is used, the type of backing shall be specified.

12.4.2.6 Filler Metal and Flux

The AWS classification number of the filler metal and flux, if available, shall be specified or the brand number of the shielding flux shall be specified in the WPS.

12.4.2.7 Size of Filler Metal

The size of the filler metal shall be specified in the WPS.

12.4.2.8 Electrical Characteristics, Travel Speed, and Heat Input

The following variables shall be specified in the WPS for each size or type of electrode used and/or each pass or pass grouping:

a) transfer mode;

b) polarity;

c) amperage;

d) voltage;

e) travel speed;

f) wire speed;

g) heat input.

12.4.2.9 Position

The welding position shall be specified in the WPS.

12.4.2.10 Direction of Welding

For fixed position welding, the direction of welding (vertical up, vertical down, or orbital) shall be specified in the WPS.

For roll welding, the rotation direction and position of the arc shall be specified in the WPS.

12.4.2.11 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 welding that shall be completed before the clamp is released shall be specified.

12.4.2.12 Cleaning

The specification shall describe the joint end and interpass cleaning required.

12.4.2.13 Preheat and Interpass Temperature

The methods, width to be heated, minimum preheat temperature, minimum ambient temperature below which preheat is required (if applicable), and maximum interpass temperature shall be specified in the WPS.

12.4.2.14 Postweld Heat Treatment (PWHT)

The methods, width to be heated, minimum and maximum temperature, time at temperature, and temperature control methods for PWHT shall be specified.

12.4.2.15 Shielding/Purging Gas and Flow Rate

If used for welding, the composition of the shielding and/or back purging gas and the range of flow rates shall be specified in the WPS.

The composition of the gas used shall be defined by the designation of AWS A5.32.

12.4.2.16 Method of Cooling After Welding

The type of cooling after welding, such as air cooling or forced cooling with water to expedite nondestructive examination and joint coating, as well as the maximum metal temperature at which forced cooling is applied, shall be specified in the WPS.

12.4.2.17 Orifice Diameter or Orifice Gas Composition

For plasma arc welding, the orifice gas nominal composition and the orifice diameter shall be specified in the WPS.

12.4.2.18 Other Factors

Other important factors that may be necessary for proper operation of the process or that may affect the quality of the work produced (e.g., the location and angle of arc for fixed position welding, the contact-tube-to-work distance, and the oscillation width and frequency) shall be specified in the WPS.

12.5 Essential Variables

12.5.1 General

A welding procedure shall be reestablished as a new welding procedure specification and shall be completely requalified when any of the essential variables listed in Table 20 are changed outside of the ranges specified for each variable.

NOTE Changes of other variables (non-essential) may be made in the procedure without the need for requalification, provided the WPS is revised to show the changes.

12.5.2 Essential Variables Categories

The variables and qualification ranges specified in Table 20 are classified in two 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 specified hardness and/or toughness values are required by the company.

Table 20—Essential Variables for the Qualification of Mechanized Welding Procedure Specifications

Welding Variable Subsection[a]	Change Requiring Requalification	Category I (Standard WPS)	Category II (Hardness and/or Toughness)
12.5.2.1 Welding Process	A change in welding process for any given pass or pass grouping	X	X
12.5.2.2 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.[b, c]	X	X
	b) Where t is the nominal pipe wall thickness used during qualification, a change that falls outside the following ranges: 1) t to $2t$, when $t \le 0.188$ in. (4.8 mm) 2) 0.188 in. (4.8 mm) to $2t$, when 0.188 in. (4.8 mm) < t ≤ 0.375 in. (9.5 mm) 3) $0.5t$ to $2t$, when 0.375 in. (9.5 mm) < t < 1.0 in. (25.4 mm) 4) $0.5t$ to unlimited, when $t \ge 1.0$ in. (25.4 mm)	X	
	c) A change in nominal wall thickness +/-25 % of the wall thickness used during qualification.		X
	d) Where D is the nominal outside diameter of the pipe used during procedure qualification, a change that falls outside the following ranges: 1) $0.5D$ to $2D$, when D < 12.75 in. (323.9 mm) 2) $0.5D$ to unlimited, when $D \ge 12.75$ in. (323.9 mm)	X	X
12.5.2.3 Joint Design	a) A change of type of joint (as defined in 12.4.2.5).	X	X
	b) A change of the bevel angle used during qualification that falls outside the following ranges:[d] 1) ±2° when bevel angle ≤ 10°; 2) ±5° when 10° < bevel angle < 30°; 3) ±10° when bevel angle is ≥ 30°.	X	X
	c) A change of root face by more than 50 % if the root pass is done with mechanized welding. An increase of root gap by more than 0.010 in. (0.25 mm) or 50 % of the root gap qualified, whichever is greater, if the root pass is done with mechanized welding.	X	X
12.5.2.4 Filler Metal and Flux	a) A change from one filler metal group to another (see Table 21) when base material SMYS is less than the “nominal SMYS” of Grade X65 [b, e]	X	
	b) A change in filler metal AWS classification when the base material SMYS is greater than or equal to the “nominal SMYS” of grade X65 [b, f]	X	
	c) A change in shielding flux outside of the limits specified in footnote “a” of Table 21.	X	
	d) A change in filler metal AWS classification. [f]		X
	e) A change in filler metal size.	X	X
12.5.2.5 Position	A change in position from roll welding to fixed position but not vice versa	X	X
12.5.2.6 Direction of welding [g]	a) A change from vertical up to vertical down and vice versa.	X	X
	b) A change from vertical up or vertical down to orbital but not vice versa.	X	X

Table 20—Essential Variables for the Qualification of Mechanized Welding Procedure Specifications (continued)

Welding Variable Subsection[a]	Change Requiring Requalification	Category I (Standard WPS)	Category II (Hardness and/or Toughness)
12.5.2.7 Shielding/ Backing Gas	a) A change of shielding gas or purging gas classification in accordance with AWS A5.32.	X	X
	b) A change in shielding gas flow rate greater than 20 % below the minimum flow rate recorded during qualification.	X	X
	c) The deletion of purging or shielding gas.	X	X
12.5.2.8 Orifice Diameter or Orifice Gas Composition	a) For plasma arc welding, a change in orifice gas nominal composition.	X	X
	b) For plasma arc welding, a change in orifice diameter.	X	X
12.5.2.9 Electrical Characteristics [h]	a) A change in current/polarity type (DCSP/DCEN, DCRP/DCEP, AC).	X	X
	b) A change to or from a wave form process.	X	X
	c) A change in heat input exceeding +/- 20 % of that recorded during procedure qualification. [i]	X	X
12.5.2.10 Preheat Temperature	a) The deletion of preheating when preheating is applied during qualification.	X	X
	b) A decrease in minimum base material preheat temperature more than 50 °F (30 °C) below that recorded during procedure qualification. [j]	X	X
12.5.2.11 Interpass Temperature	An increase in the maximum interpass temperature by more than 50 °F (30 °C) above that recorded during procedure qualification. [j]	X	X
12.5.2.12 Postweld Heat Treatment	The addition of PWHT or a change from the ranges or values specified in the PWHT procedure shall each constitute an essential variable	X	X
12.5.2.13 Cooling	a) The addition 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

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, the compatibility of the base materials of different analysis and filler metals should be considered from the standpoint of metallurgical and mechanical properties and requirements for preheat and PWHT.
d For compound bevels, the bevel angle allowances shall apply to each bevel angle accordingly.
e Changes in filler metal may be made within the groups in Table 21. The compatibility of the base material and the filler metal should be considered from the standpoint of mechanical properties.
f When under more stringent CVN requirements (projects with test temperature below 0 °F (-18 °C) or with minimum absorbed energy requirement of 37 ft-lbs (50J) or higher), or if a consumable with a "-G" classification is used, it is important to analyze the certificates of each lot used in production and ensure they have a similar chemical composition of the one used during qualification as defined by the company.
g Direction of welding only applies to fixed position welding.
h 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.
i As calculated in 5.3.2.6.
j When procedures are qualified with different preheat and/or interpass temperatures throughout the weld sequence, the temperatures shall be specified accordingly.

Table 21—Filler Metal Groups

Group	AWS Specification	AWS Electrode/Filler Metal Classification	AWS Flux Classification
4 [a]	A5.17	EL8, EL8K, EL12, EL12K, EL12K, EM12, EM12K, EM13K, EM14K, EM15K	F7A0, F7A2, F7A4, F7A6, F7A8 F7P0, F7P2, F7P4, F7P6, F7P8
5 [b]	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	—
	A5.36	E81T-1Ni1C, E81T-1Ni1M, E81T1-1Ni2C, E81T-1Ni2M, E81T-1K2C, E81T-1K2M	—

NOTE 1 Other electrodes, filler metals, and fluxes may be used but require separate procedure qualification.

NOTE 2 For any electrodes or filler metals with the "G" suffix designator (example ER80S-G) only, a change in the manufacturer or trade name is essential variable and each "G" electrode/filler metal require separate procedure qualification.

[a] Any combination of flux and electrode in Group 4 may be used to qualify a procedure. The combination is identified by its complete AWS classification number, such as F7A0-EL12 or F7A2-EM12K. Only substitutions that result in the same AWS classification number are permitted without requalification.

[b] A shielding gas (see 12.5.2.7) is required for use with the electrodes in Group 5.

12.6 Testing of Welded Joints—Butt Welds

12.6.1 Preparation

To test the butt-welded joint, test specimens shall be cut from the joint at the locations shown in Figure 37. The minimum number of test specimens and the tests to which they shall be subjected are given in Table 22. If the required number of test specimens cannot fit in a single weld, multiple test welds shall be performed. The specimens shall be air cooled to ambient temperature prior to being tested. The full-section specimens shall be tested in accordance with 12.6.2.2, 12.6.3.2, and 12.6.4.2, and shall meet the requirements of 12.6.2.3, 12.6.3.3, and 12.6.4.3.

Table 22—Type and Number of Test Specimens for Procedure Qualification Test

Outside Diameter of Pipe		Number of Specimens [a]				
in.	mm	Tensile Strength	Root Bend	Face Bend	Side Bend	Total
Wall Thickness ≤ 0.500 in. (12.7 mm)						
<2.375	<60.3	0 [b]	2	0	0	2
2.375 to 4.500	60.3 to 114.3	0 [b]	2	0	0	2
>4.500 to 12.750	>114.3 to 323.9	2	2	2	0	6
>12.750	>323.9	4	4	4	0	12
Wall Thickness > 0.500 in. (12.7 mm)						
≤4.500	≤114.3	0 [b]	0	0	2	2
>4.500 to 12.750	>114.3 to 323.9	2	0	0	4	6
>12.750	>323.9	4	0	0	8	12

[a] If more than one test weld is needed, at least one bend test and two tensile tests (when required) shall be taken from at least two separate coupons.

[b] For materials with SMYS greater than the material specified as API 5L Grade X42, a minimum of one tensile test is required.

12.6.2 Tensile Strength Test

12.6.2.1 Preparation

The full-thickness tensile strength test specimens shall be either of the types shown in Figure 38.

a) The sides of the full section specimen shown in Figure 38a shall be smooth and parallel. The 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 38b. The weld reinforcement shall be removed.

12.6.2.2 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.

12.6.2.3 Requirements

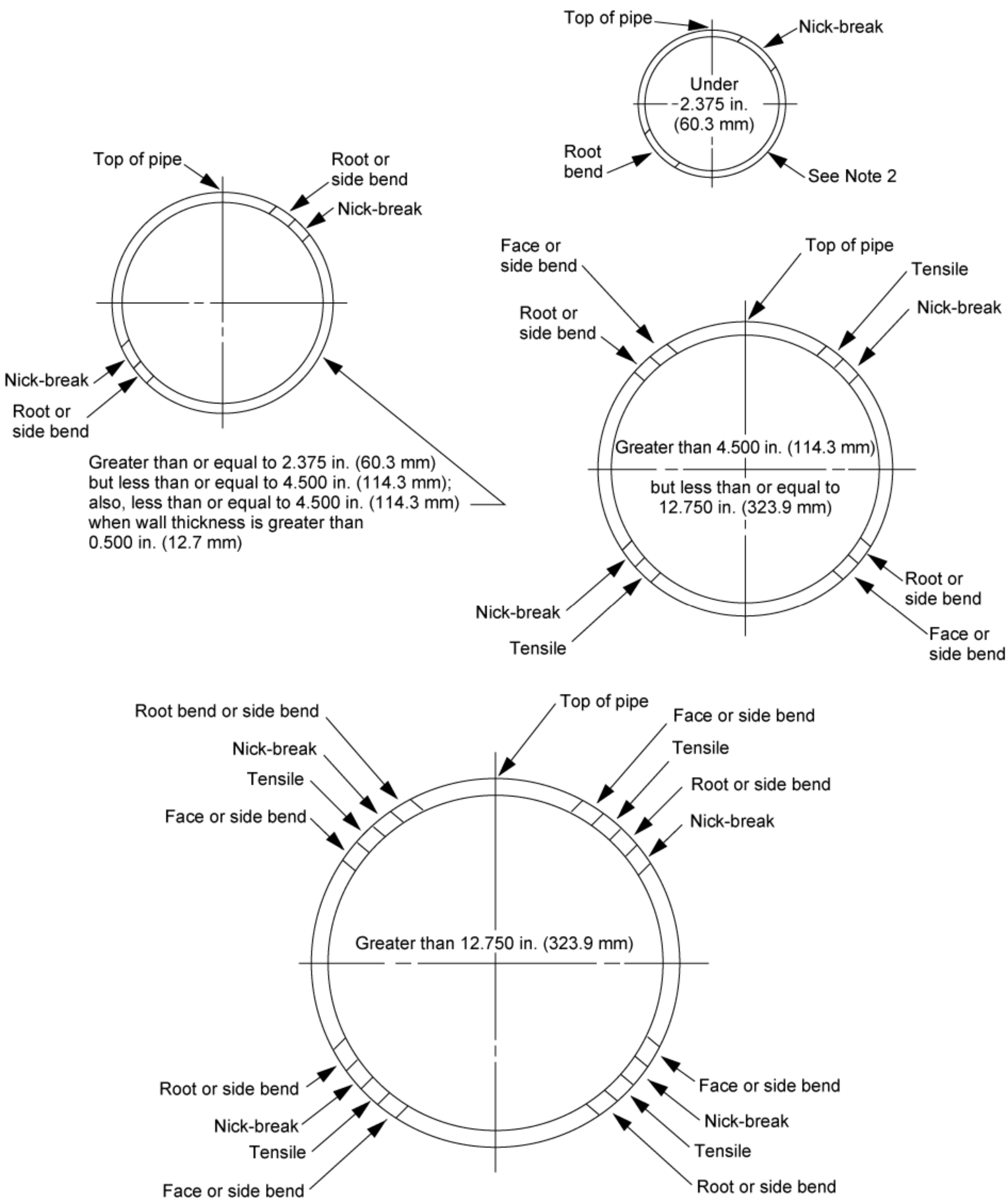
The tensile strength of the weld, including the fusion zone of each specimen, shall be greater than or equal to the specified minimum tensile strength (SMTS) of the pipe material but need not be greater than or equal to the actual tensile strength of the material. If the specimen breaks outside the weld and fusion zone (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 or fusion zone and the observed strength is greater than or equal to the SMTS of the pipe material, 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 materials of different grades, the SMTS of the lower grade shall be used as the acceptance criteria.

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



NOTE 1 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.

NOTE 2 One full-section tensile specimen may be used for pipe with an outside diameter less than or equal to 1.315 in. (33.4 mm).

Figure 37—Location of Test Butt Weld Specimens for Procedure Qualification Test

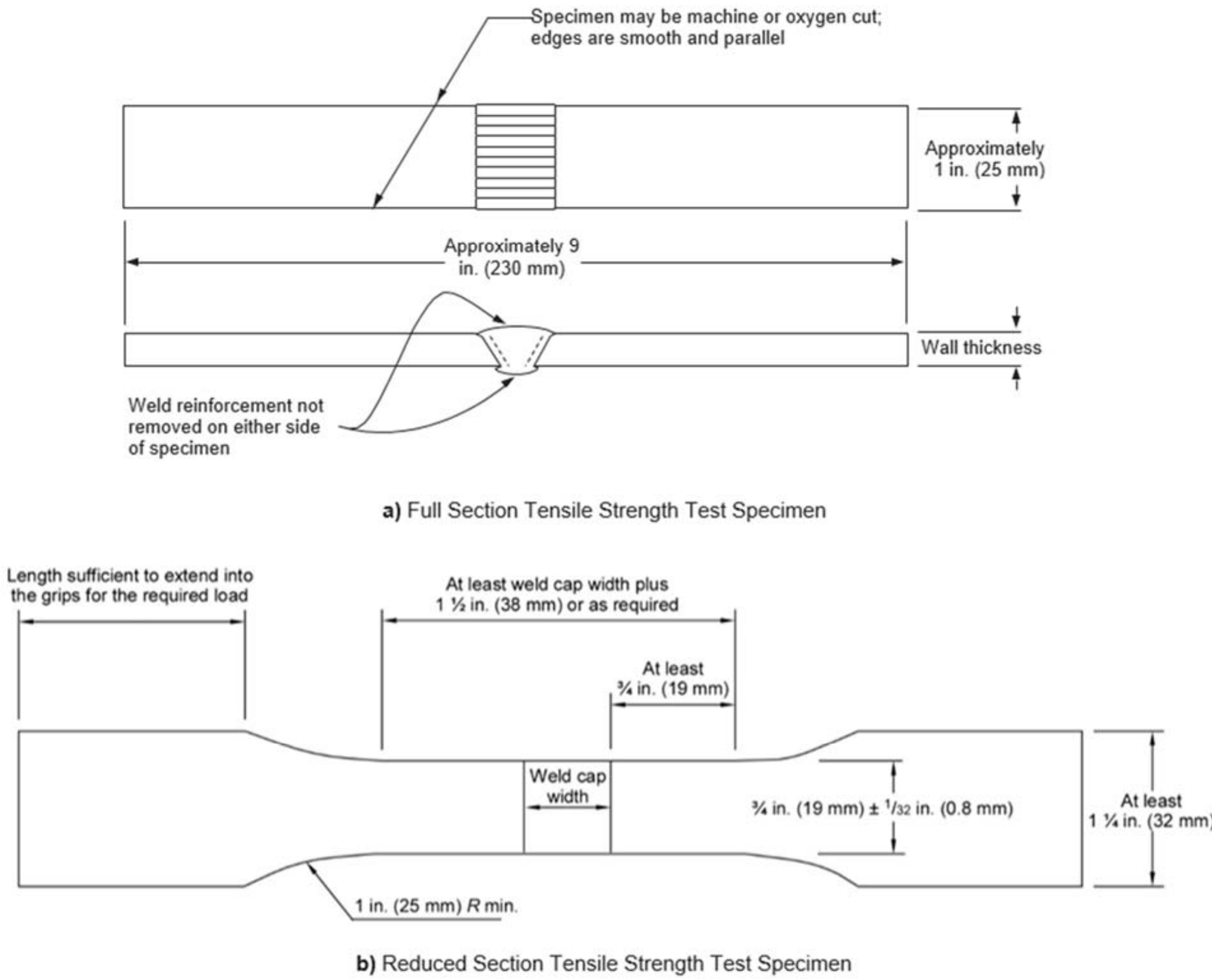


Figure 38—Tension Test Specimen

12.6.3 Root and Face Bend Test

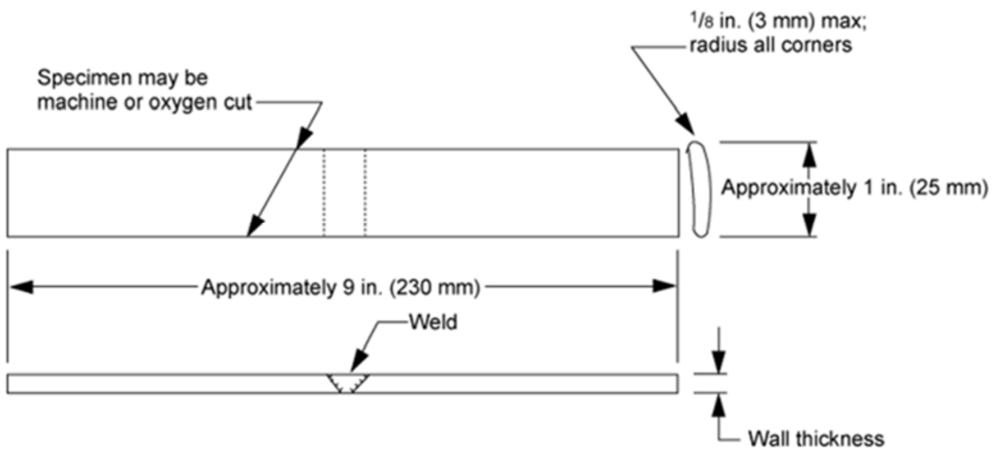
12.6.3.1 Preparation

The root and face bend test specimens (see Figure 39) 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.

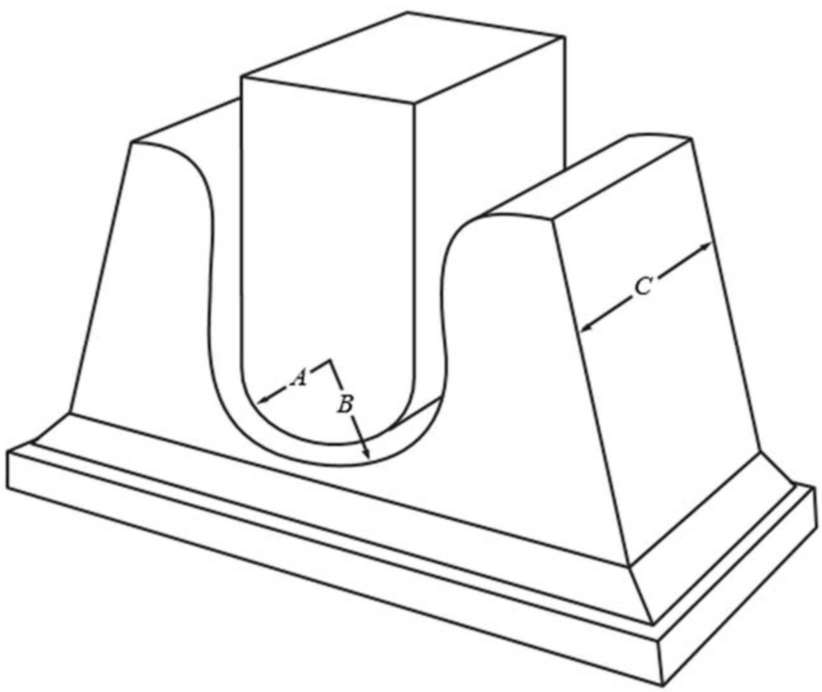
12.6.3.2 Method

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 40.



NOTE The weld reinforcement is removed from both faces and made flush with the surface of the specimen. The specimen is not flattened prior to testing.

Figure 39—Root and Face Bend Test Specimen: Wall Thicknesses Less Than or Equal to 0.500 in. (12.7 mm)



NOTE This figure is not drawn to scale. Radius of plunger, A = 1 ¾ in. (45 mm); radius of die, B = 2 5⁄16 in. (60 mm); width of die, C = 2 in. (50 mm).

Figure 40—Jig for Guided-bend Tests

12.6.3.3 Requirements

The bend test shall be considered acceptable if no crack or other imperfection exceeding 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 ¼ in. (6 mm), measured in any direction, shall not be considered unless obvious imperfections are observed. For test weld diameter greater than 12 ¾ in. (323.9 mm), if only one bend specimen fails, the specimen should be replaced with two additional specimens from locations adjacent to the failed specimen. If either of the replacement bend test specimens fails, the weld is considered unacceptable.

12.6.4 Side Bend Test

12.6.4.1 Preparation

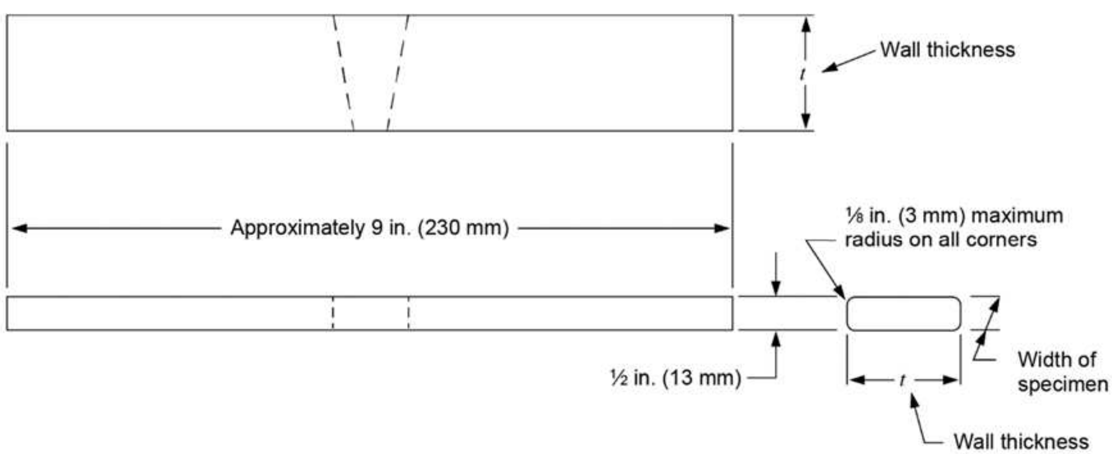
The side bend test specimens (see Figure 41) shall be approximately 9 in. (230 mm) long and approximately ½ in. (13 mm) wide, and their long edges shall be rounded. They shall be machine cut, or they may be cut by any means to approximately a ¾-in. (19-mm) width and then machined or ground to the ½-in. (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.

12.6.4.2 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 40.

12.6.4.3 Requirements

Each side bend specimen shall meet the root and face bend test requirements specified in 12.6.3.3. For a test weld diameter greater than 12 ¾ in. (323.9 mm), a single failed side bend specimen may be replaced with two additional specimens from locations adjacent to the failed specimen. If either of the replacement bend test specimens fails, the weld is considered unacceptable.



NOTE All dimensions are approximate.

Figure 41—Side Bend Test Specimen: Wall Thicknesses Greater than 0.500 in. (12.7 mm)

12.7 Qualification of Welding Operators

12.7.1 General

Each welding operator shall be qualified by producing an acceptable weld using the qualified welding procedure. The completed weld shall be tested by destructive methods or nondestructive methods or both, and shall meet the requirements of 12.7.2 through 12.7.4. If the completed weld is tested by both destructive methods and nondestructive methods, failure to meet the acceptance criteria of either method shall result in rejection of the weld. Should a welding procedure qualification utilize a manual or semiautomatic pass as outlined in 12.1, the nick break and tensile strength test in 6.5.1 shall be required as part of the welding operator qualification. It is possible to qualify a WPS and a welding operator with one test joint. It is the intent of this standard that a welding operator who satisfactorily completes the procedure qualification test shall be a qualified welding operator, provided the number of test specimens required by 12.7.3 have been removed, tested, and meet the acceptance criteria of 12.6.3 or 12.6.4, for each welding operator. 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 welding operator(s) was disqualified.

Prior to the start of welding, each welding operator shall have received adequate training in the operation of the welding equipment. If the welding procedure involves more than one operation, welding operators shall be qualified on the type of welding equipment that will be used in production welding.

Should a welding procedure utilize a combination of processes, it shall be acceptable to qualify a welding operator on one of the processes only. The welding operator shall be limited to performing that specific process.

At the option of the company, it shall be acceptable to qualify welding operators whose work is limited to specific weld passes in a multipass butt weld to those specific passes. The other weld passes necessary to make complete welds shall be made by other welding operators. Welding operators shall be qualified if all tests are acceptable.

Changes in the essential variables described in 12.7.6 require requalification of the welding operator.

12.7.2 Visual Examination

For a qualification test weld to meet the requirements for visual examination, the weld shall be free from cracks, inadequate penetration, and BT, and shall present a neat workmanlike appearance that is acceptable to the company. The depth of undercutting adjacent to the final bead on the outside of the pipe shall not be more than $^1/_{32}$ in. (0.8 mm) or 12.5 % of the pipe wall thickness, whichever is smaller, and there shall not be more than 2 in. (50 mm) of undercutting in any continuous 12-in. (300-mm) length of weld.

Filler wire protruding into the inside of the pipe shall be kept to a minimum and the company shall determine the acceptability of protruding wires.

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

12.7.3 Destructive Testing

12.7.3.1 Sampling of Test Butt Welds

When destructive tests are requested to test butt welds, samples shall be cut from each test weld. The total number of specimens and the tests to which each shall be submitted are shown in Table 23.

Table 23—Type and Number of Test Specimens for Welding Operator Qualification Test

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

If the test weld is a complete circumferential weld, bend test specimens should be removed from locations similar to bend tests in Figure 37. 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 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), root bend specimens shall be removed from two qualification welds.

12.7.3.2 Bend Test Procedures

The specimens shall be prepared for bend tests, and the tests shall be performed as described in 12.6.3 or 12.6.4 as applicable.

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 should be replaced by an additional specimen cut adjacent to the one that failed.

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

12.7.4 Nondestructive Testing (NDT)

12.7.4.1 General

At the company's option, the qualification butt weld may be examined by radiography or automated ultrasonic testing using a qualified NDT procedure instead of or in addition to the tests specified in 12.7.3.

12.7.4.2 Inspection Requirements

When radiography is utilized, radiographs shall be made of each of the test welds. The welding operator shall be disqualified if any of the test welds do not meet the requirements of 9.3.

When automated ultrasonic testing is utilized, each test weld shall be fully examined. The welding operator shall be disqualified if any of the test welds do not meet the requirements of 9.6.

Radiographic testing or automated ultrasonic testing shall not be used for the purpose of locating sound areas or areas that contain imperfections and subsequently making tests of such areas to qualify or disqualify a welding operator.

12.7.5 Retesting

If, in the mutual opinion of the company and the contractor's representatives, a welding operator fails to pass the qualification test because of unavoidable conditions or conditions beyond the welding operator's control, the welding operator should be given a second opportunity to qualify. No further retests shall be given until the welding operator has submitted proof of subsequent welding operator training that is acceptable to the company.

12.7.6 Changes Requiring Requalification

Changes in the following essential variables shall require requalification of the welding operator.

a) A change in polarity, from one welding process or welding-process combination to another or a change from a waveform process to a non-waveform process.

b) A change in the direction of welding from:

- vertical up to vertical down or vice versa;
- vertical up or vertical down to orbital but not vice versa;
- rolled to vertical up, vertical down, or orbital but not vice versa; and
- vertical progression to horizontal progression or vice versa.

c) A change in the filler metal type (solid wire, metal core, flux core).

d) A change from one specified OD group to another, to include:

- OD less than 12.75 in. (323.9 mm); and
- OD equal to or greater than 12.75 in. (323.9 mm).

e) Wall thickness:

1) If welding operator qualification weld is done on a pipe with a wall thickness less than 0.500 in. (12.7 mm), this operator shall be qualified for welding pipes with a wall thickness of $2t$ or less, where t is the wall thickness used during the qualification test;

2) If a welding operator qualification weld is done on a pipe with a wall thickness equal to or greater than 0.500 in. (12.7 mm), this operator shall be qualified for welding pipes of any wall thickness.

f) A change in position from that for which the welding operator has already qualified (e.g., a change from rolled to fixed or a change from vertical to horizontal). A welding operator who qualifies in the fixed position shall also be qualified to perform rolled welds within the essential variables qualified.

g) A change in welding bug manufacturer or model.

h) A change in the method of applying the root bead (e.g., external root versus internal root).

i) A major change in joint design (e.g., from a V-groove to a U-groove or J-groove) or any change beyond the range established for such factors as spacing, root face, and angle of bevel.

j) A welding operator only welding a certain pass or pass grouping during the qualification weld shall be qualified for this specific pass or pass grouping only.

12.8 Records of Qualified Operators

A record shall be made of the tests required by 12.7 and of the detailed results of each test. A form similar to that shown in Figure 35 should be used (this form should be developed to suit the needs of the company and should be sufficiently detailed to demonstrate that the qualification test meets the requirements of this standard). A list of qualified operators and the procedures for which they are qualified shall be maintained. An operator may be required to requalify if a question arises about their competence.

12.9 Inspection and Testing of Production Welds

Production welds shall be inspected and tested in accordance with Section 8.

12.10 Acceptance Standards for NDT

The acceptance standards for NDT shall be in accordance with Section 9 or, at the company's option, Annex A.

12.11 Repair and Removal of Defects

Repair and removal of defects shall be in accordance with Section 10.

12.12 Radiographic Testing

Radiographic testing shall be in accordance with 11.1.

12.13 Ultrasonic Testing

Ultrasonic testing shall be in accordance with 11.4.

Annex A
(normative)

Alternative Acceptance Standards for Girth Welds

A.1 General

The acceptance standards given in Section 9 are based on empirical criteria for workmanship and place primary importance on imperfection length. Such criteria have provided an excellent record of reliability in pipeline service for many years. The use of fracture mechanics analysis and fitness-for-purpose criteria for determining acceptance criteria is an alternative method and incorporates the evaluation of both imperfection height and imperfection length. Typically, but not always, the fitness-for-purpose criteria provide more generous allowable imperfection length. Additional qualification tests, stress analysis, and inspection are required to use the fitness-for-purpose criteria. Performing analysis based on the principles of fitness-for-purpose is alternatively termed engineering critical assessment, or ECA.

The fitness-for-purpose criteria in the prior versions of this annex required a minimum crack tip opening displacement (CTOD) toughness of either 0.005 in. or 0.010 in. (0.13 mm or 0.25 mm) and were independent of any higher values of fracture toughness. Improvements in welding consumables and with more precise welding procedures, especially with the increased use of mechanized welding devices, have resulted in higher and more uniform toughness and ductility in most welds. At the same time, toughness values below 0.005 in. (0.13 mm) have been observed, particularly with more stringent notching procedures of CTOD specimens than those in the prior versions of this annex. Welds with CTOD toughness below 0.005 in. (0.13 mm) have shown to perform adequately when the acceptance criteria are properly adjusted to account for the lower toughness. The acceptance criteria are revised so that they are commensurate with the measured toughness and applied load levels.

This annex includes three options for the determination of acceptance limits of planar imperfections. In numerical order, the options are increasingly complex in application but offer wider range of applicability. Option 1 provides the simplest methodology. Option 2 allows for the full utilization of the toughness of the materials, thus providing a more accurate criterion but requires more calculation. The first two options were developed with a single set of underlying procedures but are limited to applications with a low to moderate fatigue loading as described in A.2.2.1.[9] Option 3 is provided for those cases where fatigue loading exceeds the limit established for the first two options. Option 3 is not prescriptive, and its consistency could be significantly less than Options 1 and 2. Option 3 should only be exercised, when necessary, by skilled practitioners with demonstrated knowledge of fracture mechanics and pipeline load analysis.

It is usually impractical to qualify individual pipeline welds for the alternative acceptance limits after a defect under Section 9 is detected, because destructive testing is required to establish the required mechanical properties for the welding procedure under consideration.

This annex provides procedures to determine the maximum allowable imperfection sizes. It does not prevent the use of Section 9 for determining imperfection acceptance limits for any weld. Use of this annex is completely at the company's option.

In this annex, the use of the phrase imperfection acceptance limits and other phrases containing the word imperfection is not intended to imply a defective condition or any lack of weld integrity. All welds contain certain features variously described as artifacts, imperfections, discontinuities, or flaws. These terms are widely accepted and used interchangeably. The primary purpose of this annex is to define, on the basis of a technical analysis, the effect of various types, sizes, and shapes of such anomalies on the suitability of the whole weld for a specific service.

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[9] Y.-Y. Wang and M. Liu, "A Comprehensive Update in the Evaluation of Pipeline Weld Defects," U.S. DOT Agreement No. DTRS56-03-T-0008, PRCI Contract No. PR-276-04503, draft report to DOT and PRCI, November 2004.

This use of this annex is restricted to the following conditions:

— circumferential welds between pipes of equal specified wall thickness;

— nondestructive inspection performed for essentially all welds;

— no gross weld strength undermatching, see A.3.2.1;

— maximum axial design stress no greater than the SMYS;

— maximum axial design strain no greater than 0.5 %;

— welds in pump and compressor stations, fittings, and valves in the main line are excluded;

— Repair welds are excluded for Options 1 and 2, but can be assessed using Option 3 with the company's approval, see A.5.1.5.1.

A.2 Stress Analysis

A.2.1 Axial Design Stress

To use this annex, a stress analysis shall be performed to determine the maximum axial design stresses to which the girth welds may be subjected to during construction and operation. The stress analysis shall include stresses during pipeline installation and stresses induced by operational and environmental conditions.

NOTE Under typical onshore construction conditions, the highest axial stress may occur during the pipe lowering-in process. The lowering-in stress is predominantly controlled by the lift height of the pipe relative to the bottom of the trench and the lateral movement from the skids to the center of the trench. The stresses from horizontal directional drilling can be estimated from the curvature of the pipe path, pull force, and the interaction between the pipe and surrounding soil (including friction).[10] These stresses may reach their peak values at different times.

The maximum axial design stress shall be the maximum total axial stress at any given time during the design life of the pipeline.[11]

A.2.2 Cyclic Stress

A.2.2.1 Analysis

The cyclic stress analysis shall include the determination of the predicted fatigue spectrum to which the pipeline will be exposed over its design life. This spectrum shall include but is not limited to stresses imposed by hydrostatic testing, operation pressure, installation stresses, and, where applicable, thermal, seismic, and subsidence stresses. The spectrum should consist of several cyclic axial stress levels and the number of cycles applicable to each. If the stress levels vary from cycle to cycle, a suitable counting method, such as the rainflow method, should be used to determine cyclic stress levels and cycle count. [12]

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[10] More details of the stress analysis may be found in reference M. Liu, Y.-Y. Wang, and G. Rogers, "Stress Analysis of Pipe Lowering-in Process During Construction," Proceedings of the 7th International Pipeline Conference, Paper No. IPC2008- 64630, Calgary, Alberta, Canada, September 29-October 3, 2008.

[11] For consistency with the computation of the material's flow stress in this annex, stress-strain relations based on minimum specified values are recommended when converting axial strains to axial stresses. Using actual stress-strain relations may result in the overestimation of the applied load level, as the flow stress is computed from the minimum specified values (e.g., see A.5.1.3).

[12] For an example of the use of the rainflow method, see N. E. Dowling, "Fatigue Failure Predictions for Complicated Stress-Strain Histories," *Journal of Materials*, Volume 7, Number 1, pp. 71 to 87, March 1972.

The fatigue spectrum severity, S^*, is computed from Equation (A.1):

$$S^* = N_1(\Delta\sigma_1)^3 + N_2(\Delta\sigma_2)^3 + ...N_i(\Delta\sigma_i)^3 + ... + N_k(\Delta\sigma_k)^3 \quad \text{(A.1)}$$

where

S^* is the spectrum severity;

N_i is the number of cycles at the ith cyclic stress level;

$\Delta\sigma_I$ is the ith cyclic stress range, in kips per in.^{2} (ksi);

k is the total number of cyclic stress levels;

i is the number ith cyclic stress, from 1 to k.

If the spectrum severity is less than 5×10^6 and if the use of "steel in-air" crack growth curves in BS 7910 is appropriate, Options 1 and 2 acceptance criteria (A.5.1.3 and A.5.1.4) shall be applied without any further fatigue analysis. [13]

If the spectrum severity exceeds 5×10^6 and/or in-air crack growth curves are not applicable, Options 1 and 2 may be used with further analysis, or Option 3 procedures may be applied. [14]

A.2.2.2 Environmental Effects on Fatigue

The enlargement of weld imperfections due to fatigue is a function of stress intensity, cycles of loading, imperfection size, and the environment at the crack tip. In the absence of contaminating elements, oil and hydrocarbons are considered no worse than air. Water, brine, and aqueous solutions that contain CO_2 or H_2S may, however, increase the growth rate. It is normal for minor amounts of these components to be present in nominally noncorrosive pipelines. When the concentration of either CO_2 or H_2S exceeds typical historical levels experienced in noncorrosive pipelines, this annex shall not be used, unless evidence exists that the proposed levels do not result in acceleration of fatigue crack growth or adequate corrosion inhibition is applied. The effects of environment on fatigue crack growth external to the pipe at girth welds are normally mitigated by external coating and cathodic protection, and do not limit the use of this annex.

A.2.3 Sustained-load Cracking

Certain environments may enhance imperfection growth in service at sustained load or induce brittleness in the material surrounding the imperfection to the point that an otherwise dormant imperfection becomes critical. These environments typically contain H_2S, but may contain strong hydroxides, nitrates, or

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[13] The implied safety factor in the fatigue spectrum severity limit for Options 1 and 2 varies, depending on, for example, the pipe wall thickness and distribution of fatigue spectrum. For a wide range of onshore and offshore pipeline scenarios, the spectrum severity limit is estimated to provide a safety factor of more than 2 or 5 on cycles when the fatigue growth rates are based on mean+2 standard deviation or mean values of BS 7910 (e.g., Table 8.3, R > 0.5 in BS 7910:2019), respectively.

[14] Options 1 and 2 provide an adequate safety factor against fracture due to moderate cyclic loading provided the aforementioned "steel-in-air" curve is applicable. In other environments, for example, when determining allowable defect sizes at the OD of an offshore pipeline with fusion-bonded epoxy field joint coating and under cathodic protection, use of the "steel-in-air" curve is not appropriate and use of Options 1 or 2 may not be sufficiently conservative. Similarly, if cyclic loading exceeds the defined spectrum severity of 5×10^6, for example, due to cyclic stresses from offshore installation loads on a pipe lay stinger, use of Options 1 or 2 may also not be sufficiently conservative.

carbonates. When these materials are present inside the pipe, a minimum threshold stress shall be established, and this annex shall not be used if the calculated stress exceeds the threshold value. With respect to H_2S service, the definition of such service shall be that given in NACE MR0175/ISO 15156. Although external exposure to carbonates and nitrates in the soil has been shown to produce stress corrosion cracking (SCC) in a small number of cases, the cracking is normally axial and is associated with circumferential stress rather than axial stress. However, circumferential SCC failures may occur at locations where longitudinal stresses have increased over the life of the pipeline (e.g., at overbends above unstable slopes).

The frequency and severity of SCC can be mitigated using proper coating and proper cathodic protection. The use of this annex is not precluded when direct exposure to the aggressive environment is prevented by a coating designed to resist the environment.

A.2.4 Dynamic Loading

The stress analysis shall include consideration of potential dynamic loading on girth welds, such as loads from closure of check valves. This annex does not apply to welds strained at a strain rate greater than 10^{-3} second (a stress rate of 30 ksi/sec for steel).

A.2.5 Residual Stress

The effects of welding residual stress are accounted for by specifying the minimum CTOD toughness and Charpy energy, and by incorporating appropriate conservatism in Options 1 and 2 procedures (A.5.1.3 and A.5.1.4). The determination of residual stress is not required under these conditions. The effects of residual stress shall be evaluated for all time-dependent failure mechanisms, such as fatigue.

A.3 Welding Procedure

A.3.1 General

The controls of the variables necessary to ensure an acceptable level of fracture toughness in a welding procedure are more stringent than those controlling welding procedures without minimum toughness requirements. An appropriate quality control program shall be established to ensure welding is performed within the parameters of the qualified welding procedure. Qualification of welding procedures to be used with this annex shall be in accordance with Section 5 or Section 12 of this standard, with the additional mechanical property testing in accordance with A.3.4 and the essential welding variables listed in A.3.2.

A.3.2 Essential Variables

Any change in the essential variables listed in Table A.1 shall require requalification of the welding procedure.

Table A.1—Essential Variables for Qualification of Welding Procedure Specifications in Accordance with this Annex

Welding Variable Subsection[a]	Change Requiring Requalification
A.3.2.1 Welding Process	a) A change in welding process
	b) A change in mode of arc transfer
	c) A change in method of application (manual, semiautomatic, automatic)
A.3.2.2 Base Material	a) A change in the strength grade
	b) A change in the source/mill for steel (slabs, ingots, billets, etc.)
	c) A change in the processing facility for plate or coil used to make pipe
	d) A change in the pipe manufacturing facility
	e) A change in the pipe manufacturing process, including pipe forming and heat treatment process (EW, SAWL, SAWH, seamless, expanded vs. not expanded, heat treated vs. not heat treated)
	f) A change in chemistry outside the limits defined by the manufacturing procedure specification (MPS)[b] or, alternatively, if the pipe is not manufactured to an MPS, a change in any of the following: 1) increase in Pcm ≥ 0.02 for steels with carbon content ≤ 0.12 % [Pcm = C + Si/30 + (Mn+Cu+Cr)/20 + Ni/60 + Mo/15 + V/10 + 5B]; 2) increase in CE ≥ 0.03 for steels with carbon content > 0.12 % [CE = C + Mn/6 + (Cu + Ni)/15 + (Cr + Mo + V)/5]; 3) increase in C ≥ 0.02 %. Chemistry compositions requirements shall be based on heat analysis results.
	g) A change in wall thickness greater than ±0.125 in. (3.2 mm) from the wall thickness used during procedure qualification.
	h) A change in the specified pipe OD more than –0.25 D or +0.5 D, where D is the pipe OD of procedure qualification welds.
A.3.2.3 Joint Design	A major change in joint design. [c]
A.3.2.4 Position	a) A change in position from rolled to fixed
	b) A change from vertical to horizontal or vice versa
A.3.2.6 Time Between Passes	An increase in the time between the completion of the root bead and the start of the second bead. Not required for low hydrogen processes.
A.3.2.7 Direction of Welding	A change in direction (e.g., from vertical down to vertical up or vice versa).
A.3.2.8 Shielding Gas	a) A change from one AWS A5.32 shielding gas classification designation to another
	b) A change in the nominal qualified flow rate of shielding gas of more than ±10 %

Table A.1—Essential Variables for Qualification of Welding Procedure Specifications in Accordance with this Annex (continued)

Welding Variable Subsection[a]	Change Requiring Requalification
A.3.2.9 Shielding Flux	A change in the shielding flux, including a change in manufacturer within an AWS classification.
A.3.2.10 Electrical Characteristics	a) A change in the current/polarity type (DCSP/DCEN, DCRP/DCEP, AC)
	b) A change of more than ±10 % from the nominal heat input [d] range recorded for each weld pass during the procedure qualification [e]
A.3.2.11 Preheat Temperature	A change in the requirements for preheat temperature.
A.3.2.12 Interpass Temperature	A change in the interpass temperature, [f] if the interpass temperature is lower than the minimum interpass temperature recorded during the procedure qualification test or if the interpass temperature is 45 °F (25 °C) higher than the maximum interpass temperature recorded during the procedure qualification test.
A.3.2.13 Postweld Heat Treatment	A change in the PWHT requirements.

[a] The subsection numbers in this column are provided for referencing purposes.
[b] For MPS-controlled chemistry, the user is advised to consider if the chemistry limits are sufficient to ensure the desired level of weld mechanical performance.
[c] Minor changes in the angle of bevel or the land of the welding groove are not essential variables.
[d] As calculated in 5.3.2.6.
[e] Unless otherwise specified by company requirements, the 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.
[f] As defined in 3.1.29.

Table A.2—Allowed Range of Variation from the Targeted Mean Values for a Lot Defined by Controlled Chemical Composition (see A.3.2.5)

Alloying Element	Solid Wire Composition	Metal-cored Electrode Weld Deposit
%C	±0.02	±0.02
%Mn	±0.10	±0.15
%Si	±0.10	±0.10
%Ni	±0.10	±0.10
%Cr	±0.05	±0.05
%Mo	±0.05	±0.05
%Ti	±0.01	±0.02
%V	±0.02	±0.02
%Nb	±0.01	±0.01
%Cu	±0.05	±0.05
%P	±0.005	±0.005
%S	±0.005	±0.005
%B	±0.001	±0.002

A.3.3 Qualification of Multiple Pipe Sources

For low-dilution welding processes, such as mechanized gas metal arc welding, the qualification of a common weld procedure for multiple pipe materials as defined by A.3.2.2 a) through f) may be achieved by ensuring:

a) each material HAZ is CTOD tested per A.3.4.3.3;

b) each material HAZ is CVN tested per A.3.4.2;

c) cross-weld tensile testing is performed on all test weld combinations used in Items a) or b).

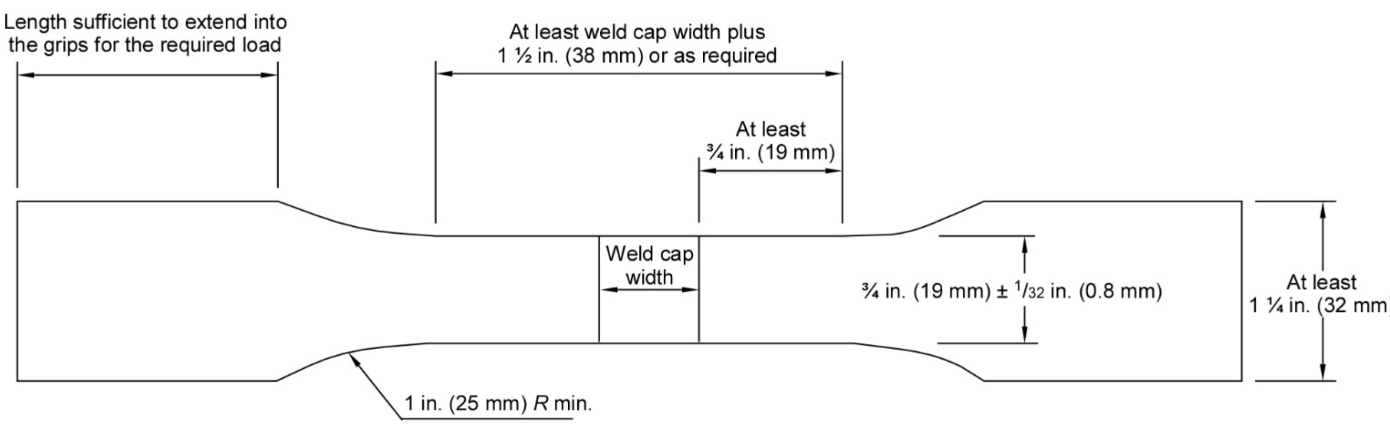
It shall not be necessary to test welds made with all possible combinations of pipe material.

A.3.4 Testing of Weld Joints—Butt Welds

A.3.4.1 Weld Tensile Properties

A.3.4.1.1 Specimen Preparation and Testing

The test specimens shall be of rectangular cross-section with reduced width at the mid-length region. The number and location of specimens shall be as indicated in Table 3 and Figure 3 in Section 5. The specimen dimensions shall be as indicated in Figure A.1. The weld reinforcement shall be removed. The weld shall be centered nominally in the length of the reduced section. The ends of the specimens shall be sufficient for the grips.



NOTE The reduced section shall be parallel within 0.010 in. (0.25 mm)

Figure A.1—Top View (Width in Circumferential Direction) of the Tensile Test Specimen

A.3.4.1.2 Requirements

The requirements for the weld based on the mechanical property test results shall be as follows:

a) If the specimen breaks at a strength equal to or greater than the SMTS of the pipe, the result is acceptable and no further testing is required. Although tensile specimen failure in the weld is acceptable, provided the strength requirement is met, gross weld strength undermatching should be avoided. [15]

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[15] The company is cautioned to consider weld undermatching issues as they relate to pipeline bending or other longitudinal tensile loads. An example of assessing weld strength undermatching is given in Y.-Y. Wang, M. Liu, D. Horsley, and G. Bauman, "A Tiered Approach to Girth Weld Defect Acceptance Criteria for Stress-based Design of Pipelines," 6th International Pipeline Conference, Paper No. IPC2006-10491, Calgary, Alberta, Canada, September 25-29, 2006.

b) If the specimen breaks in the weld or HAZ at a strength below the specified maximum yield strength of the pipe material (API 5L, PSL 2), the weld shall be rejected.

c) If a specimen breaks outside the weld or HAZ at a tensile strength less than 100 %, but not less than (lower than) 95 % of the SMTS of the pipe material, two additional specimens may be tested. Both retest specimens shall meet the SMTS of the pipe material. If either retest specimen fails to meet the minimum tensile strength requirement, no retesting is permitted.

d) Any specimen that breaks outside the weld or HAZ at a tensile strength less than (lower than) 95 % of the SMTS of the pipe material shall be rejected, and no further retesting is permitted.

A.3.4.2 Charpy Impact Energy

A.3.4.2.1 Specimen Preparation

Charpy V-notch impact test specimens shall be prepared with their lengths parallel to the pipe axis. The largest size specimens permitted by the pipe wall thickness should be used. The thickness of subsized specimens should have at least 80 % of the wall thickness. Six specimens shall be removed from each of the following positions: 12 o'clock, 6 o'clock, and 3 o'clock or 9 o'clock, for a total of 18 specimens. For each of these positions, three specimens shall have the V-notch placed in the weld centerline; the other three shall have the V-notch placed in the HAZ as shown in Figure A.2.

A.3.4.2.2 Testing

At least nine valid specimens for each notch location (weld metal or HAZ) shall be tested at or below the minimum design temperature in accordance with the requirements of ASTM E23.

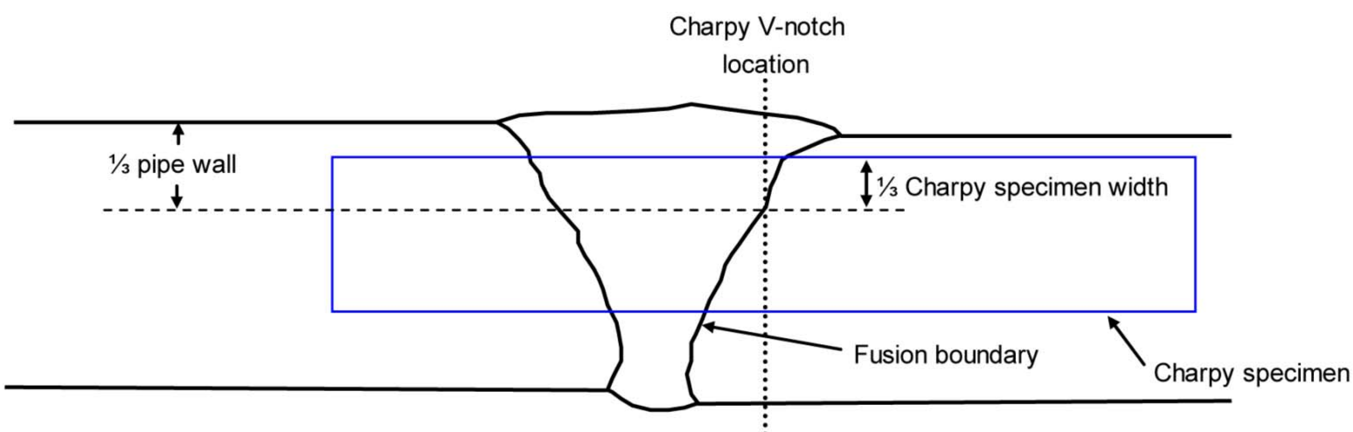

Figure A.2—Charpy Specimen and V-notch Location for HAZ Impact Testing

A.3.4.2.3 Requirements

The impact energy for each notch location (weld metal or HAZ) shall be acceptable when the following criteria are met:

a) the average absorbed energy for each set of three specimens equals or exceeds 30 ft-lb (40 J);

b) the minimum individual absorbed energy for each set of three specimens equals or exceeds 22 ft-lb (30 J);

c) when subsized Charpy specimens are used, the energy requirements, without correction or conversion, as stated in items a) and b) above shall apply.

A.3.4.2.4 Retesting

Retesting shall be permitted when no more than one specimen in each group of nine specimens (weld metal or HAZ) generates an absorbed energy less than 22 ft-lb (30 J), but the average absorbed energy from the set of three specimens that contains the low individual value exceeds 30 ft-lb (40 J). The retest requirements shall be as follows:

a) The three retest specimens shall be extracted from a location as close as possible to the location of the specimen that generated the low result.

b) The absorbed energy of all three retest specimens shall meet or exceed 30 ft-lb (40 J).

If the above retest criteria are satisfied, the Charpy results shall be acceptable. If the above criteria are not satisfied, no further retesting shall be permitted, and the weld shall be rejected.

A.3.4.3 Fracture Toughness Testing

A.3.4.3.1 General

To use the alternative acceptance criteria, the fracture toughness of the weld shall be determined by testing in accordance with BS EN ISO 15653, as supplemented by this annex.

A.3.4.3.2 Specimen Preparation

The preferred test piece ($B \times 2B$) shall be used. As shown in Figure A.3, the specimen should be oriented so that its length is parallel to the pipe axis and its width is in the circumferential direction; thus, the crack tip line is oriented in the through-thickness direction. The specimen thickness (see Figure A.4) should be equal to the pipe thickness less the minimum amount of milling and grinding necessary to produce a specimen with the prescribed rectangular cross-section and surface finish from a curved pipe segment. The weld reinforcement shall be removed. The specimen should be etched after initial preparation to reveal the weld deposit and the geometry of the HAZ. For weld metal tests, the notch and fatigue crack tip should be located at the center of the weld and completely in weld metal (see Figure A.5).

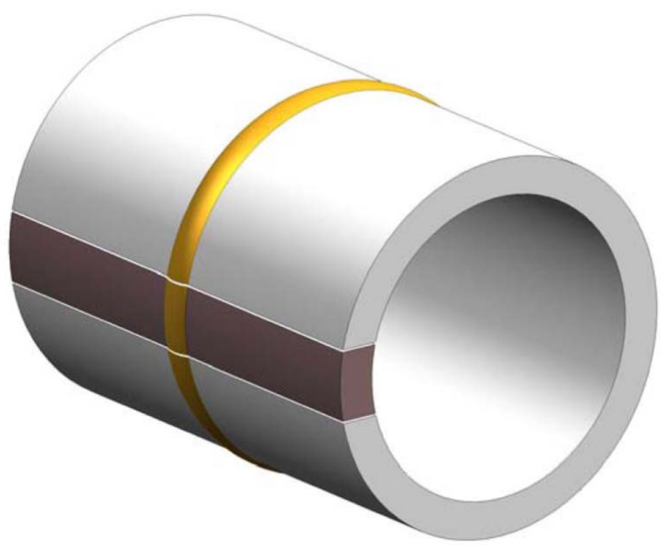

Figure A.3—Orientation of CTOD Test Specimen

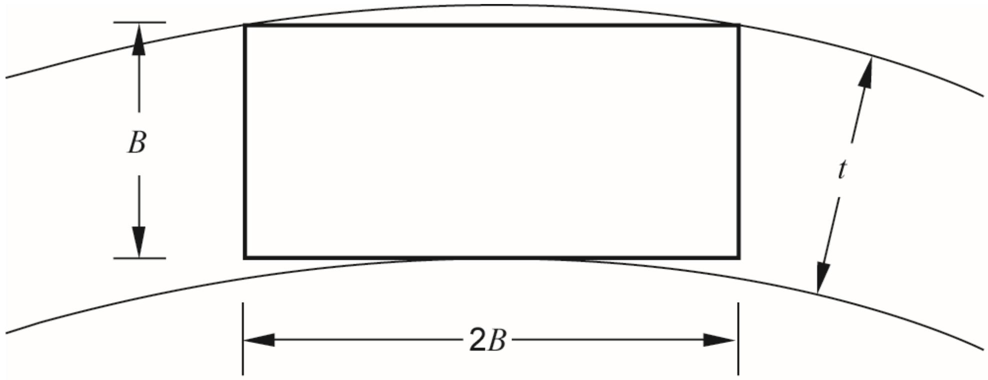

Figure A.4—Machining Objective for CTOD Test Specimen with Respect to Pipe Wall

For the HAZ tests, the fatigue precracks shall be aimed to intersect the largest unrefined coarse grain HAZ regions within the central 70 % of the specimen thickness (see Figure A.6). Each of the three HAZ specimens should be aimed at different coarse grain regions within the central 70 %. If there are fewer than three such regions in the central 70 %, multiple specimens may be aimed at the same region. Multiple specimen sampling of the cap pass coarse grain HAZ should be avoided. No more than one specimen should be devoted to the cap pass HAZ. To identify coarse grain HAZ regions, it may be useful to conduct a microhardness survey to locate the coarsest HAZ regions that have undergone the least amount of tempering by subsequent weld passes.

A.3.4.3.3 CTOD Toughness Testing

For each welding procedure, both the weld metal and the HAZ shall be tested. Each set (weld metal or HAZ) of tests shall consist of at least three valid specimen tests performed at or below the minimum design temperature. The three specimens shall consist of one each from the nominal 12 o'clock, 3 o'clock or 9 o'clock, and 6 o'clock positions on the test weld and should be permanently marked to identify the original position.

After testing, particular attention should be given to the qualification requirements (particularly crack front straightness) of BS EN ISO 15653; these criteria deal with the geometry of the fatigue crack front.

For this annex, the appropriate value of CTOD shall be δc, δu, or δm. When δm applies, care should be taken to measure from the point of first attainment of maximum load. Pop-ins shall be assessed in accordance with BS EN ISO 15653. The test report shall meet the test report requirements of BS EN ISO 15653. Particular attention should be given to reporting the position of the test specimen in the qualification weld and to distinguishing whether the reported CTOD value represents δc, δu, or δm. The test report shall also include a legible copy of the load-displacement record and a record of the appearance of the fracture surfaces; the latter requirement can be satisfied by a clear photograph of one or both fracture surfaces, or by retaining one or both fracture surfaces (properly preserved and identified) for direct observation. Unless otherwise specified by the company, the notch location shall be defined as weld positional per BS EN ISO 15653; that is, no postweld metallography is required.

NOTE δc, δu, and δm are mutually exclusive terms defined in BS EN ISO 15653 that describe the three possible and mutually-exclusive outcomes of the test. The value of δi (CTOD at initiation of stable crack growth) has no significance with regard to this annex and need not be measured.

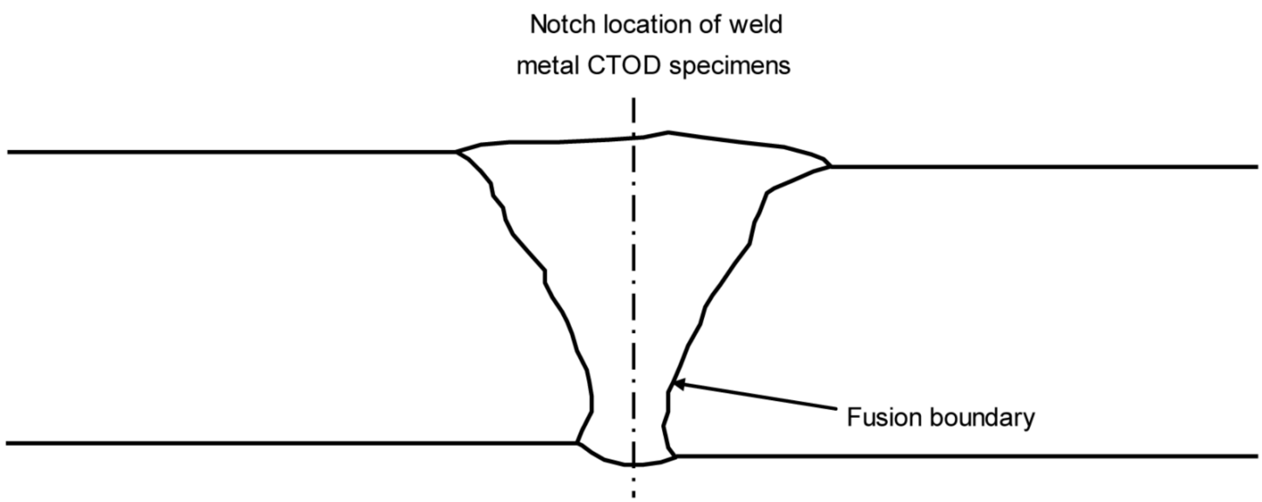

Figure A.5—Location of Notch for Weld Metal Specimen

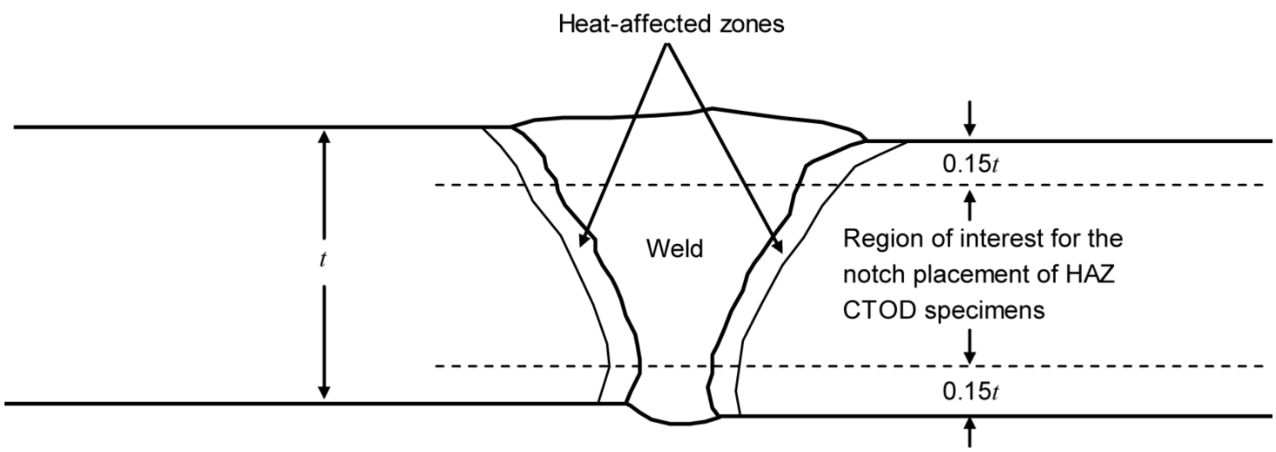

Figure A.6—Location of Notch for Heat-affected Zone Specimen

A.3.4.3.4 Retesting

Retesting shall be permitted on a one-to-one basis only when any of the following conditions exist:

a) specimens are incorrectly machined;

b) the fatigue crack front fails to meet the straightness requirements;

c) substantial weld imperfections adjacent to the crack front are observed upon the fracture of the specimen.

A.3.4.3.5 Requirements

The minimum CTOD value of all six specimens (three weld and three HAZ specimens) shall be greater than 0.002 in. (0.05 mm) to use this annex.

A.4 Qualification of Welders

Welders shall be qualified in accordance with Section 6. For mechanized welding, each operator shall be qualified in accordance with 12.7.

A.5 Inspection and Acceptable Limits

A.5.1 Planar Imperfections

A.5.1.1 General

The length and height of an imperfection, and its depth below the surface, shall be established by appropriate nondestructive inspection techniques or otherwise justified before a decision to accept or reject can be made. Conventional radiography, as described in 11.1, is adequate for measuring imperfection length but is insufficient for determining height, particularly for planar imperfections such as cracks, lack of fusion, undercutting, and some types of lack of penetration. The use of ultrasonic techniques, radiographic techniques that employ densitometers or comparative visual reference standards, acoustic imaging, inherent imperfection-size limitations due to weld-pass geometry, or any other technique for determining imperfection height is acceptable, provided the technique's accuracy has been established (e.g., see 11.4.3) and any potential inaccuracy is included in the measurement; that is, the determination of imperfection height shall be conservative. The use of conventional radiography (see 11.1) to identify imperfections that require height measurement by other means is acceptable.

A.5.1.2 Structure of the Procedures to Determine the Maximum Acceptable Imperfection Size

The procedures to determine the maximum acceptable planar imperfection size are given in three options. Option 1 is a simplified approach in graphical format. It relies on theoretically sound and experimentally validated plastic collapse criteria and has been modified by the Option 2 approach when appropriate. Option 2 is in the form of a failure assessment diagram (FAD). The FAD format allows the simultaneous consideration of brittle fracture, plastic collapse, and the interaction between those two failure modes (elastic-plastic fracture). Options 1 and 2 are limited to pipelines with limited fatigue loads as specified in A.2.2. Option 3 permits the use of validated fitness-for-purpose procedures when the cyclic loading exceeds the spectrum requirements of Options 1 and 2.

The Option 1 procedures are limited to CTOD toughness equal to or greater than 0.004 in. (0.10 mm). The Options 2 and 3 procedures may be applied at any CTOD toughness level greater than the minimum required value of 0.002 in. (0.05 mm).

The basis of the Options 1 and 2 procedures places no limit on pipe diameter or diameter-to-wall thickness ratio (D/t ratio). Theoretical validation has shown that the procedures are valid for $D/t \geq 10$.

Line pipes with ultrahigh Y/T ratio ($Y/T > 0.95$) are often associated with low uniform strain (engineering strain at ultimate tensile stress) and low ductility. Additional testing and validation may be necessary to use the alternative acceptance criteria in this annex.

A.5.1.3 Determination of Acceptable Imperfection Size by Option 1

A.5.1.3.1 General

Two sets of acceptance criteria are given, depending on the CTOD toughness value.

When the CTOD toughness is equal to or greater than 0.010 in. (0.25 mm), the maximum acceptable imperfection size is given in Figure A.7 at various load levels (P_r). If the load level is not given in Figure A.7, the maximum acceptable imperfection size can be obtained by interpolating the adjacent curves or by taking the value of the next higher load level.

When the CTOD toughness is equal to or greater than 0.004 in. (0.10 mm) and less than 0.010 in. (0.25 mm), the maximum acceptable imperfection size shall be as given in Figure A.8.

The acceptable imperfection size may be more limiting than that from the Option 2 procedure as the limits in Figure A.7 and Figure A.8 were calibrated to a CTOD toughness of 0.010 in. (0.25 mm) and 0.004 in. (0.10 mm), respectively.

The total imperfection length shall be no greater than 12.5 % of the pipe circumference. The maximum imperfection height shall be no greater than 50 % of the pipe wall thickness.

The allowable height of the buried imperfections is treated the same as the allowable height of the surface-breaking imperfections.

The built-in conservatism in the acceptable imperfection size can accommodate a certain amount of undersizing of imperfection height without negatively impacting weld integrity. The assumed height uncertainty built into the conservatism is the lesser of 0.060 in. (1.5 mm) and 8 % of pipe wall thickness.

The allowable imperfection height shall be reduced by the difference between the height undersizing error of the qualified inspection procedure and the assumed height uncertainty, if the height undersizing error is greater than the assumed height uncertainty. No change should be made to the allowable imperfection height, if the height undersizing error is less than the assumed height uncertainty. [16]

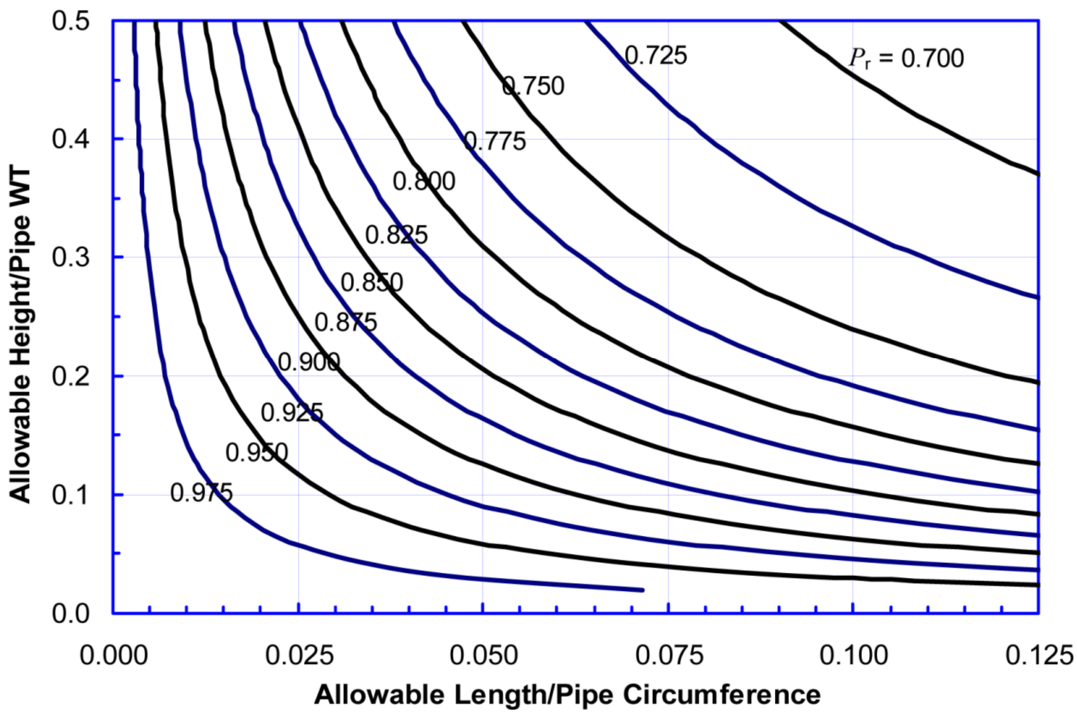

Figure A.7—Option 1 Imperfection Limits for CTOD ≥ 0.010 in. (0.25 mm)

[16] See example problem in A.5.1.3.3.

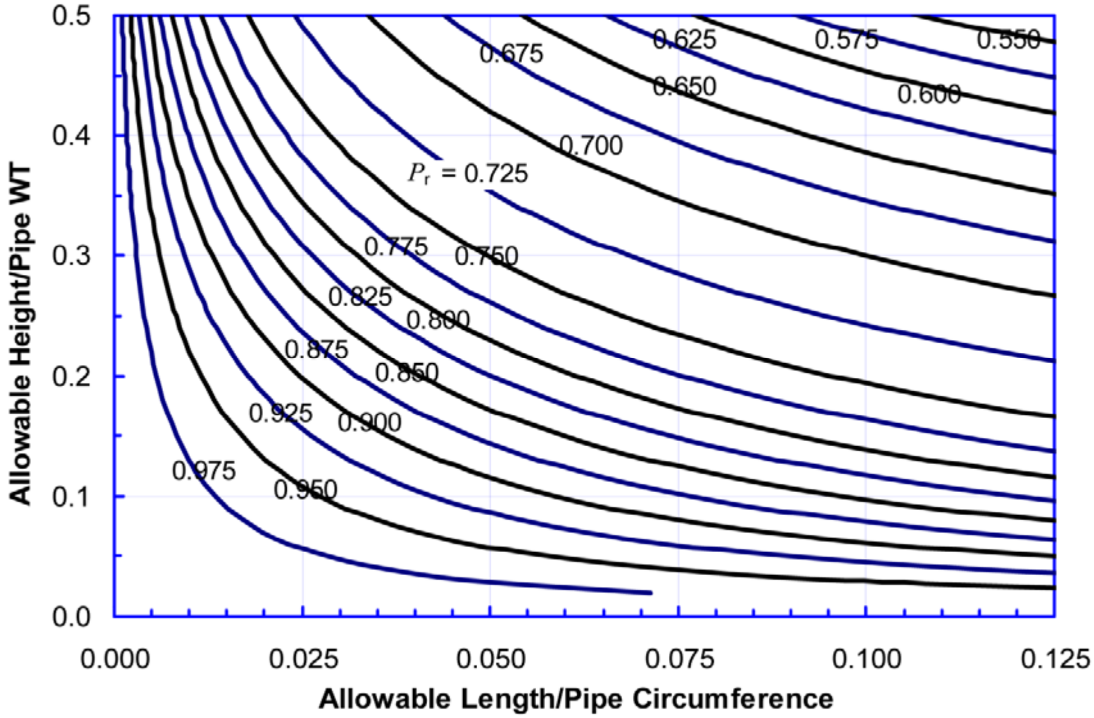

Figure A.8—Option 1 Imperfection Limits for 0.004 in. (0.10 mm) ≤ CTOD < 0.010 in. (0.25 mm)

A.5.1.3.2 Computation of the Load Level (P_r)

The material's flow stress shall be calculated to obtain the load level P_r. The flow stress shall be the averaged value of the SMYS and SMTS. Alternatively, the flow stress of API 5L, Grades X52 to X80, may be conservatively estimated by Equation (A.2).

$$\sigma_f = \sigma_y \left[1 + \left(\frac{21.75}{\sigma_y} \right)^{2.30} \right] \quad \text{(A.2)}$$

where the pipe grade, σ_y, is in the unit of ksi.

The load level, P_r, is given in Equation (A.3):

$$P_r = \frac{\sigma_a}{\sigma_f} \quad \text{(A.3)}$$

A.5.1.3.3 Example of Option 1 Application

The following is an example for performing an ECA with the Option 1 methodology. A 24-in. OD pipeline with a specified wall thickness (t) of 0.50 in. with the grade of API 5L X70 is considered. After reviewing A.1 and A.2 of this annex and consulting with the project's engineer (as required), it is understood that the maximum axial design stress is 61.5 ksi. Weld test data conducted per the requirements of the annex indicate that the minimum CTOD value is 0.011 in. These parameters are summarized as follows:

Pipe OD: 24 in.

Pipe t: 0.500 in.

SMYS: 70 ksi

SMTS: 82 ksi

CTOD: 0.011 in.

σ_a: 61.5 ksi

Allowance for inspection: 0.050 in.

The following steps detail the ECA computation.

Step 1: Determine Flow Stress

Determine the flow stress with Equation (A.2) by substituting the 70 ksi for σ_y [Equation (A.4)]:

$$\sigma_f = 70\left[1+\left(\frac{21.75}{70}\right)^{2.30}\right] = 74.76 \quad \text{(A.4)}$$

Note that for this example, the flow stress can alternatively be determined as the averaged value of SMYS and SMTS, or in this case, 76 ksi, a value very close to the value derived using Equation (A.2).

Step 2: Determine Applied Load Level

The load level P_r is now calculated by inserting the aforementioned values for σ_a and σ_f [Equation (A.5)]:

$$P_r = \frac{\sigma_a}{\sigma_f} = \frac{61.5}{74.76} = 0.823 \quad \text{(A.5)}$$

Step 3: Determine Initial Allowable Imperfection Size

Figure A.7 is utilized for determining the initial allowable imperfection size (CTOD ≥ 0.010 in. or 0.25 mm). The curve of P_r = 0.825 in the figure is now used for the interpolations. The allowable imperfection size is tabulated in Table A.3 and shown in Figure A.9.

The allowable height quantities, shown in the second column of Table A.3, are derived by multiplying the allowable height/pipe wall thickness value by the t that in this example is 0.500 in. Similarly, the allowable length is calculated by multiplying the allowable length/pipe circumference quantity by the pipe circumference (π × OD) or 3.14 × 24 in.

Table A.3—Initial Allowable Imperfection Size for P_r = 0.825

Allowable Height/Pipe Wall Thickness	**Allowable Height** in.	**Allowable Length/Pipe Circumference**	**Allowable Length** in.
0.5	0.25	0.025	1.9
0.4	0.2	0.032	2.4
0.3	0.15	0.042	3.2
0.2	0.1	0.063	4.8
0.1	0.05	0.128	9.7

Step 4: Determine Height Adjustment

Assumed height uncertainty = lesser of 8 % t and 0.060 in. = 0.040 in. (1.02 mm).

Allowance for inspection (i.e., inspection error) = 0.050 in. (1.27 mm).

Imperfect height adjustment = allowance for inspection – assumed height uncertainty

= 0.050 – 0.040

= 0.010 in. (0.25 mm).

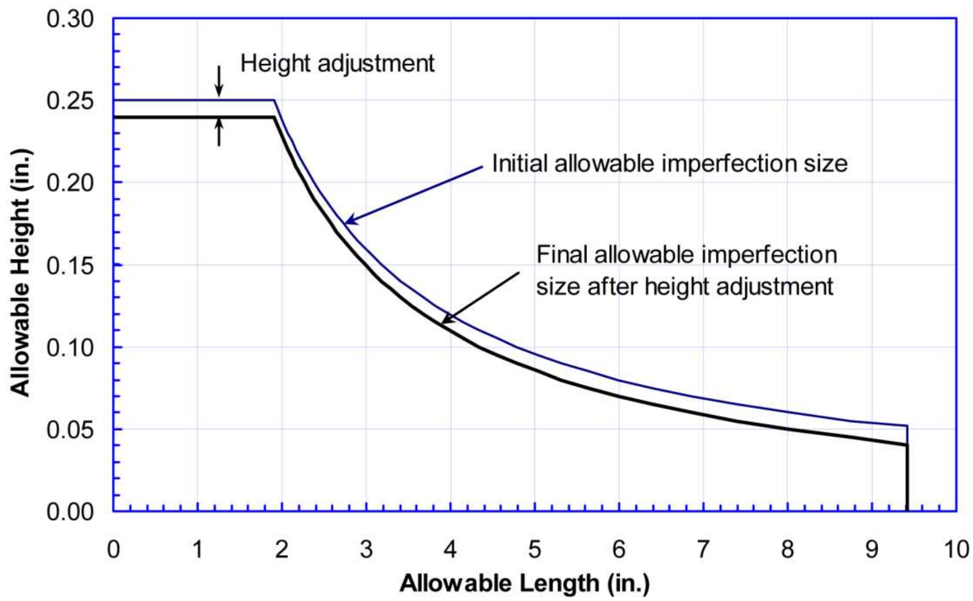

Figure A.9—Allowable Imperfection Size Curves Before and After Height Adjustment

Step 5: Produce Final Acceptance Table

The results of the ECA should be tabulated in a user-friendly format. Table A.4 suggests an operator-friendly format for this ECA example. However, a project with a heavier wall thickness may have more rows in a similar table. [17]

Table A.4—Example Acceptance Table

Allowable Imperfection Height in.	**Allowable Imperfection Length** in.
0 to 0.05	8.0
0.05 to 0.15	3.0
0.15 to 0.24	1.9
>0.24	0.0

[17] Further adjustments may be desirable, see Step 8) of A.5.1.4.2.

A.5.1.4 Determination of Acceptable Imperfection Size by Option 2

A.5.1.4.1 Background

The underlining Option 2 procedure is the FAD. There are three key components in the assessment in FAD format (see Figure A.10):

1) failure assessment curve (FAC);

2) stress or load ratio, S_r or L_r; and

3) toughness ratio, K_r.

The FAC is a locus that defines the critical states in terms of the stress and toughness ratios. The stress ratio defines the likelihood of plastic collapse. The toughness ratio is the ratio of applied crack driving force over the material's fracture toughness. It defines the likelihood of brittle fracture.

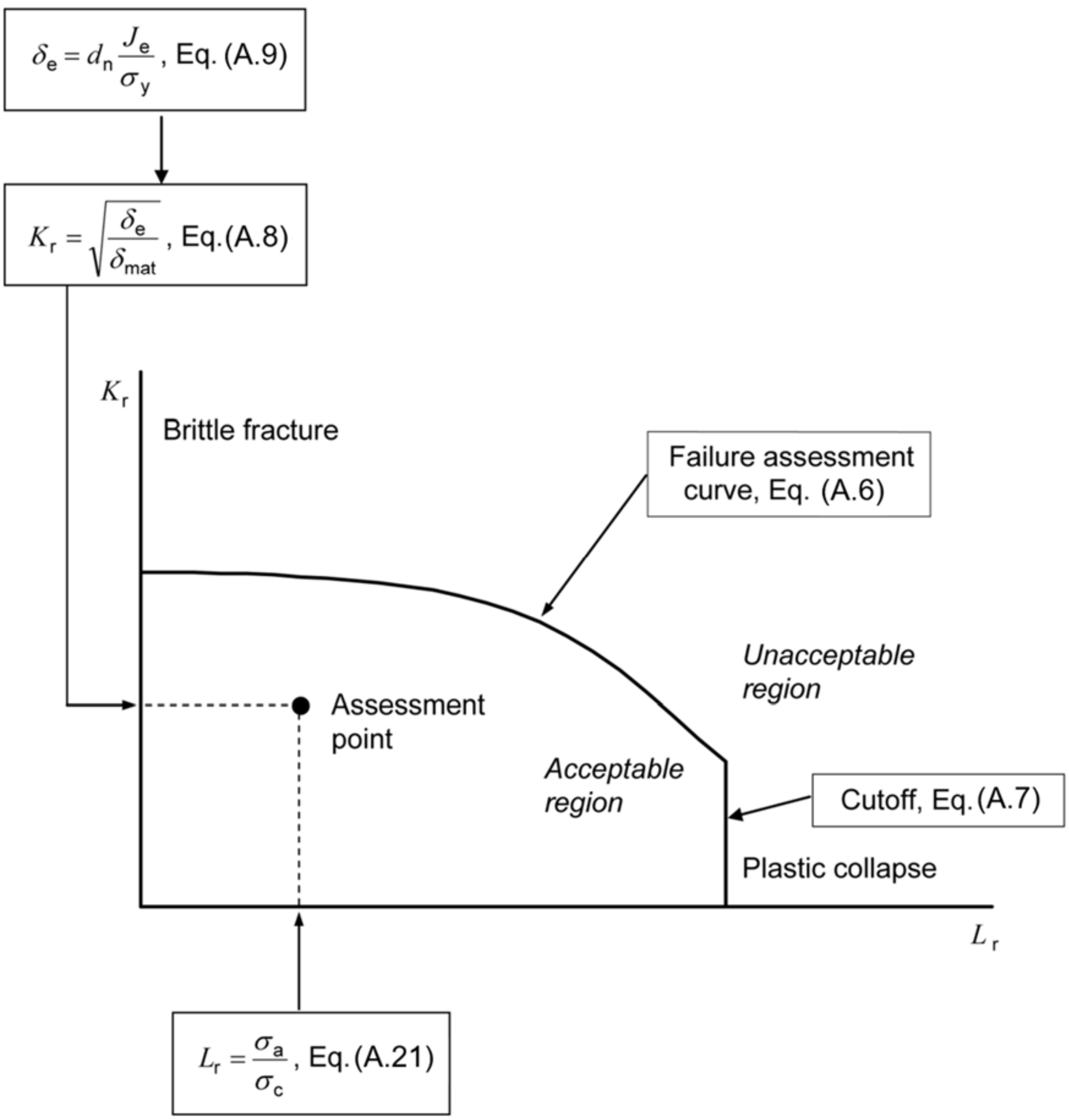

Figure A.10—Schematic Overview of the Option 2 Procedure

The FAD approach is computationally complex. Proficiency and understanding of fracture mechanics is necessary to ensure the procedure is applied correctly. A validated computer program should greatly simplify the computation.

A.5.1.4.2 Determination of Critical Imperfection Size

The critical imperfection size can be computed iteratively using equations provided in A.5.1.4.3. The following steps may be followed.

1) Select an imperfection size as a start point. A reasonable start point is an imperfection with the maximum allowed height, η = 0.5, and a small imperfection length that represents the smallest imperfection length that the selected inspection methods can confidently detect.

2) Determine the assessment point in the FAD format in accordance with A.5.1.4.3.

3) If the assessment point falls inside the safe region, increase the imperfection length and repeat Step 2).

4) If the assessment point falls outside the safe region, decrease the imperfection length and repeat Step 2).

5) If the assessment point falls on the FAC:

   a) this represents a critical state with the combination of load, material property, and imperfection size. Make a note of the imperfection height and length;

   b) reduce the imperfection height by a small increment, such as $\Delta\eta$ = 0.05. Start from the imperfection length determined in item a) and repeat Step 2);

6) Make a table of critical imperfection height and length.

7) Apply a safety factor of 1.5 on the imperfection length to produce a draft table of the allowable imperfection height versus imperfection length.

8) Make necessary adjustment to the draft table to ensure detectability of the selected inspection methods [18] and sound welding practice. [19] Produce the final table of the allowable imperfection height versus imperfection length.

The total imperfection length shall be no greater than 12.5 % of the pipe circumference. The maximum imperfection height shall be no greater than 50 % of the pipe wall thickness.

The allowable height of the buried imperfections is treated the same as the allowable height of the surface-breaking imperfections.

The built-in conservatism in the acceptable imperfection size can accommodate a certain amount of undersizing of imperfection height without negatively impacting weld integrity. The assumed height uncertainty built into the conservatism is the lesser of 0.060 in. (1.5 mm) and 8 % of pipe wall thickness.

The allowable imperfection height shall be reduced by the difference between the height undersizing error of the qualified inspection procedure and the assumed height uncertainty if the height undersizing error is greater than the assumed height uncertainty. The reduction shall be done after applying the maximum imperfection height (i.e., 50 % of pipe wall thickness (see A.5.1.3.3). No change should be made to the allowable imperfection height if the height undersizing error is less than the assumed height uncertainty.

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[18] It is necessary to ensure that the smallest imperfection height and length could be reliably detected by the selected inspection method.
[19] For thick-walled pipes, the maximum allowable height of the 50 % wall thickness could be a large value. The maximum allowable height may be reduced if such a large value is judged unnecessary by sound welding practice.

A.5.1.4.3 Determination of the Key Components in the FAD Procedure

Failure Assessment Curve (FAC)

The FAC is given as Equation (A.6):

$$K_r = f\left(L_r\right) = \left(1 - 0.14L_r^{\ 2}\right)\left[0.3 + 0.7\exp\left(-0.65L_r^{\ 6}\right)\right] \quad \text{(A.6)}$$

The cut-off of the FAC on the L_r axis is per Equation (A.7):

$$L_r^{cutoff} = \frac{\sigma_f}{\sigma_y} \quad \text{(A.7)}$$

where the flow stress σ_f is the averaged value of SMYS and SMTS, or alternatively determined by Equation (A.2).

Assessment Point, Toughness Ratio *K_r*

The toughness ratio K_r is given as Equation (A.8):

$$K_r = \sqrt{\frac{\delta_e}{\delta_{mat}}} \quad \text{(A.8)}$$

where δ_{mat} is the CTOD toughness of the material. The elastic component of the CTOD driving force, δ_e, may be computed as Equation (A.9):

$$\delta_e = d_n \frac{J_e}{\sigma_y} \quad \text{(A.9)}$$

The J to CTOD conversion factor, d_n, is estimated as Equation (A.10):

$$d_n = 3.69\left(\frac{1}{n}\right)^2 - 3.19\left(\frac{1}{n}\right) + 0.882 \quad \text{(A.10)}$$

where n is the strain hardening exponent in the following stress (σ)-strain (ε) relation in Equation (A.11):

$$\varepsilon = \frac{\sigma}{E} + \left(0.005 - \frac{\sigma_y}{E}\right)\left(\frac{\sigma}{\sigma_y}\right) \quad \text{(A.11)}$$

where E is Young's modulus.

The strain hardening exponent may be estimated from Y/T ratio [Equation (A.12)]:

$$n = \frac{ln\left(\varepsilon_t / 0.005\right)}{ln\left\{1/\left(Y/T\right)\right\}} \quad \text{(A.12)}$$

For ferritic material of API 5L, Grades X52 to X80, the Y/T ratio may be estimated as Equation (A.13):

$$Y/T = \frac{1}{1+2\left(\frac{21.75}{\sigma_y}\right)^{2.30}} \quad \text{(A.13)}$$

and the uniform strain is estimated as Equation (A.14):

$$\varepsilon_t = -0.00175\sigma_y + 0.22 \quad \text{(A.14)}$$

The pipe grade, σ_y, is in the unit of ksi in Equation (A.13) and Equation (A.14).

The elastic J_e integral is given as Equation (A.15):

$$J_e = \frac{K_1^{\ 2}}{E/\left(1-v^2\right)} \quad \text{(A.15)}$$

and Equation (A.16):

$$K_1 = \sigma_a \sqrt{\pi a} F_b \quad \text{(A.16)}$$

The parameter F_b is a function of pipe diameter ratio, α, and relative imperfection length, β, and relative imperfection height, η [Equation (A.17)]:

$$F_b\left(\alpha,\beta,\eta\right) = \begin{cases} F_{b0}\left(\alpha,\beta,\eta\right) & \eta \geq 0.1 \text{ and } \beta \leq \frac{80}{\pi}\frac{\eta}{\alpha} \\ F_{b0}\left(\alpha,\beta=\frac{80}{\pi}\frac{\eta}{\alpha},\eta\right) & \eta \geq 0.1 \text{ and } \beta \leq \frac{80}{\pi}\frac{\eta}{\alpha} \\ F_{b0}\left(\alpha,\beta=\frac{80}{\pi}\frac{\eta}{\alpha},0.1\right) & \eta \geq 0.1 \end{cases} \quad \text{(A.17)}$$

Where

$$F_{b0}\left(\alpha,\beta,\eta\right) = \left(1.09 + 2.31\alpha^{0.791}\beta^{0.906}\eta^{0.983} + \frac{m_1}{\alpha\beta} + \alpha^{0.806}\beta m_2\right) \quad \text{(A.18)}$$

$$m_1 = -0.00985 - 0.163\eta - 0.345\eta^2 \quad \text{(A.19)}$$

$$m_2 = -0.00416 - 2.18\eta - 0.155\eta^2 \quad \text{(A.20)}$$

Assessment Point, Stress Ratio L_r

The stress ratio L_r is given as Equation (A.21):

$$L_r = \frac{\sigma_a}{\sigma_c} \quad \text{(A.21)}$$

The plastic collapse stress σ_c is given as Equation (A.22) and Equation (A.23):

$$\sigma_c = \left[\frac{\pi}{4} + 385\left(0.05 - \eta\beta\right)^{2.5}\right]\left[\cos\left(\frac{\eta\beta\pi}{2}\right) - \frac{\eta\sin\left(\beta\pi\right)}{2}\right]\sigma_y \quad \text{if } \eta\beta < 0.05 \tag{A.22}$$

$$\sigma_c = \frac{\pi}{4}\left[\cos\left(\frac{\eta\beta\pi}{2}\right) - \frac{\eta\sin\left(\beta\pi\right)}{2}\right]\sigma_y \quad \text{if } \eta\beta \geq 0.05 \tag{A.23}$$

NOTE Unit for π is in radians.

A.5.1.5 Determination of Acceptable Imperfection Size by Option 3

A.5.1.5.1 General

In most offshore pipelines and flowlines, cyclic loading during construction and operation is present. The Option 3 procedures are permitted only when the fatigue spectrum severity is greater than 5×10^6.

Subject to company approval, validated fitness-for-purpose procedures and qualification tests may be used to develop imperfection acceptance criteria. One of the most widely accepted procedures is BS 7910. The procedures shall be applied by well-qualified analysts/engineers who have demonstrated command of the principles of fracture mechanics, pipeline welding, and NDT. Any selected procedure shall be taken as a whole in developing the acceptance criteria with appropriate considerations of safety factors. It should be recognized that the basic assumptions of various public-accessible assessment procedures and qualification tests may be different from those of Options 1 and 2. Mixing parts of different procedures is discouraged.

A.5.1.5.2 Fatigue Flaw Growth

Appropriate fatigue analysis shall be conducted to determine the starting flaw acceptance criteria. Various public-accessible procedures and software are available to determine the flaw growth (e.g., assessment for fatigue per BS 7910). Static fracture resistance shall be checked for all peak loads during the entire fatigue loading spectrum. Available software programs may be used by skilled practitioners to conduct this fatigue analysis and check the static failure conditions during the entire application of the cyclic loads.

The allowable flaw size from Option 1 may be used as the starting flaw sizes for both buried and surface-breaking flaws. If the critical flaw size is reached or failure from static peak loads occurs prior to the end of the service life (with the appropriate design or safety factor), the starting flaw sizes need to be reduced. Care should be taken to select the appropriate flaw growth curves (da/dN curves) for the type of service. BS 7910 provides guidance related to fatigue crack growth and selection of these curves, and the company may provide supplemental information used to generate flaw growth curves for different product conditions inside the pipe. For small D/t ratio pipes, through-thickness stress is not uniform. Analyses from multiple initial flaw locations are necessary.

A.5.1.5.3 Inspection Error and Safety Factor on Allowable Imperfect Size

The allowable flaw height shall be reduced by the inspection error extracted from NDT qualification results of qualified inspection system/procedure/operator for the specific project or project with similar material and welding procedure.

A.5.1.6 Transverse Planar Imperfections

Transverse planar imperfections shall be repaired or removed. The height of imperfections that are indicative of stacked weld bead starts and stops shall not exceed the lesser of $^1/_4$ in. (6.4 mm) or 50 % of the wall thickness.

A.5.2 Acceptable Limits of Volumetric Imperfections

Buried volumetric imperfections, such as slag or porosity, contained in material with high fracture toughness are much less likely to cause failure than planar imperfections. These imperfections may be treated and evaluated as planar imperfections or by the simplified method of Table A.5. Surface-breaking imperfections, and buried imperfections that are recategorized as surface-breaking by the imperfection interaction rules, shall be treated and evaluated as planar imperfections.

NOTE The minimum CTOD toughness and Charpy impact energy requirements are applicable regardless of how the imperfections are evaluated.

Table A.5—Acceptance Limits for Buried Volumetric Imperfections

Imperfection Type	Height or Width	Length
Porosity	Lesser of $t/4$ or 0.25 in. (6.4 mm)	Less of $t/4$ or 0.25 in. (6.4 mm)
Slag	Lesser of $t/4$ or 0.25 in. (6.4 mm)	$4t$

A.5.3 Arc Burns

Arc burns may occur on the internal or external surface of the pipe as a result of inadvertent arc strikes or improper grounding. They generally appear as a pit or cavity visible to the eye or as a dense area on the radiograph. The cavity may be surrounded by a hard HAZ that may be of lower toughness than the base material or the weld deposit.

The acceptance limits for unrepaired arc burns shall be as given in Table A.6 and are based on the premise that the HAZ has zero toughness but that any planar imperfection originating within the HAZ is blunted at the edge of the zone.

NOTE Substantial data indicate that the total depth of the arc burn, including the HAZ, are less than half the width of the burn.

Table A.6—Acceptable Limits for Unrepaired Arc Burns

Measured Dimension	Acceptance Limit
Width	Lesser of t or 5/16 in. (7.9 mm)
Length (any direction)	Lesser of t or 5/16 in. (7.9 mm)
Depth (to bottom of crater)	1/16 in. (1.6 mm)

Arc burns that contain cracks visible to the eye or on conventional radiographs are not covered by this annex and shall be repaired or removed.

A.5.4 Imperfection Interaction

If adjacent imperfections are close enough, they may behave as single larger imperfections. Figure A.11 shall be used to determine whether interaction exists. If it does, the effective imperfection sizes shown in Figure A.11 shall be computed and the acceptability of the effective imperfection shall be evaluated by the applicable acceptance criteria. If a repair is indicated, any interacting imperfections shall be repaired in accordance with A.7.

A.6 Record

The type, location, and dimensions of all imperfections rejected in accordance with this annex shall be recorded on suitable forms. This record shall be filed with the radiographs or other records of nondestructive tests of the pipeline.

A.7 Repairs

A.7.1 Repairs and Acceptance of Welds

Any imperfections that are not acceptable under the provisions of this annex shall be repaired in accordance with Section 10 or removed.

If a weld is repaired, the total accumulative length of all repair areas shall be no more than 30 % of the pipe circumference or 30 in. (762 mm), whichever is less. The repair areas shall be radiographic tested in accordance with 11.1 or ultrasonic tested in accordance with 11.4. The repair areas shall be considered acceptable when the repaired areas meet the standards of acceptability of Section 9, more stringent acceptance criteria specified by the company, or acceptance criteria of A.7.2.

A.7.2 Repair and Acceptance of Welds under Special Circumstances in Option 3

When the imperfection acceptance criteria of Option 3 are more restrictive (smaller) than the acceptance criteria of Section 9, an alternative acceptance criterion shall be established for the repair welds with appropriate qualification testing in accordance with the procedures of A.5.1.5.1.

A.8 Nomenclature [20]

a imperfection height (in. or mm)

c imperfection half length (in. or mm)

D pipe outer diameter (in. or mm)

d_n J integral to CTOD conversion factor (unitless)

D Young's modulus (ksi or MPa)

J_e elastic part of J integral (ksi in. or MPa mm)

K_I stress intensity factor [ksi (in.)$^{1/2}$ or MPa (mm)$^{1/2}$]

K_r toughness ratio in FAD format (unitless)

L_r stress ratio in FAD format (unitless)

L_r^{cutoff} cutoff stress ratio in FAD format (unitless)

n strain hardening exponent (unitless)

P_r normalized applied stress or load level (unitless)

α ratio of pipe diameter to wall thickness, $\alpha = D/t$ (unitless)

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[20] The units shown here are for illustrative purposes. It is necessary to ensure consistent units are used for all computations. Some equations, such as Equation (A.3), Equation (A.11), Equation (A.12), and Equation (A.13), shall use specified units.

β ration of imperfection length to pipe circumference, $\beta = 2c/\pi D$ (unitless)

δ_e elastic part of CTOD (in. or mm)

δ_{mat} CTOD toughness (in. or mm)

t specified pipe wall thickness (in. or mm)

η ratio of imperfection height to pipe wall thickness, $\eta = a/t$ (unitless)

ν Poisson's ratio (unitless)

σ_a maximum axial design stress (ksi or MPa)

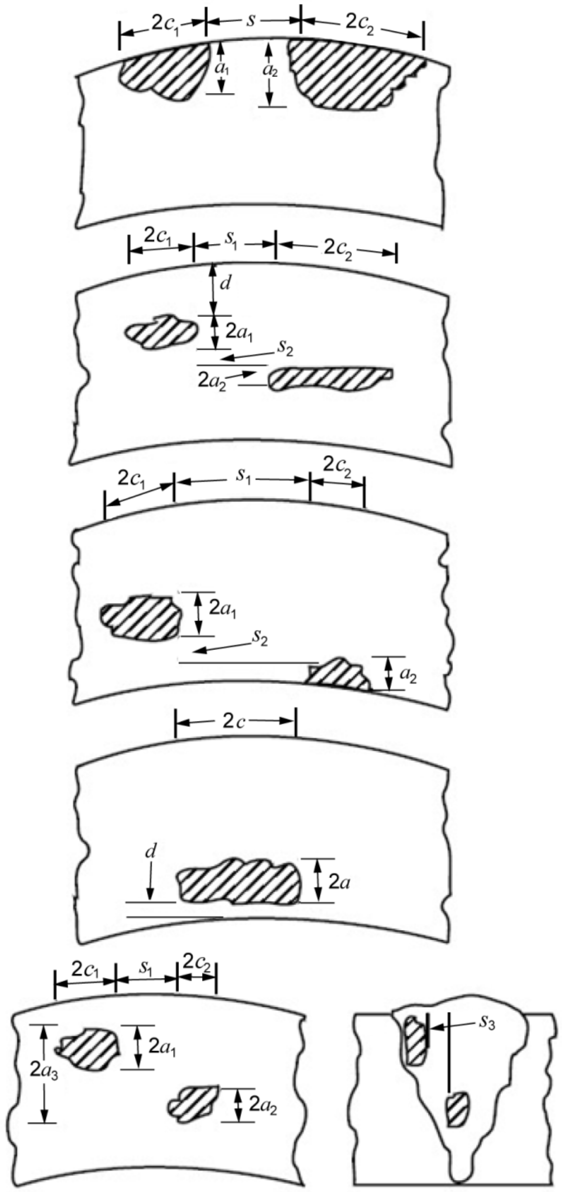
σ_c plastic collapse stress (ksi or MPa)

σ_f flow stress of the pipe material (ksi or MPa)

σ_t, T ultimate tensile strength of the pipe material (ksi or MPa)

σ_y, Y specified minimum yield strength of the pipe material, or SMYS, (ksi or MPa)

ε_t uniform strain (unitless)



	Interaction exists if	If interaction exists, effective imperfection size is
Case 1	$s < 2c_1$ $(c_1 < c_2)$	a_e = larger of a_1 and a_2 $2c_e = 2c_1 + s + 2c_2$
Case 2	$s_1 < 2c_1$ and $s_2 < a_1 + a_2$ $(c_1 < c_2)$	$2a_e = 2a_1 + s_2 + 2a_2$ $2c_e = 2c_1 + s_1 + 2c_2$
Case 3	$s_1 < 2c_1$ and $s_2 < a_1 + a_2$ $(c_1 < c_2)$	$a_e = 2a_1 + s_2 + a_2$ $2c_e = 2c_1 + s_1 + 2c_2$
Case 4	$d < a$	$a_e = d + 2a$ $2c_e = 2c$
Case 5	s_1 < smaller of $2c_1$ or $2c_2$ s_3 < smaller of $2a_1$ or $2a_2$	$2a_e = 2a_3$ $2c_e = 2c_1 + s_1 + 2c_2$

Figure A.11—Criteria for Evaluation of Imperfection Interaction

Annex B
(normative)

In-service Welding

B.1 General

This annex covers recommended welding practices for making repairs to or installing appurtenances on pipelines and piping systems that are in service. For the purposes of this annex, in-service pipelines and piping systems are defined as those that contain crude petroleum, petroleum products, or fuel gases that may be pressurized and/or flowing. The principles in this annex are equally applicable to pipelines containing air, water, and other products not listed in Section 1. In-service welds are defined as those that fuse directly into the wall of an in-service pipeline or piping system. This annex does not cover pipelines and piping systems that have been fully isolated and decommissioned or that have not been commissioned.

An in-service pipeline or piping system that operates under such conditions that do not increase the weld cooling rate or increase the risk of hydrogen cracking when compared to the Section 5 procedure qualification conditions should be welded in accordance with that Section 5 welding procedure or Annex B.

There are two primary concerns with welding onto in-service pipelines. The first concern is to avoid "burn-through," (defined in 3.1.6), where the welding arc causes the pipe wall to be breached. The second concern is for hydrogen cracking, since welds made in service cool at an accelerated rate as the result of the flowing contents' ability to remove heat from the pipe wall.

Burn-through is unlikely when installing an appurtenance if the wall thickness is 0.250 in. (6.4 mm) or greater, provided that low-hydrogen electrodes (EXX18 type) and normal welding practices are used. Welding onto thinner wall in-service pipelines is possible and considered routine by many companies; however, special precautions, such as the use of a procedure that limits heat input, are often specified. Burn-through becomes more likely when welding directly onto the pipe, which may occur when depositing the buttering layers of a temper bead deposition sequence or when performing weld deposition repair. Weld deposition repair, or repair by direct deposition of weld metal, involves restoring wall thickness by depositing weld metal directly to the area of wall loss.

For hydrogen cracking to occur, three conditions need to be satisfied simultaneously. These conditions are: hydrogen in the weld, the development of a crack-susceptible weld microstructure, and tensile stress acting on the weld. To prevent hydrogen cracking, at least one of the three conditions necessary for its occurrence need to be minimized or eliminated. For welds made onto in-service pipelines, success has been achieved using low-hydrogen electrodes or a low-hydrogen process and, since low hydrogen levels cannot always be guaranteed, using procedures that minimize the formation of crack-susceptible microstructures. The most common procedures use a sufficiently high heat input level to overcome the effect of the flowing contents. Several heat input prediction methods have been developed, including thermal analysis computer models.[21] While these or other proven methods are useful in predicting the heat input required for a given in-service welding application, they should not be considered a substitute for procedure qualification (see B.2). Preheating, where practicable, and/or the use of a temper bead deposition sequence, can also reduce the risk of hydrogen cracking. For some pipeline operating conditions, the ability of the flowing contents to remove heat from the pipe wall tends to make the effective use of preheating difficult. Examples of typical temper bead deposition sequences are shown in Figure B.1. To minimize the stress acting on the weld, attention should also be given to proper fit-up to minimize the stress concentration at the root of the weld.

The successful application of in-service welding needs to achieve a balance between safety and the prevention of unsatisfactory material properties. For example, if the pipe wall is thin [i.e., less than 0.250 in.

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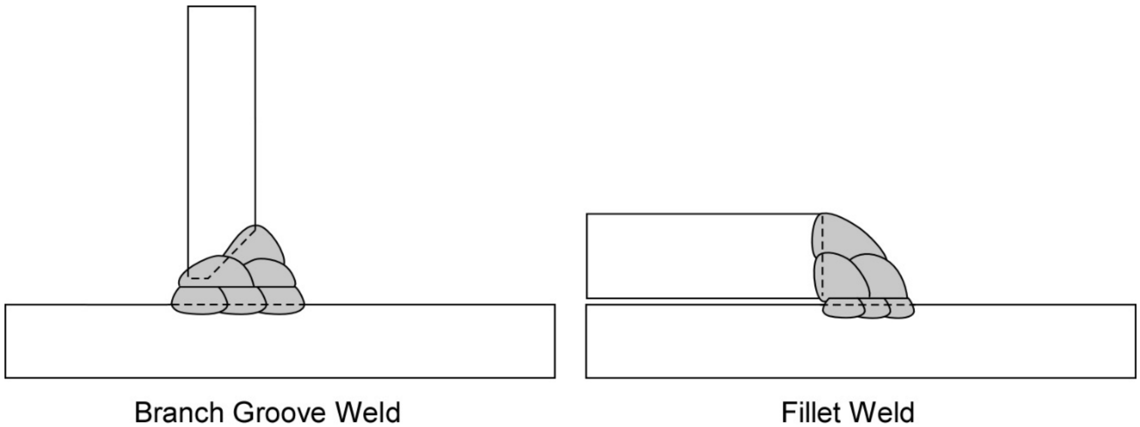
[21] "Development of Simplified Weld Cooling Rate Models for In-service Gas Pipelines," PRCI Catalog No. L51660 or "Thermal Analysis Model for Hot-tap Welding Version 4.2," PRCI Catalog No. L51837.

(6.4 mm)], it may be necessary to limit heat input to minimize the risk of burn-through; however, a low heat input level may be insufficient to overcome the ability of the contents to remove heat from the pipe wall, resulting in excessive weld cooling rates and a subsequent risk of hydrogen cracking. Thus, a compromise needs to be reached. When the maximum allowable heat input to avoid burn-through is insufficient to provide adequate protection against hydrogen cracking, alternative precautions (e.g., a temper bead deposition sequence) need to be used.



NOTES:
1. A layer of weld metal buttering is first deposited using stringer beads.
2. Higher heat input levels are used for subsequent passes, which refine and temper the HAZ of the first layer.

Figure B.1—Examples of Typical Temper Bead Deposition Sequences

The majority of this annex pertains to preventing hydrogen cracking in in-service welds. If the pipe wall thickness is less than 0.250 in. (6.4 mm), the risk of burn-through should be considered. The previously mentioned thermal analysis computer models [19] or another proven method should be used to determine heat input limits for these applications. Additional consideration should also be given for welding onto in-service pipelines and piping systems that contain products that become explosively unstable upon the application of heat or that contain products that will affect the pipe material by rendering it susceptible to ignition, stress corrosion cracking, or embrittlement. Additional guidance can be found in API 2201.

The requirements in the main body of this document should be applied to in-service welds that contact the carrier pipe, except for the alternative/additional requirements specified in this annex. For in-service welding, where discrepancies exist between this annex and the main body of this document, the annex should govern.

B.2 Qualification of In-service Welding Procedures

B.2.1 General

In addition to the applicable requirements in 5.3 for welding procedure specifications, the alternative/additional requirements specified in this annex should be applied to in-service welds.

B.2.2 Welding Procedure Specification

B.2.2.1 Specification Information

B.2.2.1.1 Materials

For in-service welds, the carbon equivalent [22] of the materials to which the procedure applies should be identified in addition to SMYS. Carbon equivalent levels may be grouped.

B.2.2.1.2 Pipeline Operating Conditions

For in-service welds, the pipeline operating conditions (pipe contents, flow rate, etc.) for which the procedure applies should be identified. Conditions may be grouped.

B.2.2.1.3 Heat Input Range

For procedures intended to overcome the effect of heat removal by the flowing contents by using a sufficiently high heat input level (see 3.1.17) (heat input control procedures), the required heat input range should be specified. For procedures intended to overcome the effect of heat removal by the flowing contents by using the temper bead deposition sequence (temper bead procedures), the required heat input range for each layer should be specified. The heat input should be determined based on the equations in 5.3.2.6.

B.2.2.1.4 Weld Deposition Sequence

For procedures intended to overcome the effect of heat removal by the flowing contents by using the temper bead deposition sequence (temper bead procedures), the required weld deposition sequence should be specified. The weld deposition sequence should include tolerances for bead spacing to assure proper tempering of the previous passes.

B.2.3 Essential Variables

B.2.3.1 Changes Requiring Requalification

An in-service procedure should be requalified and established as a new procedure when any of the essential variables described in Table B.1 are changed. The procedure should be revised to show changes other than those listed in Table B.1, but requalification is not required. Essential variables applicable to procedure qualification are included in Table B.2 and compared against those required for welder qualification.

[22] CEIIW = %C + %Mn/6 + (%Cu + %Ni)/15 + (%Cr + %Mo + %V)/5.

Table B.1—Essential Variables for Qualification of Welding Procedure Specifications in Accordance with this Annex

Welding Variable Subsection[a]	Change Requiring Requalification
B.2.3.1.1 Materials	a) For in-service fillet welds, SMYS is not an essential variable.
	b) For in-service welds other than fillet welds, the strength of the completed weld should meet or exceed the specified minimum strength of the pipe and fitting material.
	c) An increase in the carbon equivalent above that of the material used for procedure qualification constitutes an essential variable, except as provided below. A procedure may be used for higher carbon equivalent materials than the material used for procedure qualification provided that the thermal conditions are less severe than the procedure qualification conditions and there is no increase in the risk of hydrogen cracking results.
B.2.3.1.2 Pipeline Operating Conditions	For in-service welds, an increase in the severity of the pipeline operating conditions (in terms of weld cooling rates) above the group qualified constitutes an essential variable.
B.2.3.1.3 Wall Thickness	a) For in-service welds other than weld deposition repairs, wall thickness is not an essential variable. However, wall thickness of the materials being welded should be considered when considering the thermal severity of the pipeline operating conditions.
	b) For weld deposition repairs, the qualified welding procedure should not be used on a remaining pipe wall thickness less than what was used during qualification.
B.2.3.1.4 Weld Deposition Sequence	a) A change from a deposition sequence that relies on tempering to some other deposition sequence constitutes an essential variable.
	b) For a deposition sequence that relies on tempering, a change in the bead spacing beyond the limits in the welding procedure specification constitutes an essential variable.
B.2.3.1.5 Welding Process	A change from the welding process, method of application, or combination thereof used to produce the welding procedure qualification test weld.
B.2.3.1.6 Joint Design	A major change in joint design, such as a change from a longitudinal groove seam weld to a branch groove weld. A branch groove weld qualifies for all fillet welds.
B.2.3.1.7 Filler Metal	A change of filler metal(s) listed in one filler metal group to another filler metal group listed in Table 2. The compatibility of the base material and the filler metal should be considered from the standpoint of mechanical properties and hydrogen cracking susceptibility.
B.2.3.1.8 Shielding Gas	a) A change in shielding gas classification in accordance with AWS A5.32.
	b) An increase or decrease in the range of flow rates for the shielding gas greater than 20 % of the nominal flow rate used during qualification testing.
B.2.3.1.9 Electrical Characteristics	A change from direct current (DC) electrode positive to DC electrode negative, or vice versa, or a change in current from DC to alternating current (AC), or vice versa.
B.2.3.1.10 Weld Heat Input	A change in the specified heat input range. The specified heat input range should be based upon consideration of the demonstrated heat input range used in testing and the heat input range that is likely to avoid both cracking and burn-through.
B.2.3.1.11 Time Between Passes	An increase in the maximum time between completion of the root bead and the start of the second bead constitutes an essential variable. An increase in the maximum time between completion of the first layer and the start of the second layer for a temper bead sequence constitutes an essential variable.
B.2.3.1.12 Direction of Welding	A change in the direction of welding from vertical down to vertical up, or vice versa.
B.2.3.1.13 Preheat Temperature	A decrease in the specified minimum applied preheat temperature used during production of the welding procedure qualification test weld. Preheat may be eliminated or reduced if thermal modeling shows that the change in preheat does not result in a faster weld cooling rate than was experienced during qualification testing. [b, c]

Table B.1—Essential Variables for Qualification of Welding Procedure Specifications in Accordance with this Annex (continued)

Welding Variable Subsection[a]	Change Requiring Requalification
B.2.3.1.14 Interpass Temperature	A decrease in the specified interpass temperature range. The interpass temperature may be decreased without retesting provided that the thermal conditions are less severe than the procedure qualification conditions and there is no increase in the risk of hydrogen cracking results. [b, c]
B.2.3.1.15 Postweld Heat Treatment	The addition of PWHT or a change from the ranges or values specified in the procedure each constitutes an essential variable. [d]
B.2.3.1.16 Postweld Heat Maintenance to Promote Hydrogen Diffusion	A reduction in the specified time or temperature range used during qualification of the procedure. The time or temperature may be decreased provided that the thermal conditions are less severe than the procedure qualification conditions and there is no increase in the risk of hydrogen cracking results.

[a] The subsection numbers in this column are provided for referencing purposes.
[b] Thermal analysis models, as referenced in B.1, are one way of determining how changes in welding procedure parameters can affect the risk of hydrogen cracking or burn-through.
[c] Increasing the preheat or the interpass temperature may increase susceptibility to burn-through in thin wall base metals.
[d] PWHT of in-service pipelines poses a safety hazard and is not recommended.

Table B.2—Essential Variables Applicable to Procedure and Welder Qualification

Variable	In-service Procedure	In-service Fillet Welder [a]	In-service Complete Penetration Branch Welder [a]	In-service Weld Deposition Repair Welder	Longitudinal Seam Welder [b]	In-service Repair Procedure	In-service Repair Welder
Welding Process	B.2.3.1.5	B.3.1	B.3.1	B.3.1	B.3.1	B.7.1.2.3	B.7.2.4
Filler Metal Strength for Pressure Containment Welds	[c]					[c]	
Carbon Equivalent	B.2.3.1.1					B.2.3.1.1	
Weld Cooling Rate	B.2.3.1.2	B.3.2	B.3.2	B.3.2	B.3.2	B.2.3.1.2	
Joint Design	B.2.3.1.6	B.3.1	B.3.1	B.3.1	B.3.1		
Repair Type						B.7.1.2.1	B.7.2.4
Remaining Wall Thickness at Base of Repair Groove							B.7.2.4
Thickness, if Remaining Thickness is Less Than 0.250 in. (6.4 mm) and Thickness is Less Than Tested	[d]					[d]	

Table B.2—Essential Variables Applicable to Procedure and Welder Qualification (continued)

Variable	In-service Procedure	In-service Fillet Welder [a]	In-service Complete Penetration Branch Welder [a]	In-service Weld Deposition Repair Welder	Longitudinal Seam Welder [b]	In-service Repair Procedure	In-service Repair Welder
Diameter		B.3.1	B.3.1				B.7.2.4
Thickness	B.2.3.1.3.(b)	B.3.1	B.3.1	B.3.1	B.3.1		B.7.2.4
Branch Diameter		B.3.1	B.3.1				B.7.2.4
Branch Thickness		B.3.1	B.3.1				B.7.2.4
Electrical Characteristics (polarity)	B2.3.1.9					B.2.3.1.9	
Heat Input	B.2.3.1.10	B.3.2	B.3.2	B.3.2	B.3.2	B.2.3.1.10	[e]
Position of Branch		B.3.1	B.3.1				B.7.2.4
Position of Groove				B.3.1	B.3.1		B.7.2.4
Position of Fillet		B.3.1	B.3.1				B.7.2.4
Direction of Welding	B.2.3.1.12	B.3.1	B.3.1	B.3.1	B.3.1	B.2.3.1.12	B.7.2.4
Weld Deposition Sequence	B.2.3.1.4	B.3.2	B.3.2	B.3.2	B.3.2	B.2.3.1.4	B.3.2
Filler Metal Group	B.2.3.1.7	B.3.1	B.3.1	B.3.1	B.3.1	B.2.3.1.7	B.7.2.4
Shielding Gas Type	B.2.3.1.8	B.2.3.1.8	B.2.3.1.8	B.2.3.1.8	B.2.3.1.8	B.2.3.1.8	
Shielding Gas Flow Rate	B.2.3.1.8					B.2.3.1.8	
Preheat Temperature	B.2.3.1.13					B.2.3.13	
Interpass Temperature	B.2.3.1.14					B.2.3.1.14	
Postweld Heat Maintenance	B.2.3.1.16					B.2.3.1.16	

[a] Section 6.1 provides additional allowances for in-service fillet and branch groove qualified welders for production welding applications.

[b] Annex B requirements are applicable to welds that fuse into the wall of an in-service pipeline or piping system.

[c] Filler metal strength is not an essential variable; however, for in-service welds other than fillet welds, such as branch groove welds, longitudinal seam welds of full-encirclement fittings, and weld deposition repairs, the strength of the completed weld should meet or exceed the specified minimum strength of the pipe and fitting material.

[d] When the remaining wall thickness is less than 0.250 in. (6.4 mm) the susceptibility burn-through from excessive heat input or other conditions that lead to high internal surface temperatures should be evaluated.

[e] Users are cautioned that deviating from tested heat inputs by significant amounts during production welding can contribute to increases susceptibility to cracking or burn-through in some cases.

B.2.4 Welding of Test Joints

B.2.4.1 General

Pipeline operating conditions that affect the ability of the flowing contents to remove heat from the pipe wall should be simulated while test joints are being made.

NOTE Filling the test section with water and allowing water to flow through the test section while the test joint is being made has been shown to produce thermal conditions equivalent to or more severe than typical in-service welding applications (see Figure B.2). Procedures qualified under these conditions are therefore suitable for any typical in-service application. Other media (e.g., motor oil) may be used to simulate less severe thermal conditions.

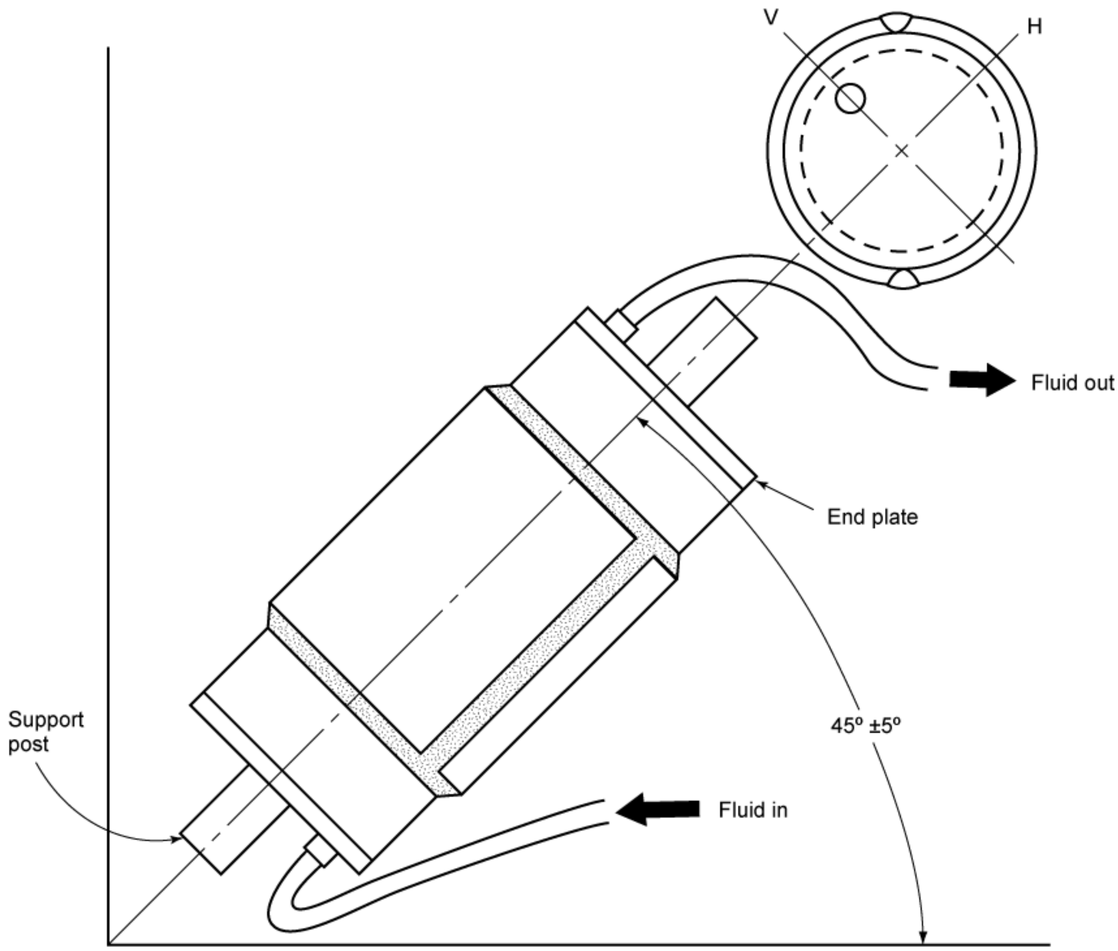


Figure B.2—An Example of Procedure and Welder Qualification Test Assembly

B.2.4.2 Branch and Fillet Welds

The requirements in 5.7 for branch groove welds and fillet welds should be applied to in-service welding.

B.2.4.3 Weld Deposition Repairs

Weld deposition repairs should be deposited on a section of pipe containing simulated wall loss. The area of simulated wall loss should be of sufficient size to remove all the required test specimens and may consist of a single larger area or multiple smaller areas (see B.2.5.1).

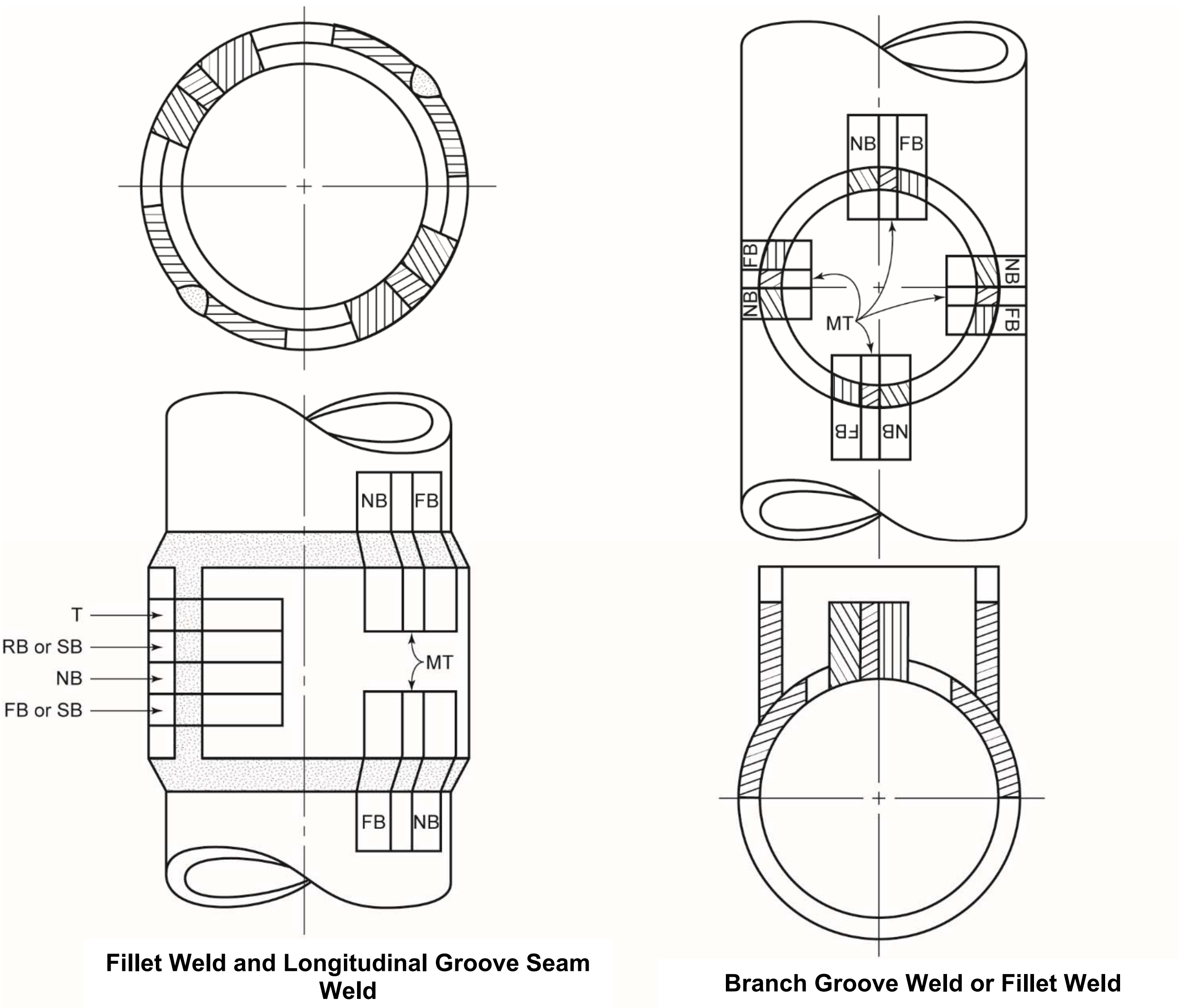
NOTE Other specimen layouts may be used at the discretion of the company.

The remaining wall thickness of the simulated wall loss should be no greater than the minimum value specified in the welding procedure specification. Weld deposition repairs should be deposited in such a way that the original wall thickness is completely restored.

B.2.5 Testing of Welded Joints

B.2.5.1 Preparation

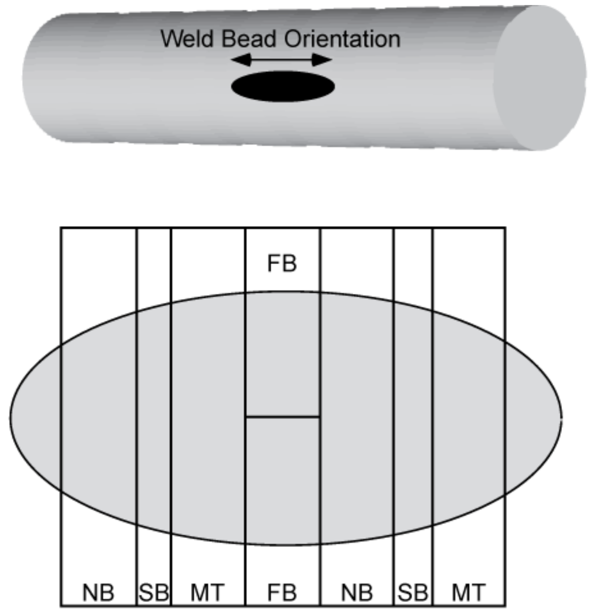
The test specimens should be cut from the joint at the locations shown in Figure B.3 or Figure B.4, and the minimum number of specimens and the tests to which they are to be subjected are shown in Table B.3. The test specimens should not be cut, machined, or destructively tested less than 24 hours after welding.



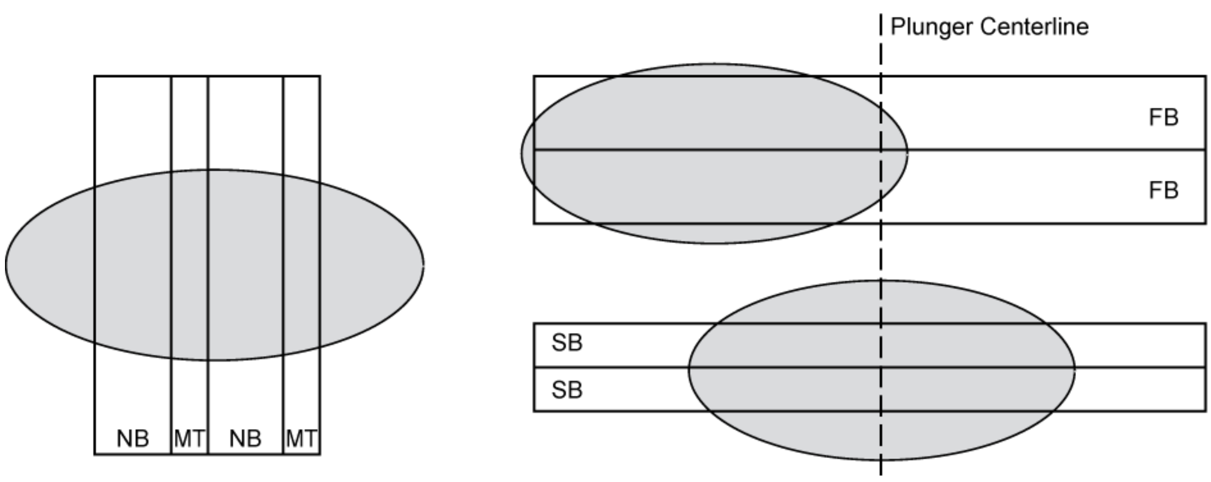
NOTE T = tensile; RB = root bend; FB = face bend; NB = nick break; SB = side bend; MT = macro test.

Figure B.3—Suggested Location of Test Specimens

Option 1:



Option 2:



NOTE 1 NB = nick-break; SB = side bend; MT = macro test; FB = face bend.

NOTE 2 The area of simulated wall loss should be of sufficient size to remove all the required test specimens and may consist of a single larger area (Option 1) or multiple smaller areas (Option 2).

Figure B.4—Suggested Location of Test Specimens for Weld Deposition Repair

Table B.3—Type and Number of Specimens—In-service Welding Procedure Qualification Test

Wall Thickness	Weld Type	Number of Specimens [a]						
		Tensile	Nick Break	Root Bend	Face Bend	Side Bend	Macro Test	Total
≤ 0.500 in. (12.7 mm)	Longitudinal groove seam	2	2	2	2			8
	Fillet		4 [b]		4		4	12
	Branch groove		4 [b]		4		4	12
	WDR [c]		2		4		2 [d]	8
> 0.500 in. (12.7 mm)	Longitudinal groove seam	2	2			4		8
	Fillet		4 [b]		4		4	12
	Branch groove		4 [b]		4		4	12
	WDR [c]		2		2	2	2 [d]	8

[a] For pipe or branch OD less than or equal to 4.500 in. (114.3 mm), two welds may be required.
[b] At the company's option, the remaining portion of these specimens may be prepared for and submitted to the face bend test (see B.2.5.5) after they are submitted to the nick break test.
[c] Weld deposition repairs.
[d] At the company's option, the remaining portion of these specimens may be prepared for and submitted to the face bend or side bend test (see B.2.5.5 or 5.6.5) after they are submitted to the macro test.

B.2.5.2 Longitudinal Groove Seam Welds

The longitudinal groove seam welds of full encirclement sleeves should be tested in accordance with 5.6. The backing material, if used, should be removed and the specimens may be flattened at room temperature before testing.

B.2.5.3 Branch Groove Welds, Fillet Welds, and Weld Deposition Repairs

Branch groove welds and fillet welds should be tested in accordance with 5.8, B.2.5.4, and B.2.5.5. Weld deposition repairs should be tested in accordance with 5.3.2, B.2.5.4, and B.2.5.5. When side bend tests are required, the side bend test should be performed in accordance with 5.6.5.

B.2.5.4 Macrosection Tests—Branch Groove Welds, Fillet Welds, and Weld Deposition Repairs

B.2.5.4.1 Preparation

The macrosection test specimens (see Figure B.5) should be at least $^{1}/_{2}$ in. (13 mm) wide. Specimens that are cut using a thermal process (plasma or oxygen) should be cut oversized and machined by a nonthermal process to remove at least $^{1}/_{4}$ in. (6 mm) from the side(s) that will be prepared. For each macrosection test specimen, at least one face should be ground to at least a 600-grit finish and etched with a suitable etchant, such as Nital, ammonium persulfate, or dilute hydrochloric acid, to give a clear definition of the weld structure.

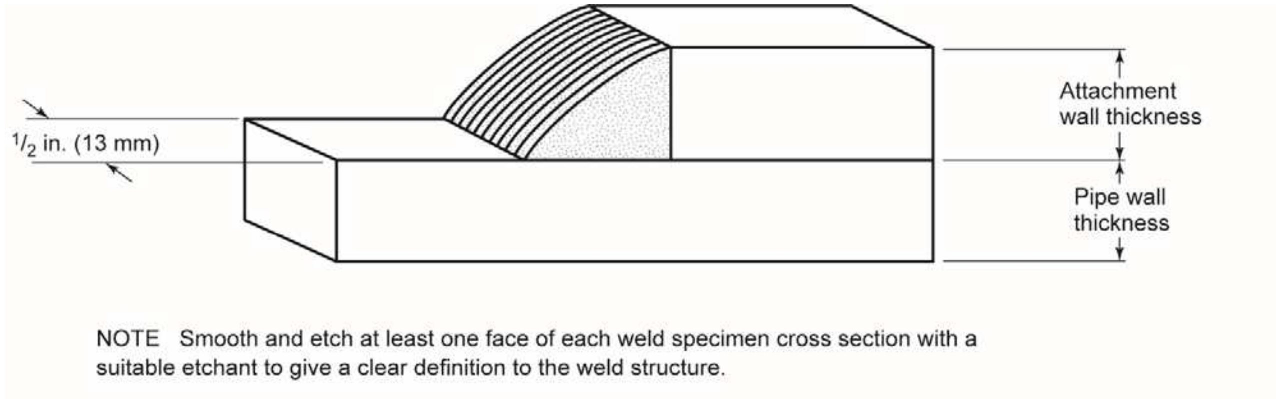


Figure B.5—Example Macro Test Specimen—In-service Fillet Welds

B.2.5.4.2 Visual Examination

The cross-section of the weld should be visually examined with lighting that will sufficiently reveal the details of the weld soundness. The use of optical devices or dye penetrants is not necessary.

B.2.5.4.3 Hardness Testing

Two of the four macro test specimens for branch groove and fillet welds and both macro test specimens for weld deposition repairs should be prepared for hardness testing in accordance with ASTM E384. A minimum of five indentations should be made using a Vickers indenter and a 10-kg load to determine the maximum hardness value in the coarse-grained HAZ at the weld toe of each specimen. A lower load may be used for the narrow heat-affected zones in some welds made by mechanized or automatic processes.

B.2.5.4.4 Requirements

A visual examination of the cross-section of the weld should show that it is completely fused at the root and free of cracks. For fillet welds, the leg lengths should be at least equal to the lengths specified in the welding procedure specification and should not deviate in concavity or convexity by more than $^1/_{16}$ in. (1.6 mm). The depth of the undercutting should not exceed $^1/_{32}$ in. (0.8 mm) or 12 $^1/_2$ % of the pipe wall thickness, whichever is smaller. The hardness for all welds onto in-service piping should not exceed the values shown in Table B.4[23] or alternate values specified by the company.

The effective thickness in Table B.4 should be calculated per Equation (B.1):

$$t_e = \frac{2t_s + t_a}{3} \tag{B.1}$$

where

t_e = effective thickness (in. or mm);

t_s = thickness of the pipe (in. or mm);

t_a = thickness of the appurtenance (in. or mm).

NOTE These values may not be applicable to microalloyed steel (with < 0.10% C) or to grades having an SMYS of 80 ksi or greater.

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[23] Bruce, W. A., and Etheridge, B. C., "Further Development of Heat-Affected Zone Hardness Limits for In Service Welding", Proceedings of the 9th International Pipeline Conference, Paper No. IPC2012-90095, Calgary, Alberta, Canada, September 24-28, 2012.

Table B.4—Weld Maximum Hardness Values, Non-Sour Service, HV10 [a]

Effective Thickness, [b, c] in. (mm)	≤0.375 (9.5)		0.500 (12.7)		0.625 (15.9)		≥0.750 (19.1)	
CE IIW [c]	≤ 0.35	≥ 0.5	≤ 0.35	≥ 0.5	≤ 0.35	≥ 0.5	≤ 0.35	≥ 0.5
Low-hydrogen welding process (max 4 ml/100 gm weld metal)	375	425	358	408	342	392	325	375
Low-hydrogen welding process (max 8 ml/100 gm weld metal [d])	350	400	335	383	317	367	300	350
Any welding process	300	350	285	335	265	315	250	300

[a] Hardness values are the average of five measurements taken in the region of anticipated maximum hardness. For sour service, see applicable the governing standard or specification document.

[b] Effective thickness (t_e) is calculated per Equation (B.1).

[c] Linear interpolation for hardness values is permitted for intermediate thickness values and/or CE values. See example below.

[d] 8 ml/100 gm weld metal could apply to low hydrogen welding processes or filler metals that result in more than 4 ml/100 gm weld metal by virtue of filler metal specification or by use of low hydrogen electrodes that have been exposed to uncontrolled atmospheric conditions that promote moisture pickup.

EXAMPLE (Pipe wall thickness of 0.406 and CE of 0.4 for "any welding process")

Interpolation for wall thickness

For CE = 0.35, HV10 = 300 - ((0.406-0.375) * (300-285) / (0.500-0.375)) = 296

For CE = 0.5, HV10 = 350 - ((0.406-0.375) * (350-335) / (0.500-0.375)) = 346

Final Interpolation for CE of 0.4

HV10 = 296 + (0.4-0.35) * (346-296) / (0.5-0.35) = 313

B.2.5.5 Face Bend Test—Branch Groove Welds, Fillet Welds, and Weld Deposition Repairs

B.2.5.5.1 Preparation

The face bend specimens (see Figure B.6) should be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide. Specimens that are cut using a thermal process (plasma or oxygen) should be cut oversized and machined by a nonthermal process, to remove at least $^1/_8$ in. (3 mm) from each side. The sides should be smooth and parallel, and the long edges should be rounded. The sleeve or branch and reinforcements should be removed flush with the surface but not below the surface of the test specimen. Any undercut should not be removed. Specimens should not be flattened prior to testing.

NOTE 1 The test specimens in Figure B.6 are shown in the axial direction; specimens in the other direction are curved.

NOTE 2 In lieu of taking separate specimens for the face bend test, the remaining portion of the nick break specimens may be used.

NOTE 3 Where wall thickness is greater than 0.500 in. (12.7 mm), it may be reduced to 0.500 in. (12.7 mm) by machining the inside surface.

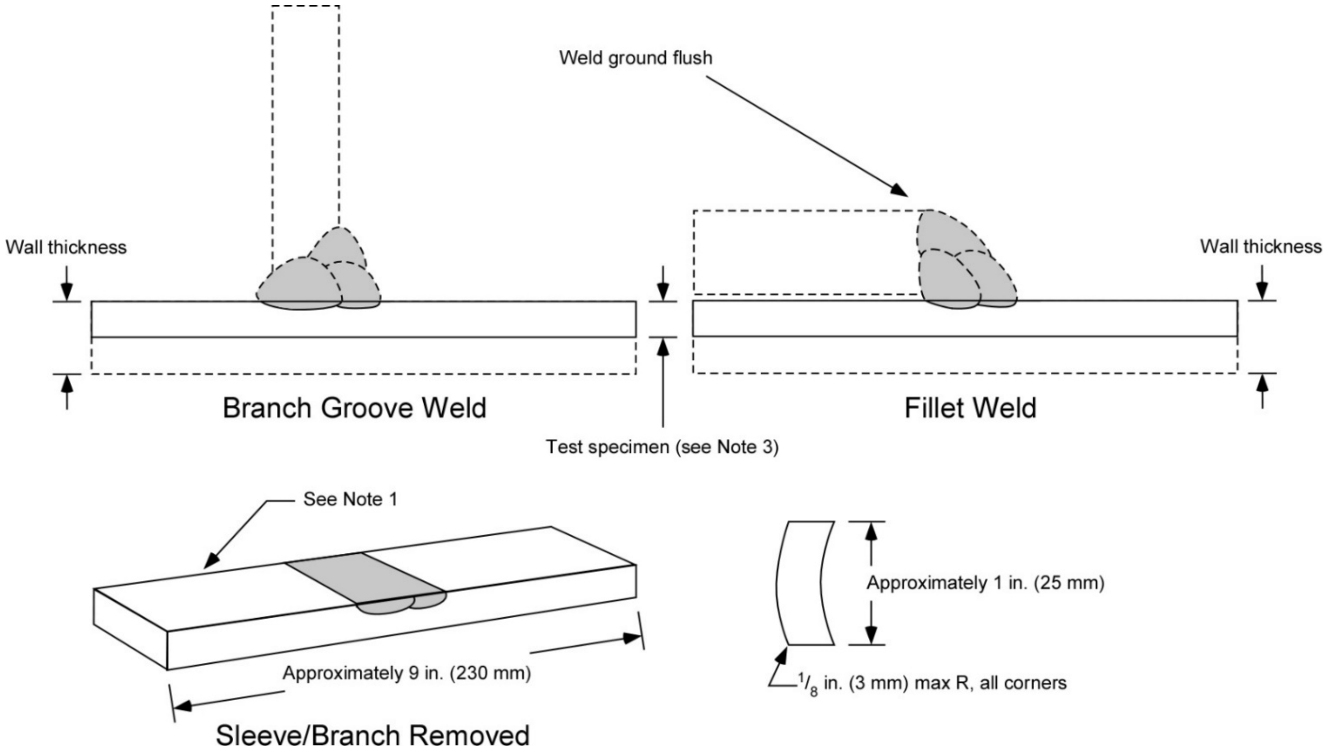


Figure B.6—Face Bend Test Specimen

B.2.5.5.2 Method

The face bend specimens should be bent in a guided-bend test jig similar to that shown in Figure 8. The bend radii may be equal to or smaller than the radii in Figure 8. Each specimen should be placed on the die with the cap pass weld toe area at midspan. The face of the weld should be placed toward the gap. The plunger should be forced into the gap until the curvature of the specimen is approximately U-shaped.

B.2.5.5.3 Requirement

The face bend test should be considered acceptable if, after bending, no crack or other imperfection exceeding $^1/_8$ in. (3 mm) or one-half the specified wall thickness, whichever is smaller, in any direction is present in the weld metal or HAZ. Cracks that originate on the outer radius of the bend along the edges of the specimen during testing and that are less than $^1/_4$ in. (6 mm), measured in any direction, should not be considered unless obvious imperfections are observed.

B.3 In-service Welder Qualification

B.3.1 General

A welder should make a test weld using a qualified in-service welding procedure in accordance with requirements in B.3.2. A welder depositing a weld deposition repair should deposit a test weld using a qualified in-service welding procedure in accordance with B.3.2 and B.2.4.3. The test welds should be tested in accordance with B.3.3. A welder who successfully completes the test weld should be qualified within the limits of the essential variables described below.

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.

c) A change of filler metal classification from Group 1 or 2 to any other group or from Group 3 through 8 to Group 1 or 2 (see Table 2). A change of filler metal classification not listed in Table 2 to any other filler metal classification or vice versa.

d) A major change in joint design. A minor change in joint design (e.g., angle of bevel) is not a change in the essential variable:

1) An in-service welder who qualifies depositing a fillet weld is qualified to deposit a fillet weld between a pipe and a sleeve or a pipe and a branch. Section 6.1 provides additional allowances for in-service fillet and branch groove qualified welders for production welding applications.

2) An in-service welder who qualifies depositing a branch groove weld joint that includes a groove and fillet weld is qualified for all branch welds and all fillet welds. Section 6.1 provides additional allowances for in-service fillet and branch groove qualified welders for production welding applications.

3) An in-service welder who qualifies by depositing an in-service longitudinal groove seam weld is qualified to deposit longitudinal groove seam welds that fuse to the carrier pipe and longitudinal groove seam welds with a backing strip. A welder who qualifies by depositing a longitudinal groove seam weld with a backing strip is only qualified to deposit longitudinal groove seam welds with a backing strip.

NOTE A longitudinal groove seam welder who qualifies with an open root is qualified to deposit non-in-service longitudinal groove seam welds within the limits of 6.2.

4) The joint design is not an essential variable for weld deposition welders.

e) An increase in the specified OD of the pipe and branch or sleeve.

1) An in-service welder who qualifies depositing a fillet weld on a nominal pipe and sleeve or branch diameter of 12.75 in. (323.9 mm) or greater is qualified for all pipe, sleeve, and branch diameters.

2) An in-service welder who qualifies depositing a branch groove weld, a joint that includes a groove and fillet weld, on a nominal pipe and branch diameter of 12.75 in. (323.9 mm) or greater is qualified for all pipe, sleeve, and branch diameters.

3) The pipe or sleeve diameters are not essential variables for weld deposition and longitudinal groove seam welders.

f) An increase in the specified thickness of the pipe and branch or sleeve. When welding on pipe wall thickness values less than 0.25 in. (6.4 mm), the welder should show to the satisfaction of the company the ability to prevent burn-through.

1) An in-service welder who qualifies depositing a fillet weld on a nominal pipe and sleeve or branch wall thickness of 0.250 in. (6.4 mm) or greater is qualified for all pipe, sleeve, and branch wall thicknesses.

2) An in-service welder who qualifies depositing a branch groove weld, a joint that includes a groove and fillet weld, on a nominal pipe and branch wall thickness of 0.250 in. (6.4 mm) or greater is qualified for all pipe, sleeve, and branch wall thicknesses.

3) A longitudinal groove seam welder who qualifies on a sleeve wall thickness of 0.375 in. (9.5 mm) or greater is qualified to deposit longitudinal groove seam welds on all sleeve wall thicknesses.

4) For weld deposition welders, the pipe wall is not an essential variable; however, the welder is only qualified to weld a remaining wall thickness no less than the remaining wall thickness used during the qualification.

g) A change in welding position.

1) An in-service welder who qualifies depositing a fillet weld on a pipe and sleeve in the horizontal or inclined 45° from the horizontal position, or a pipe in the horizontal or inclined 45° from the horizontal position with the branch positioned on the side of the pipe, the bottom of the pipe, or any location between the side and bottom of the pipe, is qualified for all positions.

2) An in-service welder who qualifies depositing a branch groove weld, a joint that includes a groove and fillet weld, on a pipe in the horizontal or inclined 45° from the horizontal position with the branch positioned on the side of the pipe, the bottom of the pipe, or any location between the side and bottom of the pipe is qualified for all positions.

3) A longitudinal groove seam welder who qualifies on a sleeve in the horizontal or inclined 45° from the horizontal position is qualified for all positions.

4) For weld deposition repair welders, a pipe in the horizontal or inclined 45° from the horizontal position with the weld deposition repair deposited on the bottom of the pipe qualifies the weld deposition repair welder for all positions; repairs deposited on the side of the pipe qualify the weld deposition repair welder for the side and top of the pipe; and repairs deposited on the top of the pipe qualify the weld deposition repair welder for only the top of the pipe.

B.3.2 Welding of Test Joint

For in-service welding, pipeline operating conditions that affect the ability of the flowing contents to remove heat from the pipe wall should be simulated while test joints are being made.

NOTE Filling the test section with water and allowing water to flow through the test section while the test joint is being made has been shown to produce thermal conditions equivalent to or more severe than typical in-service welding applications (see Figure B.2). Welders qualified under these conditions are therefore qualified for any typical in-service application. Other media (e.g., motor oil) may be used to simulate less-severe thermal conditions.

In addition to making the test joint used for the destructive testing described in B.3.3, the welder should demonstrate to the satisfaction of the company the ability to comply with aspects of the welding procedure specification that are intended to avoid the development of crack-susceptible microstructures and/or prevent burn-through. For example, for heat input control procedures, the company may choose to require the welder to demonstrate the ability to maintain a heat input level within the range specified in the welding procedure specification. For temper bead and weld deposition repair procedures, the company may choose to require the welder to demonstrate bead placement within the dimensional tolerances specified in the welding procedure specification and the ability to maintain a heat input level within the range specified in the welding procedure specification.

B.3.3 Testing of Welded Joints

The weld should be tested and considered to be acceptable if it meets the requirements of 6.4 and 6.5. For longitudinal groove seam welds that are prevented from fusing directly into the wall of the simulated in-service pipeline or piping system because of the welding process, welding technique, joint geometry, physical barrier, or a combination of these attributes, the minimum number of specimens and the tests to which they should be subjected is shown in Table B.5. For longitudinal fillet welds, test four nick-break specimens equally spaced along the fillet weld. For weld deposition repair welders, the minimum number of specimens and tests to which they should be subjected is shown in Table B.3. However, for the purpose of welder qualification under B.3, it is not necessary to calculate the tensile strength of the coupons. If calculating the tensile strength of the coupon is not performed, the specimen designated for the tensile test should be subjected to the nick-break test.

Table B.5—Type and Number of Test Specimens for Longitudinal Groove Seam—Welder Qualification

Sleeve Wall Thickness	Tensile	Number of Specimens				
		Nick Break	Root Bend	Face Bend	Side Bend	Total
≤ 0.500 in. (12.7 mm)	1	1	1	1		4
> 0.500 in. (12.7 mm)	1	1			2	4

B.3.4 Records

The pipeline operating conditions (pipe contents, flow rate, etc.) for which the welder is qualified should be identified. Conditions may be grouped.

B.4 Suggested In-service Welding Practices

B.4.1 General

The requirements for production welding in Section 7 should be applied to in-service welds, except for the alternative/additional requirements specified in this annex.

Before welding onto an in-service pipeline or piping system, welders should consider aspects that affect safety, such as operating pressure, flow conditions, and wall thickness at the location of the welding. The areas to be welded should be inspected to ensure that imperfections are not present and that the wall thickness is adequate. All welders performing repair work should be familiar with the safety precautions associated with cutting and welding on piping that contains or has contained crude petroleum, petroleum products, or fuel gases. Additional guidance can be found in API 2201.

B.4.2 Alignment

B.4.2.1 Fit-up

For sleeves or saddles, the gap between the sleeve or saddle and the carrier pipe should be within the dimensional tolerances specified by the company. Clamping devices should be used to obtain proper fit-up. When necessary, weld metal buildup on the carrier pipe can be used to minimize the gap.

B.4.2.2 Root Opening—Longitudinal Groove Seam Welds

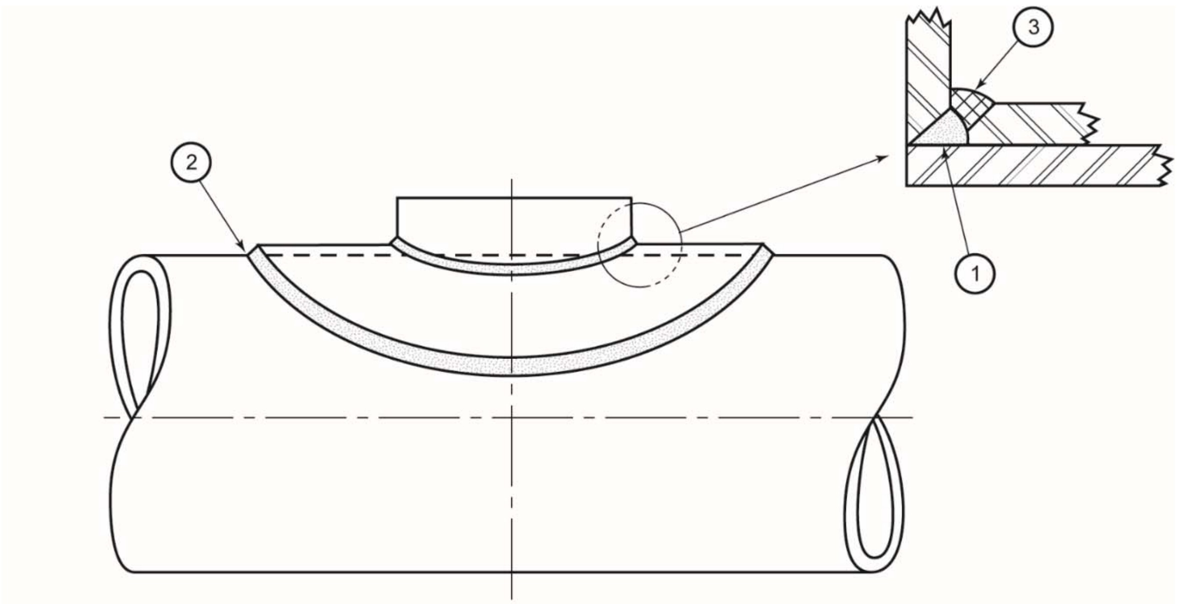
For longitudinal groove seam welds, when 100 % penetration is required, the root opening (the space between abutting edges) should be sufficient to enable full penetration of the root bead. These joints should be fitted with a mild steel backup strip or suitable tape to prevent penetration of the weld into the carrier pipe.

NOTE Penetration of the longitudinal groove seam weld into the carrier pipe is undesirable since any crack that might develop is exposed to the hoop stress in the carrier pipe. When weld metal does not penetrate into the carrier pipe, the longitudinal groove seam weld is not an in-service weld.

B.4.3 Welding Sequence

Suggested sleeve and branch welding sequences are shown in Figure B.7 through Figure B.12. For full-encirclement fittings requiring circumferential fillet welds, the longitudinal seams should be completed before beginning the circumferential welds. The circumferential weld at one end of the fitting should be completed before beginning the circumferential weld at the other end. For other types of fittings, a welding sequence that minimizes residual stress should be used.

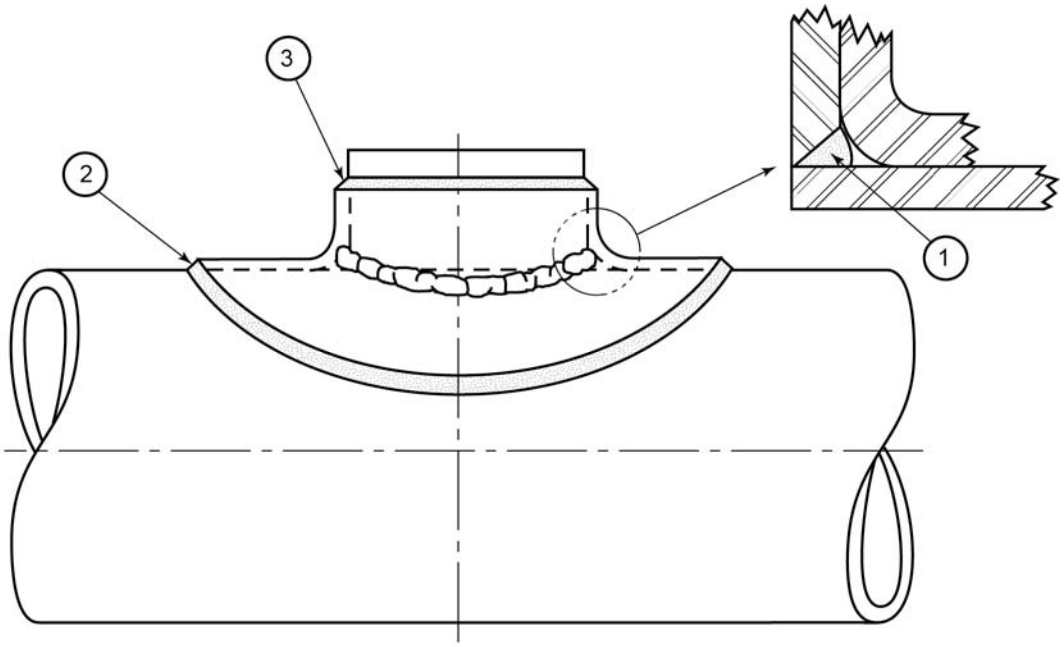
Guidelines for weld deposition repair have been developed that include preparation prior to welding and weld deposition sequence. [24] For example, a perimeter pass should be used to establish a boundary beyond which no subsequent welding is allowed. The first layer of fill passes should be deposited using established heat input limits to minimize the risk of burn-through. A second perimeter pass should be used to temper the HAZ at the toe of the first perimeter pass. Higher heat input fill passes should be used for subsequent layers to further temper the initial passes, again observing established heat input limits if necessary. Additional layers should be deposited, as necessary, for proper filling.



NOTE This is the suggested welding sequence; others may be followed at the discretion of the company.

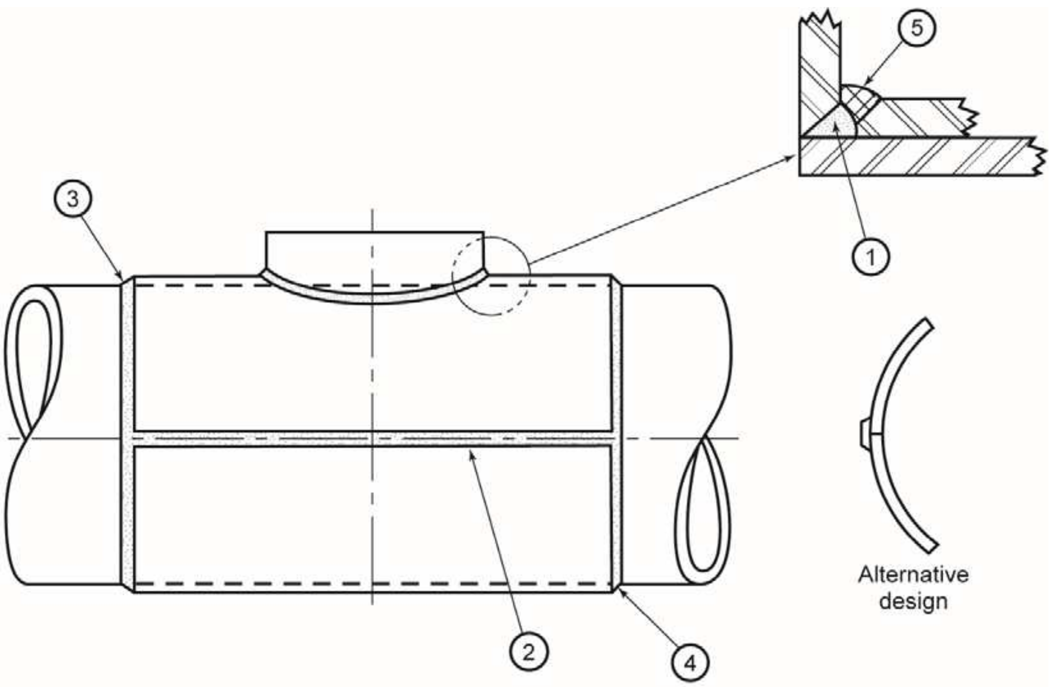
Figure B.7—Reinforcing Pad

[24] W. A. Bruce and W. E. Amend, “Guidelines for Pipeline Repair by Direct Deposition of Weld Metal,” WTIA/APIA Welded Pipeline Symposium, Welding Technology Institute of Australia, Sydney, Australia, April 3, 2009.



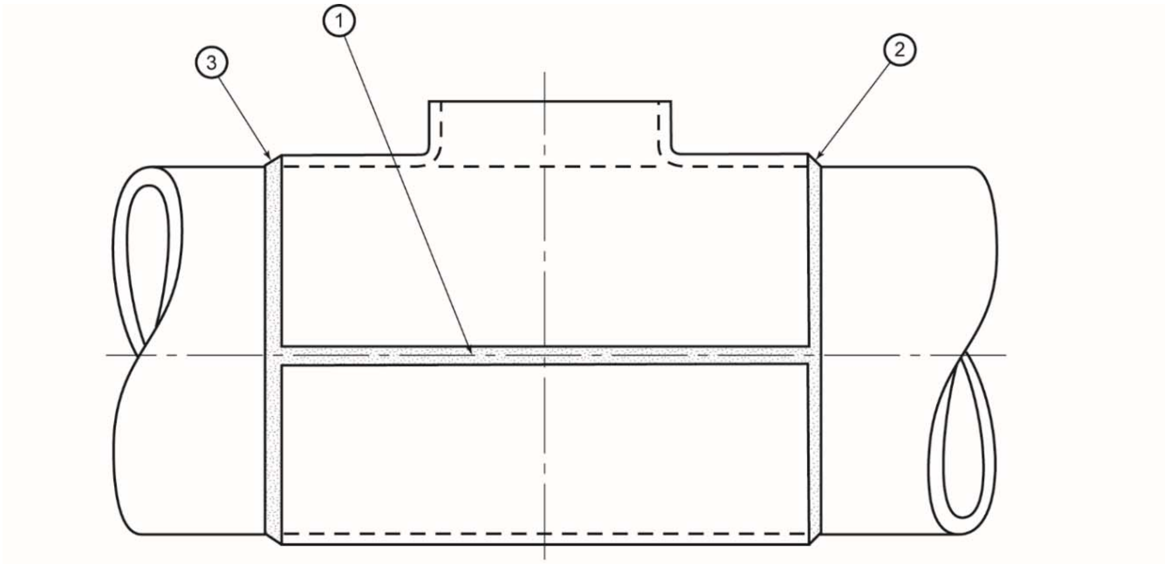
NOTE This is the suggested welding sequence; others may be followed at the discretion of the company.

Figure B.8—Reinforcing Saddle



NOTE This is the suggested welding sequence; at the discretion of the company, others may be followed and circumferential welds, numbers 3 and 4, need not be made.

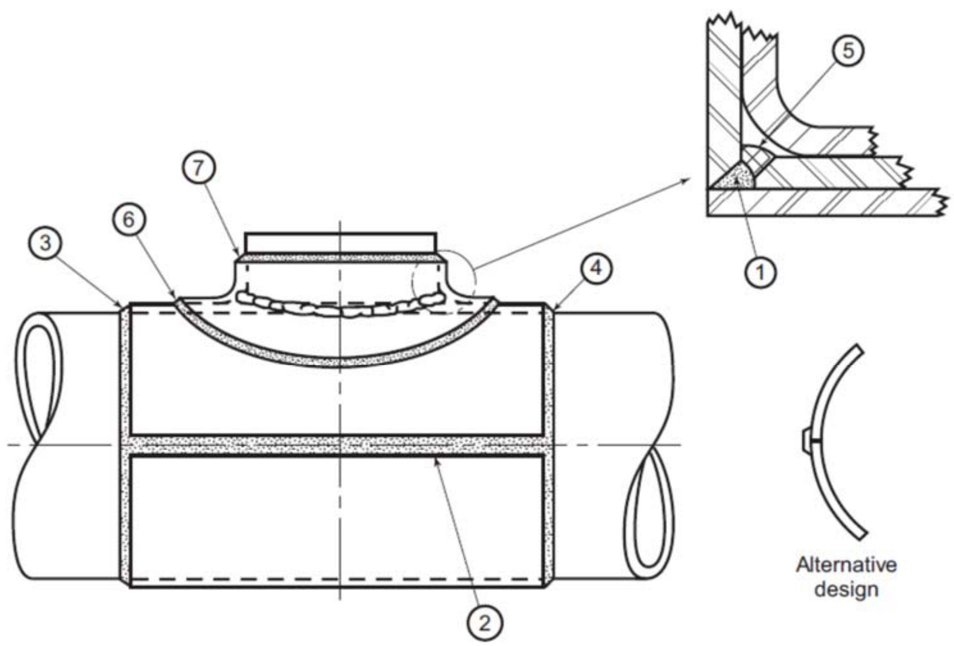
Figure B.9—Encirclement Sleeve



NOTE 1 This is the suggested welding sequence; others may be followed at the discretion of the company.

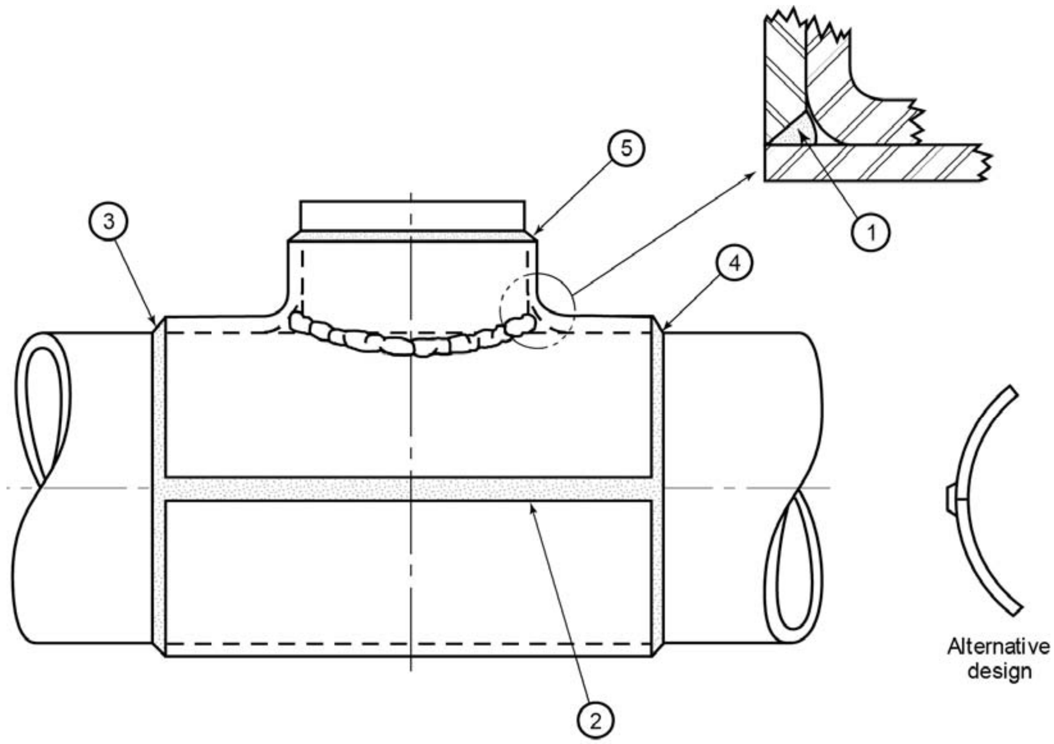
NOTE 2 When in operation, the fitting is at pipeline pressure.

Figure B.10—Encirclement Tee

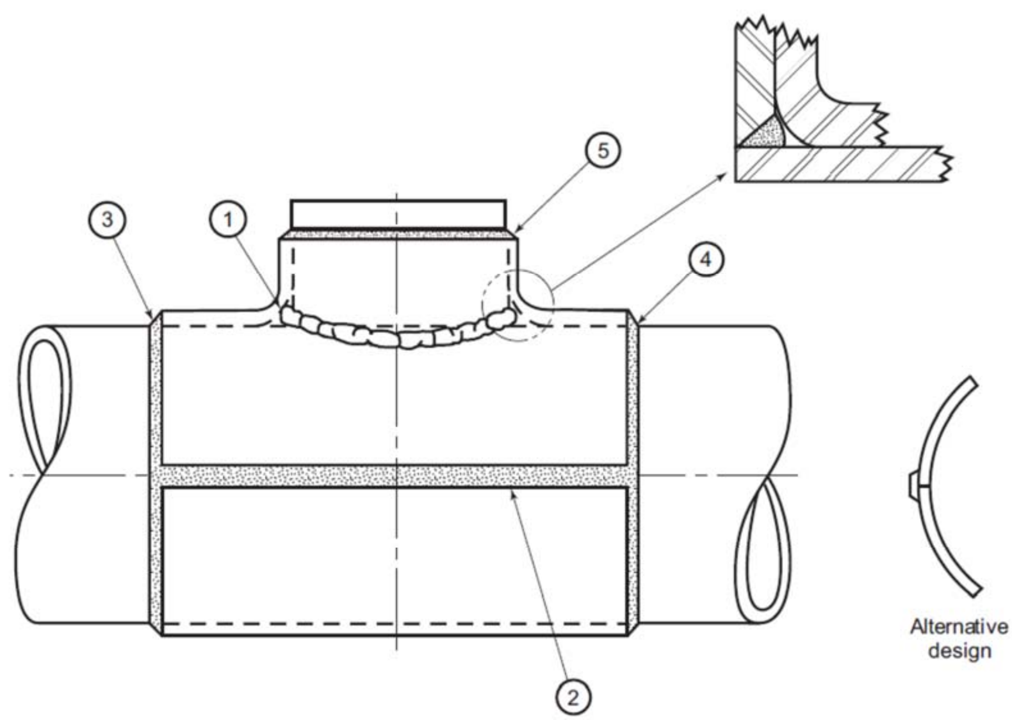


NOTE This is the suggested welding sequence; at the discretion of the company, others may be followed and circumferential welds, numbers 3 and 4, need not be made.

Figure B.11—Encirclement Sleeve and Saddle



NOTE This is the suggested welding sequence; at the discretion of the company, others may be followed and circumferential welds, numbers 3 and 4, need not be made.



NOTE This is the suggested welding sequence; at the discretion of the company, others may be followed and circumferential welds, numbers 3 and 4, need not be made.

Figure B.12—Encirclement Saddle

B.4.4 Weld Direction

In-service welds should be deposited in the circumferential direction (parallel to the hoop stress direction) whenever possible.

B.5 Inspection and Testing of In-service Welds

The requirements for inspection and testing in Section 8 should be applied to in-service welds, except for the alternative/additional requirements specified in this annex.

Since in-service welds may be particularly susceptible to underbead or delayed hydrogen cracking, an inspection method that is capable of detecting these cracks, particularly at the carrier pipe weld toe, should be used.

NOTE Magnetic particle testing, ultrasonic testing, or a combination of both, using properly developed, qualified, and approved procedures, have been shown to be effective at detecting hydrogen cracks at the toe of sleeve-, saddle-, and branch-to-carrier pipe welds. Ultrasonic testing and radiographic testing, or a combination of both, are effective for volumetric inspection for weld deposition repairs.

When determining appropriate delay times prior to inspection for hydrogen cracking, the time-dependent nature of cracking should be considered, as well as the probability of the weld to cracking. Longer delay times decrease the chance that cracking can occur after inspection has been completed. The probability of cracking, and thus the importance of determining an appropriate delay time, can be minimized by using more conservative welding procedures.

B.6 Standards of Acceptability—NDT (Including Visual)

The standards of acceptability in Section 9 for imperfections located by NDT should be applied to in-service welds. For weld deposition repair, the weld length is defined as the maximum weld length in the direction in which the wall loss is oriented.

B.7 Repair of Welds while In-Service

This section pertains to weld repairs made to new welds made onto in-service piping and to the repair of weld flaws or in-service degradation of construction welds on piping that is in-service. When construction welds that are in-service are to be repaired, the welds should be volumetrically inspected to ensure that significant imperfections are not present below the surfaces that will be affected by grinding or welding. Grinding should not be performed on construction welds that are now in-service and cannot be volumetrically inspected.

The first attempt to repair a new in-service weld should be made by a qualified in-service welder using the original in-service welding procedure specification. If a second attempt is required, then an in-service repair welding procedure and in-service repair welder should be qualified in accordance with B.7.

Any repair to a construction weld should be performed following a repair in-service welding procedure and by an in-service repair welder qualified in accordance with B.7. A welder who has qualified under 10.4 and who has qualified according to B.3 should be qualified to perform in-service weld repairs to a construction weld.

B.7.1 In-service Repair Welding Procedure Qualification

B.7.1.1 General

An in-service repair procedure should be reestablished as a new repair procedure and should be requalified when any of the essential variables in B.2.3 or the following are changed.

NOTE Changes other than those given in B.2.3 or B.7.1.2 may be made without the need for requalification, provided the repair procedure is revised to show the changes.

B.7.1.2 Essential Variables

Essential variables applicable to in-service repair procedure qualification are included in Table B.6.

Table B.6—Essential Variables for Qualification of Repair Welding Procedure Specifications in Accordance with this Annex

Welding Variable Subsection[a]	Change Requiring Requalification
B.7.1.2.1 Location of Excavation [b]	a) A change from centerline to fusion line location for excavation of partial-thickness repairs. [c]
	b) A change from centerline to fusion line location for cover pass repairs. [c]
B.7.1.2.2 Type of Repair	Any change from a repair type listed below to another repair type, except when changing from a full-thickness repair to a partial-thickness repair. 1) full-thickness repair; 2) partial-thickness repair; 3) cover pass repair; 4) back weld repair.
B.7.1.2.3 Change in Welding Process	a) A change in the welding process or method of application used to produce the repair procedure qualification test weld.
	b) A change in the welding process used to deposit the original production weld being repaired.
	c) If the weld to be repaired was produced using the OFW or self-shielded flux-cored arc welding (FCAW-S) process, procedure qualification testing should be performed on a weld that was originally deposited using the same process.

[a] The subsection numbers in this column are provided for referencing purposes.
[b] Refer to illustrations in Figures 22 through 27 for definitions of excavation locations.
[c] Qualification of fusion line repairs qualifies for use on centerline repairs.

B.7.1.3 Testing of Repair

In-service repair procedures should be qualified by visual and destructive testing. NDT may be required at the direction of the company. For repair procedure qualification, sample preparation for destructive testing and nondestructive testing should not commence until the repair weld has been allowed to cool to ambient temperature.

The repair weld should be tested and considered to be acceptable if it meets the requirements of B.2.5. For repair welds, the minimum number of specimens and the tests to which they should be subjected is shown in Table B.7. At the discretion of the company, additional types and number of tests may be required. When the production in-service welding procedure was required to be qualified with Charpy impact testing to meet design requirements, Charpy impact testing should also be performed to qualify partial-thickness and full-thickness repair procedures. As noted in Table 3, when wall thickness is over 0.500 in. (12.7 mm), the side bend tests should be substituted for face bend or root bend tests. For the purpose of this section, preparation of the repair area that results in weld metal or base metal remaining at the base of the groove is considered to be a partial-thickness repair. Grinding that results in an open root (e.g., grinding through the root of a new branch connection that has not been tapped yet) is considered to be a full-thickness repair. Complete removal of a fillet weld that does not result in an open root is qualified as a partial-thickness repair (e.g., a sleeve fillet weld in which the weld metal is removed to the root is not an open root joint).

NOTE Dependent on pipe material or welding process, the company may require additional delay time prior to destructive and nondestructive testing.

Table B.7—Type and Number of Specimens—In-service Welding Repair Procedure Qualification Test

Repair Type	Tensile Strength	Face Bend	Macro/ Hardness [a]	Total (Minimum)	Charpy Impact
Branch full-thickness	0	1	1	2	0
Partial-thickness (groove welds) and WDR	1	1	1	3	[a]
Partial-thickness (includes branch and fillet welds)	0	1	1	2	0
Cover pass	0	1	1	2	0
Branch back weld	0	1	1	2	0

[a] Hardness and Charpy impact testing should be performed at locations in the weld as specified by the company. The number of test specimens and acceptance criteria should be specified by the company

B.7.2 In-service Repair Welder Qualification

B.7.2.1 General

When required by B.7, in-service repairs should be made by an in-service repair welder, following an in-service repair welding procedure specification or using the original in-service welding procedure specification. The in-service repair welder should be qualified by either of the following two ways:

a) depositing an in-service repair weld in accordance with B.7.2.2. The weld should be acceptable if it meets the requirements of B.7.2.3;

b) qualifying as a repair welder in accordance with 10.4 and having an in-service welder qualification in accordance with B.3.

B.7.2.2 Repair Welder Testing

Welders should be qualified using a completed weld to make an in-service repair weld following all the details of the qualified in-service repair welding procedure specification.

The in-service repair weld should be deposited in the fixed position on a full-circumference test weld and qualified in the location(s) specified by the company. The base metal grade is not an essential variable for in-service repair welding. The substrate weld is not an essential variable; however, if the repair is intended for use on either OFW weld metal deposits or self-shielded flux-cored arc welding (FCAW-S) weld metal deposits, the substrate weld metal should be representative of that weld process. The welder should prepare the repair groove for the repair test.

The piping should be subject to accelerated cooling during the repair welding

The in-service repair weld should be of sufficient length to extract all of the required destructive test specimens.

A single completed weld may be used to qualify more than one welder or repair location.

Details of the in-service repair welder qualification should be recorded and maintained with the complete results of the qualification test for each location of repair in accordance with 6.8.

B.7.2.3 Testing of Repair

For a repair welder qualification test weld, the repair weld shall meet the visual examination requirements of 6.4.

The destructive test samples should be removed from each individual repair area. For repairs to fillet welds or branch groove welds, two nick breaks should be removed and tested in accordance with 6.5 for each type of repair weld. For repairs to butt welds, the destructive test samples should be removed and tested in accordance with 10.4.2.

A welder who fails to pass the in-service repair welder qualification test(s) should be permitted to retest as described in 6.7.

B.7.2.4 Welder Qualification Limits

An in-service repair welder who has qualified in accordance with B.7.2.1.1 should be qualified within the limits of the essential variables described below and in B.3.4. If any of the following essential variables are changed, the in-service repair welder using an in-service repair procedure should be requalified:

a) a change from cover pass or back weld repair to partial-thickness or full-thickness repair type;

b) a change of the filler metal group (see Table 2);

c) a decrease in the remaining ligament thickness after preparing the repair groove to less than the remaining ligament used in the in-service repair welder qualification test;

d) a change in position from that for which the in-service repair welder has already qualified. Qualification testing on the bottom qualifies the welder for all positions. Qualification welding on the side qualifies for repairs on top and side only. Qualification welding on the top position qualifies for top only;

e) a change in the thickness group of the branch connections or, for girth weld repairs or WDR, a change in the thickness group for the pipe or fitting being repaired. These groups are defined in Table 5;

f) A change in the direction of travel from vertical up to vertical down or vice versa, or from horizontal to either vertical up or vertical down. Vertical welding qualifies the welder for horizontal progression welding.

g) An in-service repair welder who has qualified in accordance with B.7.2.1.2 should be qualified within the limits of the essential variables described in 10.4.3 and B.3.4.

Annex C
(normative)

Requests for Interpretation and Requests for Revision to the Document

C.1 Introduction

The API-AGA Joint Committee on Oil and Gas Pipeline Field Welding Practices will consider written requests for interpretations and revisions in a formal manner. The committee's activities in this regard are limited strictly to interpretations of this standard, or to the consideration of revisions to this standard on the basis of new data or technology. Such requests are handled as expeditiously as possible, but due to the complexity of the work and the procedures that shall be followed, some responses may require considerable time. As a matter of policy, API does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity related to the use of this standard. Accordingly, any requests for interpretation requiring such consideration shall not be addressed. API does not act as a consultant on specific welding problems or on the general application or understanding of this standard. If, based on the information submitted in the request for interpretation, it is the opinion of the committee that the inquirer should seek professional assistance, the request for interpretation is not addressed with the recommendation that such assistance be obtained. Requests for interpretation that do not provide the information needed for the committee's full understanding shall not be addressed, and the inquirer is so notified.

C.2 Requirements

C.2.1 General

Requests for interpretation shall be limited strictly to interpretations of this standard (and not include interpretations of any normative references), or to the consideration of revisions to this standard on the basis of new data or technology. Requests shall be submitted in writing. Requests shall contain the name, address, and affiliation of the inquirer, and shall provide enough information for the committee to fully understand the point of concern in the inquiry.

Requests for interpretation of the standard should be directed to http://rfi.api.org.

Proposed revisions to the standard should be directed to standards@api.org.

C.2.2 Scope

Each request or interpretation shall be limited to only one single provision of the standard; however, the point of the inquiry may include two or more interrelated provisions as references or supporting information. The particular provision(s) shall be identified, including reference to the applicable edition, addenda, and errata.

C.2.3 Purpose of Inquiry

The purpose of the inquiry shall be stated. The purpose may be either to obtain an interpretation or to propose consideration of a revision to a particular provision in the standard.

C.2.4 Content

The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Omit superfluous background information. The inquiry should be technically and editorially correct. If the point of the inquiry is to obtain an interpretation, the inquiry shall be stated in such a manner that the response to the inquiry is either "yes" or "no". The committee shall not address inquiries that pose questions of "how" or "why". If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

C.2.5 Proposed Reply

A request for interpretation may include a proposed reply, stating a believed interpretation of the requirements of the provision in question, or recommended wording for a revision.

C.2.6 Additional/New Proposed Processes

Processes other than those described in this document can be considered for inclusion in this standard. Persons who wish to have other processes included shall submit, at a minimum, the following information for the committee's consideration:

a) a description of the welding process;

b) a proposal on the essential variables;

c) a welding procedure specification;

d) weld inspection methods;

e) types of weld imperfections and their proposed acceptance limits;

f) repair procedures.

C.2.7 Response Time by the Committee

The committee shall review and provide a response to a request for interpretation as quickly as possible. The committee shall review the requests in the order they were received by API. However, since some responses may require input from several sources, a response may take up to one year to formulate and issue to the inquirer. The committee shall not accelerate this process to meet a deadline or schedule requirement of the inquirer. The inquirer should take into consideration this time frame.

For proposals of revision that are submitted, the committee shall determine the need for immediate change to inclusion in the document (an addendum) or if the revision may be delayed until the next overall edition of the document is published.

Bibliography

[1] API Recommended Practice 2201, *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*

[2] AWS A5.01, *Procurement Guidelines for Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

[3] BS 7910:2019, *Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures*

[4] Ferdinand Hurter and Vero Charles Driffield, “Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates,” J. Soc. Chem. Ind., May 31, 1890.

[5] Y.-Y. Wang and M. Liu, “A Comprehensive Update in the Evaluation of Pipeline Weld Defects,” U.S. DOT Agreement No. DTRS56-03-T-0008, PRCI Contract No. PR-276-04503, draft report to DOT and PRCI, November 2004.

[6] M. Liu, Y.-Y. Wang, and G. Rogers, “Stress Analysis of Pipe Lowering-in Process During Construction,” Proceedings of the 7th International Pipeline Conference, Paper No. IPC2008- 64630, Calgary, Alberta, Canada, September 29-October 3, 2008.

[7] N. E. Dowling, “Fatigue Failure Predictions for Complicated Stress-Strain Histories,” Journal of Materials, Volume 7, Number 1, pp. 71 to 87, March 1972.

[8] Y.-Y. Wang, M. Liu, D. Horsley, and G. Bauman, “A Tiered Approach to Girth Weld Defect Acceptance Criteria for Stress-based Design of Pipelines,” 6th International Pipeline Conference, Paper No. IPC2006-10491, Calgary, Alberta, Canada, September 25-29, 2006.

[9] “Development of Simplified Weld Cooling Rate Models for In-service Gas Pipelines,” PRCI Catalog No. L51660 or “Thermal Analysis Model for Hot-tap Welding Version 4.2,” PRCI Catalog No. L51837.

[10] Bruce, W. A., and Etheridge, B. C., “Further Development of Heat-Affected Zone Hardness Limits for In Service Welding", Proceedings of the 9th International Pipeline Conference, Paper No. IPC2012-90095, Calgary, Alberta, Canada, September 24-28, 2012.

[11] W. A. Bruce and W. E. Amend, “Guidelines for Pipeline Repair by Direct Deposition of Weld Metal,” WTIA/APIA Welded Pipeline Symposium, Welding Technology Institute of Australia, Sydney, Australia, April 3, 2009.

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