# Annex D

## (normative)

# **Repair Welding Procedure**

## **D.1 General**

**D.1.1** Repair welds shall be made:

- a) with the pipe axis being in the horizontal plane,
- b) in accordance with a qualified welding procedure, and
- c) by a welding machine operator (hereafter called operator) or repair welder who is qualified in accordance with D.3.

**D.1.2** Repair welds shall be made by one or more of the following methods:

- a) automatic submerged arc,
- b) automatic or semi-automatic gas metal arc, or
- c) manual shielded metal arc using low-hydrogen electrodes.

**D.1.3** All welding materials shall be properly handled and stored in accordance with the manufacturer's recommendations, so as to preclude moisture or other contamination.

**D.1.4** Test welds shall be made on strip, plate, or pipe.

**D.1.5** The manufacturer shall maintain a record of the welding procedure and the procedure qualification test results. Copies of the WPS and the welding procedure qualification record shall be provided to the purchaser upon request.

# D.2 Repair Welding Procedure Qualification

## D.2.1 General

**D.2.1.1** Welding procedures shall be qualified by preparing and testing welds in accordance with this annex, except as allowed by D.2.1.2.

**D.2.1.2** At the option of the manufacturer, the welding procedure qualification mechanical tests specified in ISO 15614-1 <sup>[23]</sup>, API 5L 43rd Edition <sup>[17]</sup>, or ASME Section IX <sup>[26]</sup> may be substituted for those specified in D.2.3.

**D.2.1.3** For the purpose of this annex, the term "automatic welding" includes machine welding, mechanized welding, and automatic welding.

### D.2.2 Essential Variables

An existing procedure shall not be applicable and a new procedure shall be qualified if any of the following essential variables is changed beyond the stated limits.

- a) Welding process:
  - 1) a change in the welding process, such as submerged arc to gas metal arc, or
  - 2) a change in the method, such as manual to semi-automatic.
- b) Pipe material:
  - a change in pipe grade category; if different alloying systems are used within one pipe grade category, each alloying composition shall be separately qualified, wherein pipe grade categories are as follows:
    - i) pipe Grade  $\leq$  L290 or X42,
    - ii) pipe Grade > L290 or X42, and pipe Grade < L450 or X65,
    - iii) each pipe Grade  $\geq$  Grade L450 or X65;
  - 2) within each pipe grade category, a thicker material than the material qualified;
  - 3) within the pipe grade category and thickness range, a carbon equivalent ( $CE_{IIW}$  if the carbon mass fraction is greater than 0.12 % and  $CE_{Pcm}$  if the carbon mass fraction is less than or equal to 0.12 %), based on product analysis for the material to be repaired, that is more than 0.03 % greater than the carbon equivalent of the material qualified; or
  - 4) change in delivery condition (see Table 3).
- c) Welding materials:
  - 1) change in the filler metal classification;
  - 2) when impact tests are required, a change in the consumable brand name;
  - 3) change in the electrode diameter;
  - 4) change in the composition, *X*, of the shielding gas of more than  $(X \pm 5)$  %;
  - 5) change in the flow rate, q, of the shielding gas of more than  $(q \pm 10)$  %; or
  - 6) change in submerged arc welding flux from one designation to another.
- d) Welding parameters:
  - 1) change in the type of current (such as from alternating current to direct current);
  - 2) change in polarity;
  - 3) for automatic and semi-automatic welding, the ranges of welding current, voltage, speed, and heat input may be established to cover ranges of wall thickness. Within the range, appropriately

selected points shall be tested to qualify the entire range. Thereafter, a new qualification is required if there is a deviation from the qualified range greater than one or more of the following:

- i) 10 % in amperage,
- ii) 7 % in voltage,
- iii) 10 % in travel speed for automatic welding,
- iv) 10 % in heat input; or
- 4) any increase in groove depth, *a*, over that qualified. The depth of groove shall be set by the manufacturer, unless otherwise agreed.
- e) Weld bead: for manual and semi-automatic welding, a change in bead width greater than 50 %;
- f) Preheat and post-weld heat treatment:
  - 1) repair welding at a pipe temperature lower than the pipe temperature of the qualification test, or
  - 2) the addition or deletion of post-weld heat treatment.

#### D.2.3 Mechanical Testing

#### D.2.3.1 Number of Test Pieces

Two test pieces for each type of test (see D.2.3.2 and D.2.3.3) shall be prepared and tested for each welding procedure qualification test. For impact testing, three test pieces for each location shall be prepared and tested (see D.2.3.4).

#### D.2.3.2 Transverse Tensile Test

**D.2.3.2.1** The reduced width of transverse tensile test pieces shall be 38 mm (1.5 in.) and the repair weld shall be at the mid-length of the test piece, as shown in Figure 8 a). The weld reinforcement shall be removed from both faces and the longitudinal edges shall be machine cut.

NOTE Although Figure 8 a) shows a guided-bend test specimen, it is referred to for guidance of where the repair weld is to be located for a tensile specimen.

**D.2.3.2.2** The tensile strength shall be at least equal to the minimum specified for the applicable pipe grade.

#### D.2.3.3 Transverse Guided-bend Test

**D.2.3.3.1** The transverse guided-bend test pieces shall be as shown in Figure D.1, with the weld having been made in a groove.

**D.2.3.3.2** Each test piece shall be bent 180° in a jig (see Figure 9 and Table D.1), with the exposed surface of the weld in tension.

**D.2.3.3.3** Except as allowed by D.2.3.3.4, the bend test shall be considered acceptable if no crack or other defect exceeding 3.2 mm (0.125 in.) in any direction is present in the weld metal or base metal after bending.

**D.2.3.3.4** Cracks that occur at the edges of the test piece during testing shall not be cause for rejection, provided that they are not longer than 6.4 mm (0.250 in.).

## D.2.3.4 Charpy (CVN) Impact Test

**D.2.3.4.1** Charpy impact test pieces shall be taken from weld-repaired areas of repair welding procedure qualification tests (see D.2.1.1).

**D.2.3.4.2** Charpy test pieces shall be prepared in accordance with the requirements of 10.2.3.3 of this specification.

**D.2.3.4.3** The CVN impact test shall be carried out in accordance with the requirements of 9.8 and 10.2.4.3 of this specification.

**D.2.3.4.4** The minimum average absorbed energy (of a set of three test pieces) for each repaired pipe weld and its associated HAZ, based on full-size test pieces and a test temperature of 0 °C (32 °F) or, if agreed, a lower test temperature, shall be not less than that specified in 9.8.3 for the pipe seam weld metal and HAZ.

Where pipe dimensions do not permit the preparation and testing of full-size CVN test pieces from repair welding procedure qualification tests and sub-size CVN test pieces are used, the requirements of 10.2.3.3 and Table 22 shall apply.

## D.2.4 NDT of Weld Repair Procedure Qualification Test

The weld repair procedure qualification test piece shall be inspected in accordance with E.3, by using either the radiographic inspection technique in accordance with E.4 or the ultrasonic inspection technique in accordance with E.5 or a combination of both techniques. The weld-repaired area shall meet the same acceptance criteria specified in E.4.5 and/or E.5.5 as appropriate.



#### Key

- A before repair welding Section view
- B after repair welding Plan view
- C after repair welding Section view
- 1 longitudinal edges machined, cold sawn, thermally cut, or any combination thereof
- 2 repair weld metal with weld reinforcement removed
- 3 pre-existing SAW/COW weld (if applicable) with weld reinforcement removed
- 4 repair groove
- a Groove depth.
- b Wall thickness (see D.2.2 b) 2).
- <sup>c</sup> The radius, *r*, shall be less than or equal to 1.6 (0.063).

#### Figure D.1—Guided-bend Test Piece

Pipe Grade	Dimension <sup>a</sup> mm (in.)			
-	ra <sup>b</sup>	r <sub>b</sub> b	Agb <sup>b</sup>	B <sup>b</sup>
≤ L290 or X42	3.0 <i>t</i>	4.0 <i>t</i> + 1.6 (0.063)	6.0 <i>t</i>	8.0 <i>t</i> + 3.2 (0.125)
L320 or X46	3.5 <i>t</i>	4.5 <i>t</i> + 1.6 (0.063)	7.0 <i>t</i>	9.0 <i>t</i> + 3.2 (0.125)
L360 or X52	4.0 <i>t</i>	5.0 <i>t</i> + 1.6 (0.063)	8.0 <i>t</i>	10.0 <i>t</i> + 3.2 (0.125)
L390 or X56	4.0 <i>t</i>	5.0 <i>t</i> + 1.6 (0.063)	8.0 <i>t</i>	10.0 <i>t</i> + 3.2 (0.125)
L415 or X60	4.5 <i>t</i>	5.5 <i>t</i> + 1.6 (0.063)	9.0 <i>t</i>	11.0 <i>t</i> + 3.2 (0.125)
L450 or X65	4.5 <i>t</i>	5.5 <i>t</i> + 1.6 (0.063)	9.0 <i>t</i>	11.0 <i>t</i> + 3.2 (0.125)
L485 or X70	5.0 <i>t</i>	6.0 <i>t</i> + 1.6 (0.063)	10.0 <i>t</i>	12.0 <i>t</i> + 3.2 (0.125)
L555 or X80	5.0 <i>t</i>	6.0 <i>t</i> + 1.6 (0.063)	10.0 <i>t</i>	12.0 <i>t</i> + 3.2 (0.125)
L620 or X90	5.5 <i>t</i>	6.5 <i>t</i> + 1.6 (0.063)	11.0 <i>t</i>	13.0 <i>t</i> + 3.2 (0.125)
L690 or X100	6.0 <i>t</i>	7.0 <i>t</i> + 1.6 (0.063)	12.0 <i>t</i>	14.0 <i>t</i> + 3.2 (0.125)
L830 or X120	7.0 <i>t</i>	8.0 <i>t</i> + 1.6 (0.063)	14.0 <i>t</i>	16.0 <i>t</i> + 3.2 (0.125)

#### Table D.1—Guided-bend Test Jig Dimensions

<sup>a</sup> For intermediate grades, the dimensions shall be as specified for the next lower grade, or shall be obtained by interpolation.

<sup>b</sup>  $r_{a}$ ,  $r_{b}$ ,  $A_{gb}$ , and *B* are as shown in Figure 9.

## D.3 Welding Personnel Performance Qualification

#### **D.3.1 Qualification**

#### D.3.1.1 General

Each repair welder and operator shall be qualified according to the requirements of this section. Alternatively, at the option of the manufacturer, welders and operators may be qualified to ISO 9606-1 <sup>[25]</sup>, ASME Section IX <sup>[26]</sup>, API 5L 43rd Edition <sup>[17]</sup>, Appendix C, or EN 287-1 <sup>[24]</sup>.

A repair welder or operator qualified on one pipe grade category [see D.2.2 b)] is qualified for any lower pipe grade category, provided that the same welding process is used.

#### D.3.1.2 Inspection

To qualify, a repair welder or operator shall produce welds that are acceptable by inspection as follows:

- a) film radiographic inspection in accordance with Annex E,
- b) two transverse guided-bend tests (see D.2.3.3).

#### D.3.1.3 Inspection Failures

If one or more of the inspections in D.3.1.2 fail to meet the specified requirements, the welder or operator may make one additional qualification weld. If that weld fails one or more of the inspections in D.3.1.2, the welder or operator is disqualified. No further retests shall be permitted until the welder has completed additional training.

## D.3.2 Re-qualification

Re-qualification in accordance with D.3.1 shall be required if one or more of the following applies:

- a) one year has elapsed since the last prior applicable qualification;
- b) the welder or operator has not been welding using qualified procedures for a period of 3 months or more; or
- c) there is reason to question the welder's or operator's ability.

# Annex E

# (normative)

# Nondestructive Inspection for Pipe Not Required to Meet Annex H, J, or N

# E.1 Qualification of Personnel

**E.1.1** ISO 9712, ISO 11484, or ASNT SNT-TC-1A or an equivalent shall be the basis for the qualification of nondestructive inspection personnel (excluding visual inspection). Such personnel shall be re-qualified for any method previously qualified, if they have not performed nondestructive inspection in that method for a period exceeding 12 months.

**E.1.2** Nondestructive inspection shall be conducted by Level 1, 2, or 3 personnel.

**E.1.3** Evaluation of indications shall be performed by Level 2 or 3 personnel, or by Level 1 personnel under the supervision of Level 2 or 3 personnel.

# E.2 Standard Practices for Inspection

Except as specifically modified in this annex, the required nondestructive inspection, other than for surface inspection (see 10.2.7) and wall thickness verification, shall be performed in accordance with one of the following standards or an equivalent:

a)	electromagnetic (flux leakage):	ISO 10893-3 or ASTM E570;
b)	electromagnetic (eddy current):	ISO 10893-2 or ASTM E309;
c)	ultrasonic:	ISO 10893-8, ISO 10893-9, ISO 10893-10, ASTM A435, ASTM A578, or ASTM E213;
d)	automated ultrasonic (weld seam):	ISO 10893-11 or ASTM E273;
e)	manual ultrasonic (weld seam):	ISO 10893-11, ASTM E164, ASTM E587;
f)	magnetic particle:	ISO 10893-5 or ASTM E709;
g)	radiographic (film):	ISO 10893-6 or ASTM E94;
h)	radiographic (digital):	ISO 10893-7, ASTM E2698, or ASTM E2033;
i)	liquid penetrant:	ISO 10893-4 or ASTM E165.

# E.3 Methods of Inspection

## E.3.1 General

**E.3.1.1** For grades  $\geq$  L210 or A, the weld seams of welded pipe with  $D \geq$  60.3 mm (2.375 in.) shall be nondestructively inspected, full length (100 %) for the entire thickness, as given in Table E.1. In addition, the coil/plate end weld in finished helical seam pipe shall be nondestructively inspected, full length (100 %) for the entire thickness, as given in Table E.1.

Wold Soom Type	Nondestructive Inspection Method <sup>a</sup>			
weid Seam Type	Electromagnetic	Ultrasonic	Radiographic	
EW	One method or a combination of methods is required		Not applicable	
LW	Not applicable	Required	Not applicable	
SAW	Not applicable	Required <sup>b</sup>	If agreed	
COW	Not applicable	Required	Not applicable	
Coil/plate end	Not applicable	Required <sup>b</sup>	If agreed	
<sup>a</sup> The weld seam at the pipe ends may require additional inspection (see E.3.2).				
<sup>b</sup> Required unless the manufacturer and the purchaser have agreed to replace it by radiographic inspection.				

#### Table E.1—Pipe Weld Seam Nondestructive Inspection

**E.3.1.2** All PSL 2 SMLS pipe and PSL 1 Grade L245 or B quenched and tempered SMLS pipe shall be nondestructively inspected full length (100 %), as given in Table E.2. If agreed, other PSL 1 SMLS pipe shall be nondestructively inspected as given in Table E.2.

Table E.2—SMLS Pipe Body Nondestructive Inspection

	Nondestructive Inspection Method		
Item	Electromagnetic	Ultrasonic	Magnetic Particle (Circular Field)
PSL 2 pipe, any grade	One method or a combination of methods is required		
PSL 1 pipe, Grade L245 or B, quenched and tempered	One method or a combination of methods is required		
PSL 1 pipe, other than above	If agreed, one method or a combination of methods is required		

**E.3.1.3** The location of equipment in the manufacturer's facility shall be at the discretion of the manufacturer, except that:

 a) the required nondestructive inspection of weld seams of cold-expanded pipe shall take place after cold expansion; the required nondestructive inspection of SMLS pipe shall take place after each heat treating and cold-expansion operations, if performed, but may take place before cropping, beveling, and end sizing;

b) by agreement, the weld seams in LFW and HFW pipe shall be inspected following hydrostatic test.

## E.3.2 Pipe End Inspection—Welded Pipe

**E.3.2.1** If an automated ultrasonic or electromagnetic inspection system is applied to meet the requirements of E.3.1.1, the weld at any pipe end not covered by the automated inspection system shall be inspected for defects by the manual or semi-automatic ultrasonic angle beam method or by the radiographic method, whichever is appropriate, or such noninspected pipe end shall be cut off. Records in accordance with E.5.4 shall be maintained.

**E.3.2.2** For SAW and COW pipe, the weld at each pipe end for a minimum distance of 200 mm (8.0 in.) shall be inspected by the radiographic method. The results of such radiographic inspection shall be recorded on either film or another imaging medium.

**E.3.2.3** If agreed, ultrasonic inspection in accordance with the method described in ASTM A578 and ASTM A435, or ISO 10893-8 shall be used to verify that the 25 mm (1.0 in.) wide zone at each pipe end is free of laminar imperfections > 6.4 mm (0.25 in.) in the circumferential direction.

## E.3.3 Pipe End Inspection—SMLS Pipe

**E.3.3.1** If an automated ultrasonic or electromagnetic inspection system (combined equipment, operating procedures, and personnel) is applied to meet the requirements of E.3.1.2, the portion at the pipe end that is not covered by the automated inspection system shall be inspected for defects by the manual or semi-automatic ultrasonic angle beam method or the magnetic particle method, otherwise such noninspected pipe ends shall be cut off. Records in accordance with E.5.4 shall be maintained.

**E.3.3.2** If agreed for pipe with  $t \ge 5.0$  mm (0.197 in.), ultrasonic inspection in accordance with ISO 10893-8 or ASTM A578 and ASTM A435 shall be used to verify that the 25 mm (1.0 in.) wide zone at each pipe end is free of laminar imperfections > 6.4 mm (0.25 in.) in the circumferential direction.

# E.4 Radiographic Inspection of Weld Seams

## E.4.1 Radiographic Technique

When applicable, radiographic inspection of the weld seam shall be conducted in accordance with the following:

a) for film radiographic inspection: ISO 10893-6 image quality class A or B, or ASTM E94;

b) for digital radiographic inspection: ISO 10893-7, ASTM E2698, or ASTM E2033.

## E.4.2 Radiographic Inspection Equipment

**E.4.2.1** The homogeneity of weld seams examined by radiographic methods shall be determined by means of X-rays directed through the weld material in order to create a suitable image on a radiographic film or digital imaging medium (i.e. CR, DDA), provided that the required sensitivity is demonstrated.

**E.4.2.2** The radiographic films used shall be in accordance with ISO 11699-1:2008, class C4 or C5, or ASTM E1815-08, class I or class II, and shall be used with lead screens.

**E.4.2.3** The density of the radiograph shall be not less than 2.0 (excluding the weld seam) and shall be chosen such that:

a) the density through the thickest portion of the weld seam is not less than 1.5, and

b) the maximum contrast for the type of film used is achieved.

# E.4.3 IQIs

**E.4.3.1** Unless otherwise agreed, wire-type IQIs shall be used. If other standard IQIs are used, equivalent or better sensitivity shall be achieved.

**E.4.3.2** If ISO wire-type IQIs are used, they shall be W 1 FE, W 6 FE, or W 10 FE, in accordance with ISO 19232-1:2004, and the essential wire diameters shall be as given in Table E.3 for the applicable weld thickness.

**E.4.3.3** If ASTM wire-type IQIs are used, they shall be in accordance with ASTM E747, and the essential wire diameters shall be as given in Table E.4 for the applicable weld thickness.

**E.4.3.4** Except as allowed by E.4.3.5, the IQI used shall be placed across the weld at a location representative of full weld reinforcement and shall contain both essential wire diameters, with one being determined based on the weld thickness with full reinforcement and the other being determined based on the weld thickness without reinforcement.

E.4.3.5 Two IQIs may be used—one placed across the weld and the other placed on the parent metal.

**E.4.3.6** IQIs shall be placed on the source side. When the source side is inaccessible, the IQIs may be placed on the film/detector side of the object. In these circumstances a letter "F" shall be placed near the IQIs, and this procedural change shall be recorded in the test report.

NOTE A trial exposure with IQIs on both source and detector sides of a piece of pipe is an effective means to assess relative sensitivity.

Weld Thickness <sup>a</sup> mm (in.)	Essential Wire Diameter mm (in.)	FE Wire Set	Wire Number
≤ 8 (0.3)	0.16 (0.006)	W 10 to W 16	14
> 8 (0.3) to 11 (0.4)	0.20 (0.008)	W 10 to W 16	13
> 11 (0.4) to 14 (0.6)	0.25 (0.010)	W 10 to W 16 or W 6 to W 12	12
> 14 (0.6) to 18 (0.7)	0.32 (0.013)	W 10 to W 16 or W 6 to W 12	11
> 18 (0.7) to 25 (1.0)	0.40 (0.016)	W 10 to W 16 or W 6 to W 12	10
> 25 (1.0) to 32 (1.2)	0.50 (0.020)	W 6 to W 12	9
> 32 (1.2) to 41 (1.6)	0.63 (0.025)	W 6 to W 12	8
> 41 (1.6) to 50 (2.0)	0.80 (0.032)	W 6 to W 12	7
> 50 (2.0)	1.00 (0.039)	W 6 to W 12	6
<sup>a</sup> The weld thickness is the sum of the specified wall thickness and the estimated thickness of the weld reinforcement.			

Table E.3—ISO Wire-type IQI for Radiographic Inspection

Weld Thickness <sup>a</sup> mm (in.)	Essential Wire Diameter mm (in.)	Wire Set	Wire Identity
≤ 8 (0.3)	0.16 (0.006)	А	4
> 8 (0.3) to 11 (0.4)	0.20 (0.008)	A	5
> 11 (0.4) to 14 (0.6)	0.25 (0.010)	A or B	6
> 14 (0.6) to 18 (0.7)	0.33 (0.013)	В	7
> 18 (0.7) to 25 (1.0)	0.41 (0.016)	В	8
> 25 (1.0) to 32 (1.2)	0.51 (0.020)	В	9
> 32 (1.2) to 41 (1.6)	0.64 (0.025)	В	10
> 41 (1.6) to 50 (2.0)	0.81 (0.030)	B or C	11
> 50 (2.0)	1.02 (0.040)	С	12
<sup>a</sup> The weld thickness is the sum of the specified wall thickness and the estimated thickness of the weld reinforcement.			