

7.9.16.8

For localized stress relieving, temperatures shall be monitored by using thermocouple pyrometers or other suitable devices.

7.10 Arc and gas welding — Inspection and testing of production welds

7.10.1 General

7.10.1.1

Inspectors shall be competent and their qualifications shall be approved by the company.

Note: CSA W178.2 provides an example of welding inspector training and competency requirements.

7.10.1.2

Except as allowed by Clause 7.10.1.4, production welds that are not required to be nondestructively inspected (see Clause 7.10.3) shall be inspected visually or by a combination of visual and nondestructive methods to determine compliance with the applicable acceptance criteria. The inspection method or methods to be used shall be at the option of the company and as specified in Clauses 7.10.2 and 7.10.4.

7.10.1.3

Welds that are nondestructively inspected using ultrasonic methods shall be visually inspected as specified in Clause 7.10.2.

7.10.1.4

The company shall have the right to inspect production welds nondestructively or by removing them and conducting mechanical tests. Such inspections may be made during or after welding, or both.

7.10.2 Visual inspection

7.10.2.1

The completed welds on the outside surface of the piping shall be visually inspected for 100% of the weld length for any imperfections that are not detectable by nondestructive inspection, in accordance with documented procedures approved by the company. Such procedures shall include requirements for extent and frequency of visual inspection, personnel qualification and visual acuity, maximum viewing distance and angle, lighting conditions, evaluation tools, and reporting.

7.10.2.2

Surface imperfections detected by visual inspection shall be evaluated on the basis of the applicable requirements of Clause 7.11.

7.10.2.3

Results of the visual inspection of completed welds shall be reported in a format approved by the company. Reports of defective welds shall include

- (a) weld identification;
- (b) description, position, and length of defects;
- (c) date; and
- (d) signature of qualified visual inspector.

7.10.2.4

Visual inspection records shall be kept until the piping is abandoned.

Note: Consideration should be given to maintaining such records for any abandoned piping that can be returned to service.

7.10.3 Mandatory nondestructive inspection

7.10.3.1

All welds within the limits of uncased road and railway crossings, all welds within the limits of water crossings, all pressure-retaining welds that will not be pressure tested in place, and a minimum of 15% of all other production welds made each day shall be nondestructively inspected

- (a) for 100% of their lengths;
- (b) as specified in Clause 7.10.4; and
- (c) where such welds are butt welds, using radiographic or ultrasonic methods, or a combination of such methods.

Where the daily results of the nondestructive inspection are unacceptable to the company, more nondestructive inspection or remedial actions shall be required.

Note: *Welds that are inspected should be reasonably representative of the daily production.*

7.10.3.2

For carbon dioxide pipeline systems, all butt welds shall be inspected by radiographic or ultrasonic methods, or a combination of such methods, for 100% of their circumferences, as specified in Clause 7.10.4.

7.10.3.3

Partial-penetration butt welds shall be radiographically inspected for 100% of their circumferences, as specified in Clauses 7.10.4 and 7.11.1.3.

7.10.4 Nondestructive inspection

7.10.4.1 Methods

In selecting methods of nondestructive inspection, the company shall consider the

- (a) nature of imperfections that can result from the welding processes to be used;
- (b) capability of the nondestructive inspection methods to detect such imperfections; and
- (c) accuracy of indication, interpretation, and evaluation possible with such nondestructive inspection methods.

The nondestructive inspection procedures used shall be documented and approved by the company.

Note: *The company can require personnel responsible for nondestructive inspection to demonstrate the capability of the procedure to detect imperfections and to demonstrate their ability to correctly interpret indications.*

7.10.4.2 Evaluation of results

Except as allowed by Clause 7.10.4.3, welds inspected nondestructively shall be evaluated on the basis of the requirements of Clauses 7.11 or 7.15.10, whichever is applicable.

7.10.4.3 Alternative evaluation of results

At the option of the company, as an alternative to the requirements of Clauses 7.11 and 7.15.10, Annex K may be used for the evaluation of circumferential butt welds in designated portions of lines that

- (a) are made using a welding procedure qualified as specified in Annex K;
- (b) are inspected as specified in Annex K;
- (c) join pipes of equal nominal wall thickness and grade;
- (d) are intended for other than sour service as defined in Clause 16.2;
- (e) are located in other than pump stations, compressor stations, measuring stations, or pressure-regulating stations, or other assembly piping; and
- (f) are located where significant imperfection growth in service is not anticipated.

7.10.5 Destructive testing

7.10.5.1

Destructive testing shall consist of removing completed welds, sectioning them into test specimens, and testing the specimens as specified in Clauses 7.7.2 to 7.7.10. The company shall have the right to disqualify from further work, or to require further testing of, welders making welds that are not in accordance with such requirements.

7.10.5.2

Trepanning methods of testing shall not be used.

7.10.6 Disposition of defective welds

7.10.6.1

Except as allowed by Clause 7.10.6.2, welds that are unacceptable on the basis of Clause 7.11, Clause 7.15.10, or Annex K, whichever is applicable, shall be removed, or repaired as specified in Clause 7.12.

7.10.6.2

Welds that have previously been accepted and are subsequently found to be unacceptable on the basis of Clauses 7.11.3 to 7.11.17, Clause 7.15.10, or Annex K, whichever is applicable, shall be

- (a) accepted, provided that the weld imperfections are found to be acceptable on the basis of an engineering critical assessment involving consideration of service history and loading, anticipated service conditions (including the effects of corrosive and chemical attack), accurately established dimensions and location of the imperfections, and weld properties (including fracture toughness);
- (b) repaired as specified in Clause 7.12; or
- (c) removed.

Note: A recommended practice for determining the acceptability of imperfections in fusion welds in pipeline systems using engineering critical assessment is included in Annex J.

7.11 Arc and gas welding — Standards of acceptability for nondestructive inspection

7.11.1 General

7.11.1.1 Applicability

These standards of acceptability shall apply to the determination of the acceptability of indications of imperfections of the size and type located by radiography and other nondestructive inspection methods other than ultrasonic inspection. Requirements specified for welds made using pipe shall also apply to welds made using components and where applicable, shall be governed by the component nominal wall thickness at the bevel and by the outside diameter of the matching pipe. Such standards of acceptability are intended as a measure of adequate welding competence, as performed in accordance with qualified welding procedure specifications.

Notes:

- (1) The company has the option of using alternative standards of acceptability as specified in Clause 7.10.4.3.
- (2) Additional standards of acceptability for sour service pipelines are specified in Clause 16.9.3.3.

7.11.1.2 Rights of rejection

Since nondestructive inspection methods generally give only two-dimensional results, the company may reject welds that appear to meet these standards of acceptability where, in its opinion, the depth, location, or orientation of imperfections can be significantly detrimental to the structural integrity of the welds.

7.11.1.3 Partial-penetration butt welds

Radiographic inspection of partial-penetration butt welds shall require the use of the comparative radiograph(s) obtained during the welding procedure qualification (see Clause 7.7.10.1) for estimating incomplete penetration. The standards of acceptability for partial-penetration butt welds shall be as specified in Clauses 7.11.2 to 7.11.17, except that

- (a) weld penetration shall be from 85 to 100% of the nominal wall thickness;
- (b) internal projection shall not be allowed;
- (c) individual indications of burn-through areas shall not be allowed; and
- (d) indications of incomplete fusion in the root and hot passes shall not be allowed.

7.11.2 Weld crown

At no point shall the outside crown surface of welds be below the surface of the adjacent base metal or above it by more than the amount shown in Table 7.6, except that, at the option of the company, an additional 1.0 mm shall be allowed for localized deviations.

Table 7.6
Outside crown height
(See Clause 7.11.2 and Tables 7.8 and 7.9.)

| Nominal wall thickness, mm | Outside crown height, maximum, mm |
|----------------------------|-----------------------------------|
| 10.0 or less | 2.5 |
| Greater than 10.0 | 3.5 |

7.11.3 Incomplete penetration of the root bead

A schematic representation of incomplete penetration of the root bead (incomplete filling of the root of the joint) is shown in Figure 7.15. Except where partial-penetration welds are required by design, the following shall apply:

- (a) Individual indications of incomplete penetration conditions shall not exceed 12 mm in length.
- (b) The cumulative length of such indications in any 300 mm length of weld shall not exceed 25 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length.

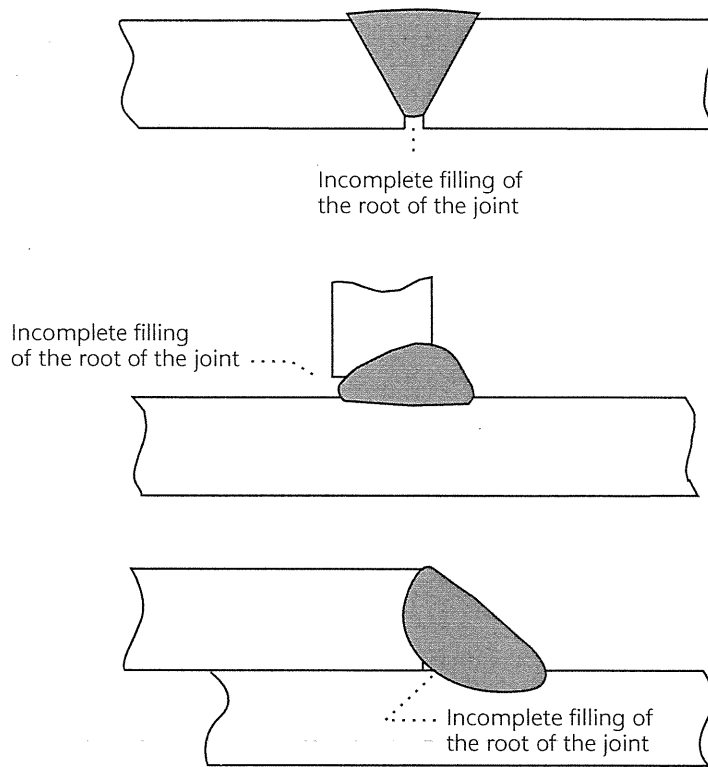


Figure 7.15
Incomplete penetration of the root bead
 (See Clause 7.11.3.)

7.11.4 Incomplete fusion

A schematic representation of incomplete fusion (a lack of bond between the weld metal and the base metal at the root or top of the joint) is shown in Figure 7.16. Individual indications of incomplete fusion conditions shall not exceed 12 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 25 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length.

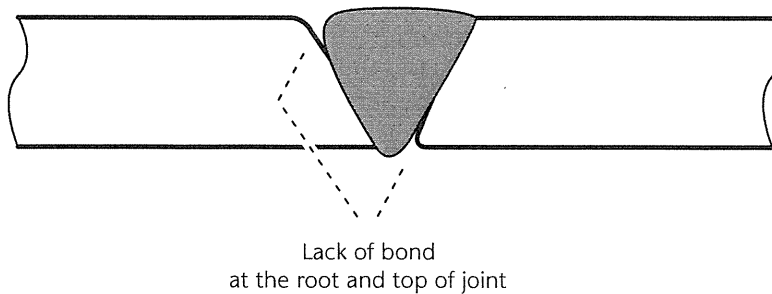
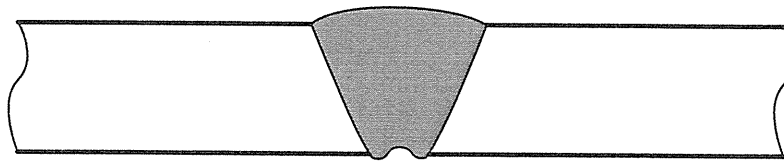


Figure 7.16
Incomplete fusion
 (See Clause 7.11.4.)

7.11.5 Internal concavity

A schematic representation of internal concavity (incomplete filling of the root of the joint, wherein the sides of the root are filled and the centre is not) is shown in Figure 7.17. This condition is acceptable regardless of length, provided that the minimum thickness of the weld metal exceeds the thickness of the adjacent base metal. Where the minimum thickness of the weld metal does not exceed that of the adjacent base metal, individual indications of internal concavity shall not exceed 50 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length.

Note: Where radiography is used to evaluate internal concavity, this imperfection is acceptable regardless of length, provided that the density of its radiographic image does not exceed the density of the radiographic image of the adjacent base metal.



Root bead is fused to both surfaces, but the centre of the bead is below the inside pipe surface

Figure 7.17
Internal concavity
(See Clause 7.11.5.)

7.11.6 Undercut

7.11.6.1

Undercut is a groove melted into the base metal adjacent to a weld toe at the root or top of the joint and left unfilled by the deposited weld metal.

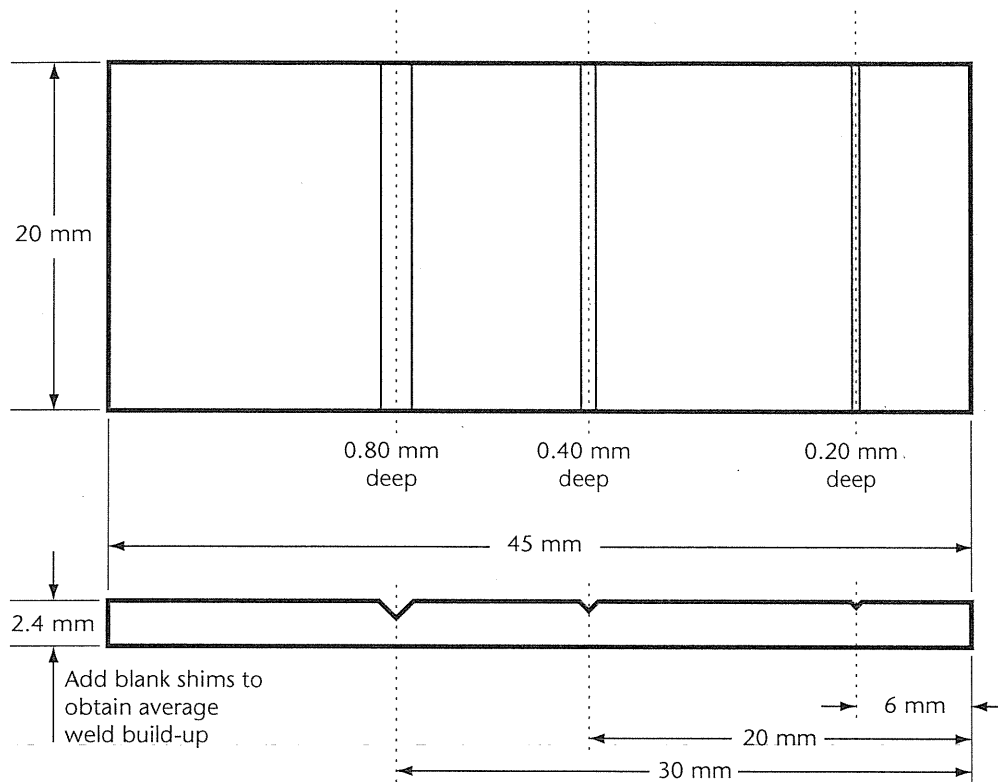
7.11.6.2

Except as allowed by Clause 7.11.6.3, the following shall apply:

- (a) Individual lengths of indications of undercut shall not exceed 50 mm.
- (b) The cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length.
- (c) For qualification of welders, the maximum depth of undercuts adjacent to the final test weld bead on the outside of the pipe or component shall not exceed 1 mm.

7.11.6.3

Undercut depths less than 0.5 mm or 6% of the nominal wall thickness, whichever is the lesser, shall be acceptable regardless of length, provided that a visual, mechanical, or nondestructive method of assessing the depth is used. Assessment of undercut depths using radiography is allowed only where comparator shims as described in Clause 7.13.7 and shown in Figure 7.18 are used.

**Notes:**

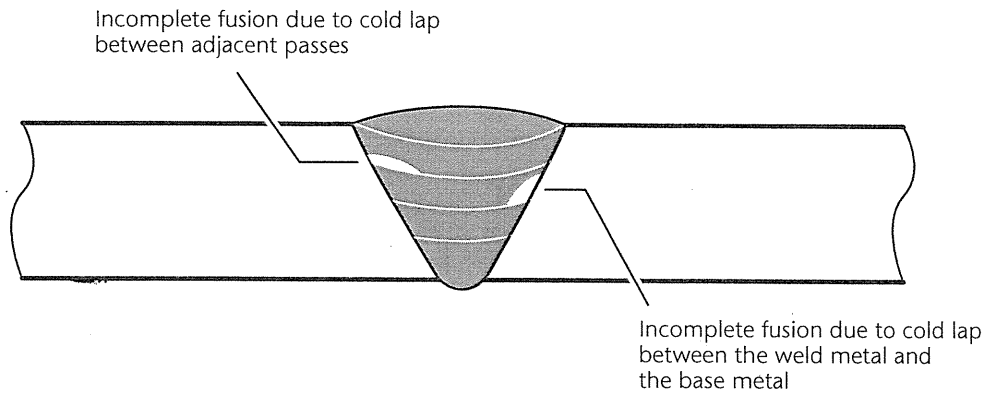
- (1) Notch location tolerance shall be ± 0.5 mm.
- (2) All notches are V-shaped with 45° included angles.
- (3) Notch depth tolerance shall be ± 0.025 mm.

Figure 7.18 Comparator shim

(See Clauses 7.11.6.3 and 7.13.7.)

7.11.7 Incomplete fusion due to cold lap

Incomplete fusion due to cold lap is a subsurface lack of bond between weld beads (cold lap) or between the weld metal and the base metal (lack of side wall fusion). A schematic representation of an example of this imperfection is shown in Figure 7.19. Individual indications of incomplete fusion due to cold lap conditions shall not exceed 50 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length.



Note: *Incomplete fusion due to cold lap is not surface-connected.*

Figure 7.19
Incomplete fusion due to cold lap
 (See Clause 7.11.7.)

7.11.8 Lack of cross-penetration

Lack of cross-penetration is a lack of penetration occurring at the weld interior where the joint preparation incorporates abutting surfaces. Such an imperfection occurs due to lack of penetration of the second weld pass. A schematic representation of an example of this imperfection is shown in Figure 7.20. Individual indications of lack of cross-penetration conditions shall not exceed 50 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length.

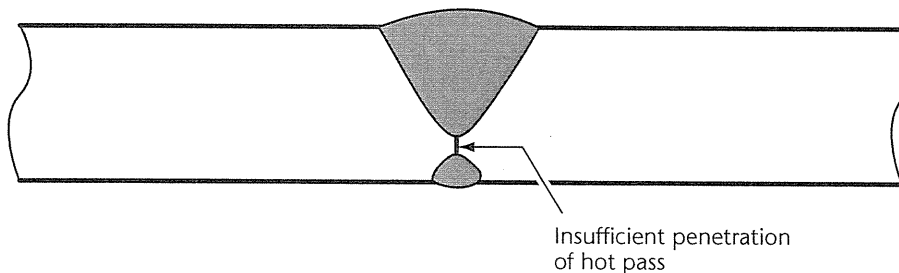


Figure 7.20
Lack of cross-penetration
 (See Clause 7.11.8.)

7.11.9 Elongated slag inclusions

7.11.9.1

Elongated slag inclusions are nonmetallic solids that are entrapped in the weld metal or between the weld metal and the base metal and produce indications that are less than 1.5 mm in width.

7.11.9.2

For pipe 60.3 mm OD or larger and components NPS 2 or larger, individual indications of elongated slag inclusions shall not exceed 50 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length. Indications of parallel slag lines shall be considered to be separate indications if the width of one or both of them exceeds 0.8 mm.

7.11.9.3

For pipe smaller than 60.3 mm OD and components smaller than NPS 2, individual indications of elongated slag inclusions and cumulative lengths of such indications shall not exceed 3 times the nominal wall thickness in length. Indications of parallel slag lines shall be considered to be separate indications if the width of one or both of them exceeds 0.8 mm.

7.11.10 Hollow bead

Hollow bead is linear porosity or cylindrical gas pockets occurring in the root bead. A schematic representation of an example of this imperfection is shown in Figure 7.21. Individual indications of hollow bead conditions shall not exceed 12 mm in length. The cumulative length of such indications in any 300 mm length of weld shall not exceed 25 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length.

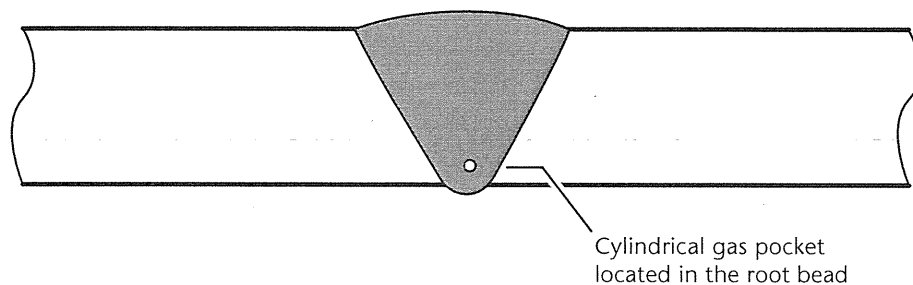


Figure 7.21
Hollow bead
(See Clause 7.11.10.)

7.11.11 Burn-through areas**7.11.11.1**

Burn-through areas are those portions of root beads where excessive arc penetration has caused the weld puddle to be blown into the insides of the parts joined.

7.11.11.2

For pipe 60.3 mm OD or larger and components NPS 2 or larger, individual indications of burn-through areas shall not exceed 5 mm or the thickness of the base metal, whichever is the lesser, in any dimension. The cumulative maximum dimensions of such indications in any 300 mm length of weld shall not exceed 12 mm.

7.11.11.3

For pipe smaller than 60.3 mm OD and components smaller than NPS 2, not more than one indication of burn-through area is acceptable, and it shall not exceed 6 mm or the thickness of the base metal, whichever is the lesser, in any dimension.

7.11.11.4

Welds that contained burn-through areas shall be considered to have been properly repaired if the density of the radiographic image of the repaired area does not exceed that of the adjacent base metal.

7.11.12 Isolated slag inclusions**7.11.12.1**

Isolated slag inclusions are nonmetallic solids that are entrapped in the weld metal or between the weld metal and the base metal and produce indications that are 1.5 mm or greater in width.

7.11.12.2

For pipe 60.3 mm OD or larger and components NPS 2 or larger, individual indications of isolated slag inclusions shall not exceed 2.5 mm or 0.33 times the nominal wall thickness of the base metal, whichever is the lesser, in any dimension. The cumulative maximum dimensions of such indications in any 300 mm length of weld shall not exceed 10 mm and there shall be no more than 4 such indications of the maximum dimension allowed in such 300 mm lengths. Adjacent indications of isolated slag inclusions shall be separated by a minimum of 50 mm of sound weld metal.

7.11.12.3

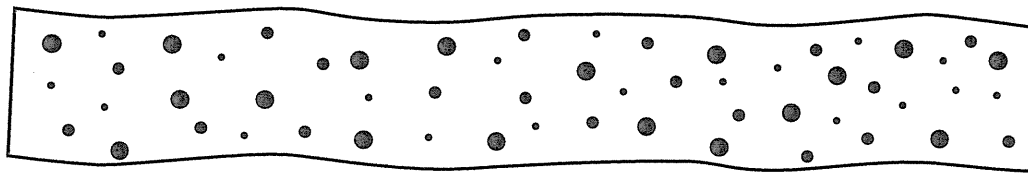
For pipe smaller than 60.3 mm OD and components smaller than NPS 2, individual indications of isolated slag inclusions shall not exceed 2.5 mm or 0.33 times the nominal wall thickness of the base metal, whichever is the lesser, in any dimension. The cumulative length of such indications shall not exceed 2 times the nominal wall thickness of the base metal.

7.11.13 Spherical porosity

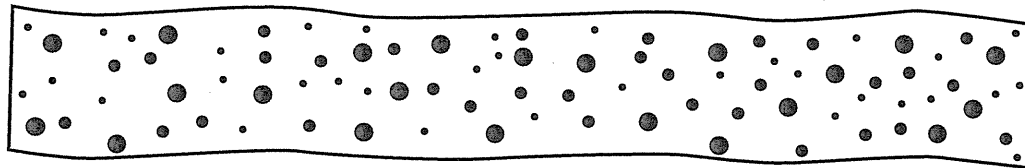
Spherical porosity is gas pockets having a circular section and occurring in the weld metal. Individual indications of spherical gas pockets shall not exceed 3 mm or 25% of the nominal wall thickness of the base metal, whichever is the lesser, in any dimension. The cumulative amount of indications of spherical porosity in any 150 mm of weld length, expressed in terms of the projected area on the radiograph, shall not exceed the value given in Table 7.7. An example of each of such amounts of spherical porosity is shown in Figure 7.22.

Table 7.7
Maximum acceptable amount of spherical porosity
(See Clause 7.11.13.)

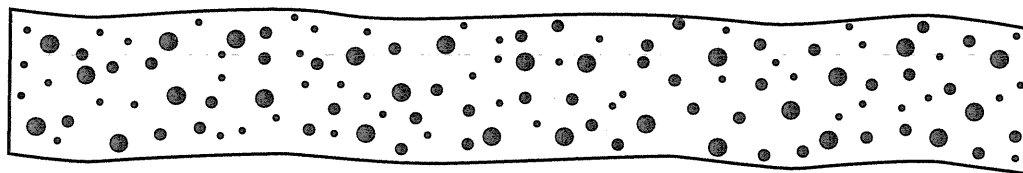
| Weld thickness, mm | Maximum acceptable projected area on radiograph, % |
|-----------------------|--|
| Less than 14 | 3 |
| 14–18 | 4 |
| Greater than 18 | 5 |



(a) 3% projected area



(b) 4% projected area



(c) 5% projected area

Figure 7.22
Spherical porosity
 (See Clause 7.11.13.)

7.11.14 Wormhole porosity

Wormhole porosity is an elongated gas pocket, resulting from gas rising through the solidifying weld metal, that has an orientation that tends to be partly in the through-thickness direction. Individual indications of wormhole porosity shall not exceed 2.5 mm or 0.33 times the nominal wall thickness of the base metal, whichever is the lesser, in any dimension. The cumulative length of such indications in any 300 mm length of weld shall not exceed 10 mm and there shall be not more than 4 such imperfections of the maximum dimension allowed in such 300 mm lengths. Adjacent indications of wormhole porosity shall be separated by a minimum of 50 mm of sound weld metal. The orientation of wormhole porosity can substantially affect the density of its radiographic image; when applying these limits, consideration shall be given to the requirements of Clause 7.11.1.2.

7.11.15 Cracks and arc burns

7.11.15.1

Indications of cracks shall be unacceptable regardless of location (weld metal or HAZ).

7.11.15.2

Indications of arc burns shall be unacceptable regardless of location.

7.11.16 Unequal leg length — Fillet welds

Except where required by design, there shall be not more than 3 mm difference between the leg lengths of each fillet weld.

7.11.17 Accumulation of imperfections

7.11.17.1

The cumulative length of the indications of all imperfections that are restricted by the requirements of Clauses 7.11.3, 7.11.4, 7.11.10, and 7.11.11 shall not exceed 25 mm in any 300 mm length of weld, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length. The cumulative length of the indications of all other imperfections that are restricted by the requirements of Clauses 7.11.5 to 7.11.9, and of the indications of those imperfections that are restricted by the requirements of Clauses 7.11.12 to 7.11.14, shall not exceed 50 mm in any 300 mm length of weld, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 16% of the weld length.

7.11.17.2

For partial-penetration welds, the cumulative length of the indications of all imperfections, other than those at the root, shall not exceed 25 mm in any 300 mm length of weld, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length.

7.11.18 Weld conditions limiting radiographic interpretation

Weld conditions that prevent proper interpretation of radiographs shall be cause for rejection of the welds, unless they can be inspected by other acceptable methods.

7.12 Arc and gas welding — Repair of welds containing repairable defects

7.12.1 Partial-penetration butt welds

Root defects in partial-penetration butt welds are nonrepairable and shall be removed by cutting out a cylinder of pipe containing the defect and rewelding.

7.12.2 Authorization for repairs

Without prior company authorization, welds containing defects other than cracks in the cover pass may be repaired. With prior company authorization, welds containing any type of repairable defect may be repaired.

7.12.3 Repair procedures

7.12.3.1

Before weld repairs are made, defects shall be entirely removed to expose clean metal. Slag and scale shall be removed by wire brushing.

7.12.3.2

Preheating to a temperature of at least 120 °C shall be used when performing repairs. Preheating shall extend to a distance of at least 150 mm from any point of the area to be repaired. Care shall be taken to prevent overheating, and no part of the area shall be heated to a temperature in excess of 200 °C unless the requirements of Clause 4.3.5.2 are met.

7.12.3.3

The length of repair welds shall be at least 50 mm.

7.12.4 Removal of arc burns in weld areas

Arc burns shall be completely removed either by cutting out cylinders containing the arc burns or, where authorized by the company, by using repair procedures that include

- (a) checking for complete removal of the altered metallurgical structure by etching the repair area with a 10% solution of ammonium persulphate or a 5% solution of nital; and
- (b) measuring the wall thickness in the repaired area using mechanical or ultrasonic techniques, or both, to determine that the minimum wall thickness requirements are maintained.

Note: *The effectiveness of the etchant should be periodically tested by obtaining a positive indication from an arc burn, since lower metal temperatures and the age of the etchant can adversely affect the results obtained.*

7.12.5 Removal of cracks in circumferential butt welds and in fillet welds

Cracks in circumferential butt welds and in fillet welds shall be completely removed by cutting out cylinders containing such cracks, except that where authorized by the company, welds containing cracks may be repaired using a documented repair procedure that includes

- (a) a requirement to establish the location of the crack;
- (b) a specification of the crack removal method, which shall be for a crack originating at
 - (i) an accessible surface, by grinding to remove the crack and to establish the repair welding groove contour; or
 - (ii) the root and repaired from the outside surface, by grinding, drilling holes at the crack extremities, sawing through to form a new root bead opening, and grinding to establish the repair welding groove contour;
- (c) a requirement that complete removal of the cracks be confirmed by liquid penetrant or wet magnetic particle inspection of the ground areas by inspectors qualified as specified in CAN/CGSB-48.9712; and
- (d) a requirement that areas ground out be repaired by welding as specified in Clause 7.12 and in accordance with qualified welding procedure specifications.

Notes:

- (1) *For new installations, welds containing cracks should be removed by cutting out cylinders; however, it is recognized that in some circumstances it can be more appropriate to repair such welds.*
- (2) *Low-hydrogen welding practices should be used for repair welding; where such practices are not used, higher preheating and interpass temperatures should be considered.*

7.12.6 Inspection of repairs

7.12.6.1

Repaired areas of welds shall be inspected by the same means previously used. Where repairs are unacceptable, welds shall be completely removed by cutting out cylinders containing the repaired welds or, where authorized by the company, further repairs shall be made.

Notes:

- (1) *For welds that contained cracks, consideration should be given to an additional inspection of the full weld by ultrasonic inspection, where this was not the means previously used.*
- (2) *Consideration should be given to an additional inspection of the repaired areas in cases where the original inspection method may not be applicable to the welding process used for repairing the welds.*

7.12.6.2

The acceptability of repaired areas of welds shall be determined as specified in Clause 7.11 or 7.15.10, whichever is applicable.

7.13 Arc and gas welding — Materials and equipment for radiographic inspection

7.13.1 General

Radiographic images shall be produced on film or other imaging media. The resulting radiographic images shall be in accordance with the applicable requirements of Clauses 7.13 and 7.14. Non-film radiographic techniques shall produce permanent radiographic image records that can be readily retrieved for viewings and the image data shall be stored in its original unaltered format.

7.13.2 Radiographic procedure

A written procedure shall be developed for each radiographic inspection technique used for both film and non-film imaging systems. The procedure shall detail the specifics of the radiographic technique, including such things as the type and thickness of material for which the procedure is suitable, the image collection and viewing system, radiation source, use of intensifying screens, film type, the type of image quality indicators, exposure geometry, and image storage practices.

7.13.3 Radiation sources

Sources of radiation shall be X-ray machines or radioisotopes.

7.13.4 Imaging media

7.13.4.1

For film radiography, radiographic films of high contrast and relatively fine grain shall be used.

7.13.4.2

Radiographic films shall be classified according to ISO 5579 as follows:

- (a) GI: very fine-grained film, very slow speed;
- (b) GII: fine-grained film, slow speed;
- (c) GIII: medium-grained film, medium speed; and
- (d) GIV: large-grained film, high speed.

Note: *The following schematic illustrates the relationship between film quality and film speed:*

Improving image quality →
GIV GIII GII GI
 ← Increasing film speed

7.13.4.3

The use of non-film radiography requires the use of alternative imaging media. Such imaging media shall be capable of consistently producing radiographic images in accordance with the applicable requirements of Clauses 7.13 and 7.14.

7.13.5 Screens

Where intensifying screens are used, the resulting radiographs shall clearly show the image quality indicators as specified in Clause 7.14.6.4.

Note: *Film holders should be backed with sheet lead wherever secondary or scattered radiation would detrimentally influence the results of radiography.*

7.13.6 Image quality indicators

7.13.6.1

Image quality indicators (IQIs) shall be used to measure the sensitivity of the radiographic image. Either standard hole-type or wire-type IQIs shall be used. Hole-type IQIs shall conform to ASTM E1025 and

wire-type IQIs shall conform to ASTM E747 or ISO 19232-1. The size of the hole-type or wire-type IQI to be used depends on the thickness of the weld to be radiographed and shall be as given in Table 7.8 for X-ray radiography and Table 7.9 for radioisotope gamma radiography.

7.13.6.2

Where weld reinforcement has not been removed, hole-type IQIs require the use of a shim of radiographically similar material, so that the total thickness being radiographed under the IQI is approximately equal to the total weld thickness.

7.13.7 Comparator shims

Where comparator shims are used, the depth of internal undercut shall be estimated by comparing the density of the image of the internal undercut with the density of images of known notch depths in the comparator shims (see Figure 7.18). Shims shall be made of material that is radiographically similar to the material being inspected and the image of at least one shall appear on each radiograph.

Table 7.8
Image quality indicator selection criteria for X-ray radiography

(See Clauses 7.13.6.1 and 7.14.6.4.)

| Weld thickness, mm | Hole-type IQI | | | Wire-type IQI | | |
|--------------------|---------------|-------------|----------------|--------------------------------------|-------------|----------|
| | Thickness, mm | Designation | Essential hole | Essential wire diameter, maximum, mm | Wire number | ASTM set |
| up to 8 | 0.25 | 10 | 2T | 0.16 | 14 | A |
| > 8 up to 11 | 0.30 | 12 | 2T | 0.20 | 13 | A |
| >11 up to 14 | 0.38 | 15 | 2T | 0.25 | 12 | A or B |
| >14 up to 18 | 0.43 | 17 | 2T | 0.32 | 11 | B |
| >18 up to 25 | 0.51 | 20 | 2T | 0.40 | 10 | B |
| >25 up to 38 | 0.64 | 25 | 2T | 0.50 | 9 | B |
| >38 up to 44 | 0.76 | 30 | 2T | 0.63 | 8 | B |

Notes:

- (1) For hole-type image quality indicators, a smaller hole in a thicker IQI, or a larger hole in a thinner IQI, may be substituted for any weld thickness given in this Table, provided that an equivalent or better sensitivity is achieved. Approximate equivalence between hole-type IQIs is given in the ASME Boiler and Pressure Vessel Code, Section V, Table T-283. Approximate equivalence between hole and wire type IQIs is given in Table 4 of ASTM E747.
- (2) Wire number relates to the ISO wire-type IQIs.
- (3) Weld thickness shall not exceed the sum of the nominal wall thickness plus the maximum permissible weld crown height, as defined in Table 7.6. For welds joining material of unequal thickness, the weld thickness shall not exceed the sum of t_w in Figure 7.2 plus the maximum permissible weld crown height, as defined in Table 7.6.

Table 7.9
Image quality indicator selection criteria for gamma radiography
 (See Clauses 7.13.6.1 and 7.14.6.4.)

| Weld thickness, mm | Hole-type IQI | | | Wire-type IQI | | |
|--------------------|---------------|-------------|----------------|--------------------------------------|-------------|----------|
| | Thickness, mm | Designation | Essential hole | Essential wire diameter, maximum, mm | Wire number | ASTM set |
| up to 8 | 0.30 | 12 | 2T | 0.20 | 13 | A |
| > 8 up to 11 | 0.38 | 15 | 2T | 0.25 | 12 | A or B |
| >11 up to 14 | 0.43 | 17 | 2T | 0.32 | 11 | B |
| >14 up to 18 | 0.51 | 20 | 2T | 0.40 | 10 | B |
| >18 up to 25 | 0.51 | 20 | 2T | 0.40 | 10 | B |
| >25 up to 38 | 0.64 | 25 | 2T | 0.50 | 9 | B |
| >38 up to 44 | 0.76 | 30 | 2T | 0.63 | 8 | B |

Notes:

- (1) For hole-type image quality indicators, a smaller hole in a thicker IQI, or a larger hole in a thinner IQI, may be substituted for any weld thickness given in this Table, provided that an equivalent or better sensitivity is achieved. Approximate equivalence between hole-type IQIs is given in the ASME Boiler and Pressure Vessel Code, Section V, Table T-283. Approximate equivalence between hole and wire-type IQIs is given in Table 4 of ASTM E747.
- (2) Wire number relates to the ISO wire-type IQIs.
- (3) For pipe diameters 114.3 mm OD and smaller and components NPS 4 and smaller, a one size larger essential wire diameter may be used.
- (4) Weld thickness shall not exceed the sum of the nominal wall thickness plus the maximum permissible weld crown height, as defined in Table 7.6. For welds joining material of unequal thickness, the weld thickness shall not exceed the sum of t_w in Figure 7.2 plus the maximum permissible weld crown height, as defined in Table 7.6.

7.14 Arc and gas welding — Production of radiographs

7.14.1 Radiation source location

The radiation source shall be located either inside or outside the pipe or component. Where radiation sources are located on the outside, the image of one or both walls shall be acceptable for interpretation.

7.14.2 Geometric relationship

7.14.2.1

During exposure, film or other imaging media shall be as close to the surface of the weld as practical.

7.14.2.2

The distance between the source of radiation and the film or other imaging media shall be not less than 7 times the distance between the film or other imaging media and the weld surface farthest removed from it.

Note: Preferably, the source-to-imaging media distance should be at least 10 times the distance between the imaging media and the weld surface farthest removed from it.

7.14.2.3

Radiation sources shall not be offset by more than 5° from the plane of circumferential welds, except where necessary for elliptical projection. For elliptical projection, the offset angle shall be increased by the minimum amount required to separate the images of the opposite sides of the weld so that there is no superimposition of such images produced as specified in Clause 7.14.3.

7.14.2.4

An elliptical double-wall viewing technique may be used for welds on pipe 88.9 mm OD or smaller and components NPS 3 or smaller, provided that the technique is applied as specified in Paragraph T271.2(b) of the ASME *Boiler and Pressure Vessel Code*, Section V.

7.14.3 Size of radiation field

Where both the radiation source and the imaging media are located outside the pipe or component and diametrically opposite each other, at least three equally spaced exposures shall be required to constitute 100% radiographic coverage of the weld, except that where an elliptical projection technique is used, at least two exposures shall be required, taken 90° apart.

7.14.4 Location of image quality indicators

7.14.4.1

For a panoramic single-wall exposure technique, at least three IQIs shall be spaced equally around the weld circumference.

7.14.4.2

For a double-wall exposure, single-wall view technique, IQIs shall be placed at both ends within 25 mm of the acceptable limits of coverage for each exposure. For pipe diameters 114.3 mm OD and smaller and components NPS 4 and smaller, an IQI may be used at one end of the acceptable limits of coverage for each exposure.

7.14.4.3

The IQI shall be placed on the source side for the double-wall exposure, double-wall view elliptical technique.

7.14.4.4

When a repaired weld is radiographed, at least one IQI shall be placed adjacent to each repair.

7.14.4.5

Hole-type IQIs shall be placed adjacent to the weld, using shims if necessary. Wire-type IQIs shall be placed across the weld, with the wires perpendicular to the weld direction.

7.14.5 Radiographic image identification markers

7.14.5.1

Radiographic images shall be clearly identified by the use of lead numbers, letters, or markers, or any combination thereof, so that the weld and any discontinuity in the weld can be quickly and accurately located. Where more than one image is used to inspect a complete circumferential weld, identification markers shall appear on each image and each weld section reference marker location shall be common to two successive images so as to establish that the entire weld has been examined.

7.14.5.2

Except as allowed by Clause 7.14.5.3, markers shall be placed on the joint on the downstream side of the weld so that they can be read clockwise when viewed from the upstream side.

7.14.5.3

The company may specify that markers be placed on the joint on either side of the weld. In such cases, records of the location and orientation of the markers shall be retained for a minimum of two years.

7.14.6 Processing of radiographic images

7.14.6.1 General

Radiographs shall be processed in accordance with the applicable manufacturer's recommended practices.

7.14.6.2 Image defects

Radiographs shall be free of mechanical and processing defects. Radiographic images containing artifacts that interfere with the interpretation of the radiograph shall be discarded, and the welds shall be re-radiographed.

7.14.6.3 Film density

Film shall be exposed so that the density is between 2.0 and 4.0 throughout the area of interest, except for small localized areas caused by irregular weld configurations. The density in such small localized areas shall be at least 1.5. The unexposed base density of the film shall not exceed 0.30.

7.14.6.4 Definition of the IQI image

The image of the essential hole or wire shall be clearly defined. The essential hole and wire for a given weld thickness shall be as given in Table 7.8 for X-ray radiography and Table 7.9 for radioisotope gamma radiography.

7.14.6.5 Film-viewing illuminators

Film-viewing illuminators shall be used that produce sufficient light intensity so that all portions of the radiograph of the weld and base metal transmit sufficient light to reveal the pertinent details of the radiograph.

7.14.7 Radiation protection

7.14.7.1

Every worker shall be informed of the hazards of working in an area where exposure to radiation is possible. Adequate precautions shall be taken to protect the radiographer and any other person in the vicinity. The radiographer shall be responsible for making sure that the area is properly posted.

7.14.7.2

Areas affected by radiation shall be surveyed and the limits of hazards posted.

7.14.8 Radiographers

7.14.8.1

Radiographers shall be qualified as specified in CAN/CGSB-48.9712. For radiographic image interpretation, radiographers shall be qualified as specified in CAN/CGSB-48.9712 to Level II or III.

7.14.8.2

The company may examine the qualifications of radiographers to determine that the requirements of Clause 7.14.8.1 are met and that radiographs are produced, processed, and interpreted only by experienced radiographers.

7.14.9 Retention of radiographic records

Records of the interpretation of radiographs shall be kept until the piping is abandoned. Radiographs shall be retained for a minimum of 2 years.

Note: See also Clause 7.14.5.3.

7.15 Arc and gas welding — Ultrasonic inspection of circumferential butt welds in piping

7.15.1 Methods

Clause 7.15 describes the methods that shall be employed for ultrasonic inspection of circumferential butt welds in piping, other than partial-penetration butt welds.

Notes:

- (1) *Ultrasonic inspection might not be appropriate for some combinations of diameter and wall thickness. Factors to consider in selecting methods of nondestructive inspection are specified in Clause 7.10.4.1.*
- (2) *Visual inspection is a mandatory requirement with ultrasonic inspection (see Clause 7.10.1.3).*

7.15.2 Terminology

The definitions contained in Mandatory Appendix III of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 5, apply in Clause 7.15 of this Standard.

7.15.3 General

7.15.3.1

Ultrasonic inspection shall be performed in accordance with a documented procedure approved by the company. Such a procedure shall include the applicable information listed in Paragraph T-421 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4, and a description of the methodology used to investigate indications, to the extent that they can be evaluated in terms of the standards of acceptability.

7.15.3.2

The complete volume of weld metal and HAZ in the weld shall be inspected. Inspection requirements shall be as specified in Paragraph T-471 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4, except that the entire weld may be inspected using an array of search units operating in pulse-echo or tandem mode, each designed to inspect specific parts of the required inspection volume.

7.15.3.3

The length of imperfections shall be determined using the 6 dB drop technique.

7.15.4 Equipment and supplies — General

The equipment and supplies shall be as specified in Paragraphs T-431, T-432, T-461, and T-466 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4. For each search unit used for inspection, the signal to electronic noise ratio shall exceed 40 dB when the maximum response from the basic calibration reflector is set at 80% of full screen height. Under the same conditions, the signal-to-noise ratio of the ultrasonic system shall exceed

- (a) 20 dB for search units other than creeping wave search units; or
- (b) 16 dB for creeping wave search units.

7.15.5 Equipment and supplies — Additional requirements for mechanized inspection systems

7.15.5.1

In addition to the pulse-echo mode, the instrument shall be capable of operating in pitch-catch transmission mode.

7.15.5.2

The equipment shall include a means of displaying the weld and the position of imperfections in the weld.

7.15.5.3

The equipment shall include a means of monitoring the effectiveness of the acoustic coupling.

7.15.5.4

The maximum temperature differential between the search units and the surface of the material (calibration block or piping, whichever is applicable) to be inspected, within which the required accuracy and resolution are to be maintained, shall be established.

7.15.5.5

The equipment shall be capable of measuring the position of indications with an accuracy of 10 mm and a resolution of 2 mm in the circumferential direction. The array of search units shall be centred within 1 mm of the pre-weld centreline of the joint. The effect of search unit beam width, pulse repetition frequency, scanning velocity, and weld shrinkage shall be considered in evaluating the accuracy and resolution of distance measurements. The equipment shall include a means of validating the accuracy of distance measurements.

7.15.5.6

The performance of search units shall be as specified in ESI 98-2. Search units shall have contact surfaces that have the same curvature as that of the surface of the material to be inspected. The search unit dimensions that necessitate the repair or replacement of the search unit shall be established by the manufacturer or the inspection company.

7.15.6 Qualification of ultrasonic inspectors

Ultrasonic inspectors shall be qualified as specified in CAN/CGSB-48.9712 for Level II or III. The company may require ultrasonic inspectors to demonstrate their competence in operating, and evaluating the results of, the inspection system.

7.15.7 Calibration

7.15.7.1

Except as required by Clause 7.15.7.2, the calibration block and reflectors shall be as specified in Paragraph T-434 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4.

7.15.7.2

Where welds are to be evaluated as specified in Annex K, a calibration block made of pipe material, with specific reflectors designed to simulate the expected imperfections, shall be used. The effect of variations in acoustic velocity in the pipe material shall be considered in the design of the calibration block.

7.15.7.3

Calibration blocks shall be identified with a unique serial number and shall be under the control of the inspection company. Records of serial number, pipe diameter, wall thickness, acoustic velocity, and reflector dimensions and positions shall be available when the calibrated blocks are used.

7.15.7.4

The system calibration shall be performed as specified in Paragraphs T-462, T-463, T-464, and T-465 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4, except that the interval between calibration checks shall not exceed 1 h during a series of similar examinations, and the calibration block required by Clause 7.15.7.2 shall be used where applicable. Reference levels shall be set at 80% full screen height and recording levels shall be set at 40% full screen height (6 dB below the reference level).

7.15.8 Inspection procedure for production welds

7.15.8.1

Except as allowed by Clause 7.15.8.3, the inspection of production welds shall be performed as specified in Paragraph T-472 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4.

7.15.8.2

Except where the calibration block required by Clause 7.15.7.2 is used, the reference reflector shall be the 2.4 mm diameter side-drilled hole in the calibration block (see Clause 7.15.7.1).

7.15.8.3

A distance amplitude correction (DAC) curve shall not be required for inspection of welds in materials with a wall thickness of 15 mm or less.

7.15.9 Inspection procedure for production welds — Additional requirements for mechanized inspection

7.15.9.1

The methodology used to interpret system output in terms of non-recordable indication, acceptable indication of an imperfection, or indication of a defect shall be described in the inspection procedure. Such methodology shall include the positioning of recording gates and the effects of conditions such as bead misalignment.

7.15.9.2

Circumferential distance references shall be marked onto the piping surface to allow the positioning of defects from the output of the inspection system.

7.15.9.3

Inspection sensitivity shall be measured using the calibration block at regular intervals not exceeding 1 h or every 10 welds, and when any part of the inspection system is changed, the result from the sensitivity measurements shall be recorded. Any decrease of more than 3 dB from the sensitivity established in the calibration required by Clause 7.15.7.4 for any search unit shall require recalibration and a reinspection of all welds inspected since the last acceptable sensitivity verification.

7.15.9.4

The temperature differential between the search units and the surface of the material being inspected shall be determined at regular intervals. Any deviation from the established maximum temperature differential (see Clause 7.15.5.4) shall be recorded and corrected and all welds inspected since the last acceptable verification shall be reinspected.

7.15.9.5

The circumferential position accuracy of the system output shall be validated at regular intervals by comparing it to the actual distance travelled around the piping. Any deviation from the requirements of Clause 7.15.5.5 shall be recorded and corrected.

7.15.9.6

Any change in search unit position shall be recorded and shall require a verification of recording gate positions and inspection sensitivity.

7.15.9.7

Search units shall be examined for wear at regular intervals not exceeding 500 welds. Search units that have dimensions that necessitate repair or replacement (see Clause 7.15.5.6) shall be repaired or replaced.

7.15.9.8

A reinspection of the complete weld, or a supplementary manual inspection, shall be required for any of the following conditions:

- (a) a coupling loss in a single channel over a circumferential distance not exceeding 12 mm, unless such loss is compensated by data from other inspection channels to maintain full volumetric inspection;
- (b) concurrent coupling losses in two adjacent inspection channels; or
- (c) a coupling loss over a circumferential distance exceeding 12 mm.

7.15.10 Standards of acceptability for ultrasonic inspection**7.15.10.1**

These standards of acceptability shall apply to the determination of acceptability of indications of imperfections of the size and type located by ultrasonic inspection. Such standards of acceptability are intended as a measure of adequate welding competence, as performed in accordance with qualified welding procedure specifications.

Notes:

- (1) *The company may use alternative standards of acceptability as specified in Clause 7.10.4.3.*
- (2) *Additional standards of acceptability for sour service pipelines are specified in Clause 16.9.3.3.*

7.15.10.2

The company may reject welds that meet these standards of acceptability where, in its opinion, the depth, location, or orientation of imperfections can be significantly detrimental to the structural integrity of the welds.

Note: *Indications of imperfections having an acceptable length should be investigated to ensure that they do not create a potential leak path.*

7.15.10.3

The standards of acceptability for indications of imperfections recorded by ultrasonic inspection (i.e., weld imperfections giving indications that exceed the established recording level) shall be as follows:

- (a) Indications of imperfections characterized as cracks shall be unacceptable regardless of length or location.
- (b) Individual indications of imperfections (other than those characterized as cracks) that are identified as not extending into the weld beads closest to the piping surfaces shall not exceed 50 mm in length, and the cumulative length of such indications in any 300 mm length of weld shall not exceed 50 mm, except that for welds less than 300 mm long, the cumulative length of such imperfections shall not exceed 16% of the weld length.
- (c) Individual indications of imperfections other than those covered by Items (a) and (b) shall not exceed 12 mm in length and the cumulative length of such imperfections in any 300 mm length of weld shall not exceed 25 mm, except that for welds less than 300 mm long, the cumulative length of such indications shall not exceed 8% of the weld length.

7.15.10.4

Weld conditions that prevent proper interpretation of the ultrasonic indications shall be cause for rejection of the welds, unless they can be inspected by other acceptable methods.

7.15.11 Ultrasonic inspection reports and records**7.15.11.1**

Reports and records shall be as specified in Paragraph-T-492 of the ASME *Boiler and Pressure Vessel Code*, Section V, Article 4, except that the information may be recorded using a combination of project log books