
**Non-destructive testing of steel
tubes —**

**Part 6:
Radiographic testing of the weld seam
of welded steel tubes for the detection
of imperfections**

Essais non destructifs des tubes en acier —

*Partie 6: Contrôle radiographique du cordon de soudure des tubes en
acier soudés pour la détection des imperfections*



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Contents

	Page
Foreword	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 General requirements	2
5 Test method	3
6 Image quality	6
7 Processing of film	10
8 Viewing conditions for radiographs	11
9 Classification of indications	11
10 Acceptance limits	11
11 Acceptance	12
12 Test report	12
Annex A (informative) Examples of distribution of imperfections	13
Bibliography	15

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes*.

This second edition cancels and replaces the first edition (ISO 10893-6:2011), which has been technically revised. The main changes compared with the previous edition are as follows:

- a) evidences about film overlap have been included in [4.7](#);
- b) a safety warning for X and gamma rays has been added at the end of [Clause 4](#);
- c) [Figure 2](#) has been aligned with ISO 17636-1 up to 1 000 kV;
- d) film side position and location have been clarified in [Clause 6](#);
- e) requirements for film processing have been specified in [Clause 7](#);
- f) a reference to ISO 5580 has been added in [Clause 8](#);
- g) the figures in [Annex A](#) have been revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Non-destructive testing of steel tubes —

Part 6:

Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections

1 Scope

This document specifies requirements for film-based radiographic X-ray testing of the longitudinal or helical weld seams of automated fusion arc-welded steel tubes for the detection of imperfections.

It can also be applicable to the testing of circular hollow sections.

NOTE As an alternative, see ISO 10893-7 for digital radiographic testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 5576, *Non-destructive testing — Industrial X-ray and gamma-ray radiology — Vocabulary*

ISO 5579, *Non-destructive testing — Radiographic testing of metallic materials using film and X- or gamma rays — Basic rules*

ISO 5580, *Non-destructive testing — Industrial radiographic illuminators — Minimum requirements*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 10893-7, *Non-destructive testing of steel tubes — Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

ISO 11699-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography*

ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film*

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

ISO 19232-2, *Non-destructive testing — Image quality of radiographs — Part 2: Determination of the image quality value using step/hole-type image quality indicators*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5576, ISO 11484 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

tube

hollow long product open at both ends, of any cross-sectional shape

3.2

welded tube

tube (3.1) made by forming a hollow profile from a flat product and welding adjacent edges together, and which after welding can be further processed, either hot or cold, into its final dimensions

3.3

manufacturer

organization that manufactures products in accordance with the relevant standard(s) and declares the conformity of the delivered products with all applicable provisions of the relevant standard(s)

3.4

agreement

contractual arrangement between the *manufacturer* (3.3) and the purchaser at the time of enquiry and order

4 General requirements

4.1 Unless otherwise specified by the product standard or agreed on by the manufacturer and the purchaser, a radiographic inspection shall be carried out on tubes after completion of all the primary production process operations (rolling, heat treating, cold and hot working, sizing, primary straightening, etc.).

4.2 This inspection shall be carried out by trained operators who are certified (e.g. ISO 9712) or qualified (e.g. ISO 11484 or ASNT SNTTC-1A), and supervised by competent personnel nominated by the manufacturer. In the case of third-party inspection, this shall be agreed on between the manufacturer and the purchaser.

The operating authorization issued by the employer shall be according to a written procedure. Non-destructive testing (NDT) operations shall be authorized by a level 3 NDT individual approved by the employer.

NOTE The definitions of level 1, 2 and 3 can be found in the appropriate International Standards, e.g. ISO 9712 and ISO 11484.

4.3 The tubes under test shall be sufficiently straight and free of foreign matter as to ensure the validity of the test. The surfaces of the weld seam and adjacent parent metal shall be sufficiently free of such foreign matter and surface irregularities, which can interfere with the interpretation of the radiographs.

Surface grinding is permitted in order to achieve an acceptable surface finish.

4.4 In cases where the weld reinforcement is removed, markers, usually in the form of lead arrows, shall be placed on each side of the weld such that its position can be identified on the radiograph.

4.5 Identification symbols, usually in the form of lead letters, shall be placed on each section of the weld beam radiograph such that the images of these symbols appear in the radiograph to ensure unequivocal identification of the section.

4.6 Location information shall be provided by permanent markings on the source side of the tube surface to provide reference points for the accurate relocation of the position of each radiograph.

Permanent markings are not required when local information for relocating the radiographs, e.g. by paint marking or reference to accurate sketches are provided.

4.7 When carrying out radiography of a continuous length of a weld with separate films, adjacent films shall overlap by at least 10 mm to ensure that no portion of the weld length remains unexamined. Overlap shall be proved using mechanical mark on the surface.

WARNING — Exposure of any part of the human body to X-rays or gamma-rays can be highly injurious to health. Wherever X-ray equipment or radioactive sources are in use, appropriate safety measures shall be applied.

Local, national or international safety precautions when using ionizing radiation shall be strictly applied.

5 Test method

5.1 The weld of longitudinally or helically welded tubes shall be radiographically tested using the X-ray film technique. The application of non-film, digital radiographic techniques shall conform to ISO 10893-7.

5.2 Two image quality classes A and B, in accordance with ISO 17636-1, shall be specified:

- class A: X-ray examination technique with standard sensitivity;
- class B: X-ray examination technique with enhanced sensitivity.

NOTE Most applications are covered by the use of image quality class A. Image quality class B is intended for more important and difficult applications where image quality class A can be insufficiently sensitive to reveal all the imperfections being detected. Image quality class B requires the use of film system class C4 or higher (fine grain films and lead screens) and, therefore, generally requires a longer exposure time. The required image quality class is usually stated in the relevant product standard.

5.3 The film system class used shall be at least film system class C5 for image quality class A and shall be at least C4 (C3 for X-ray voltage < 150 kV) for image quality class B. The classes shall be as defined in ISO 5579, ISO 11699-1 and ISO 17636-1.

The front intensifying metal screen, for both image quality class B and image quality class A, shall have a thickness of between 0,02 mm and 0,25 mm. Other thicknesses may be adopted for the back intensifying screen. In cases where a double film technique is used, both intensifying screens, if used, shall be in the upper thickness range of the front intensifying screen.

5.4 Salt intensifying screens shall not be used.

5.5 Care shall be taken to ensure that the amount of back-scattered and internally scattered X-ray radiation absorbed by the film is minimized.

If there is doubt regarding the adequacy of protection from back-scattered X-ray radiation, a characteristic symbol (typically, a 10 mm high lead letter, typically "B" and 1,5 mm thick) shall be attached to the back of the cassette or film holder and a radiograph shall be made in the normal manner. When the image of this symbol appears on the radiograph at a lighter density than the background, it is an indication that protection against back-scattered X-ray radiation is insufficient and it is essential that additional precautions be taken.

5.6 The beam of radiation shall be directed at the centre of the section of the weld seam under examination and shall be normal to the tube surface at that point.

5.7 The diagnostic length shall be such that the increase in penetrated thickness at the ends of the useful length of a radiograph shall not exceed the penetrated thickness at the centre of the radiograph by more than 10 % for image quality class B or by more than 20 % for image quality class A, provided the conditions specified in [5.11](#) and [Clause 8](#) are not compromised.

5.8 The single wall penetration technique shall be used. If this technique is impracticable for dimensional reasons, use of the double wall penetration technique is permitted by agreement.

5.9 The separation between the film and the weld surface shall be as small as possible.

5.10 The minimum value of the source-to-weld distance, f , shall be selected such that the ratio of this distance to the effective focal spot size d , i.e. f/d , conforms to the values given by [Formulae \(1\)](#) and [\(2\)](#):

for image quality class A:

$$\frac{f}{d} \geq 7,5 \times b^{2/3} \quad (1)$$

for image quality class B:

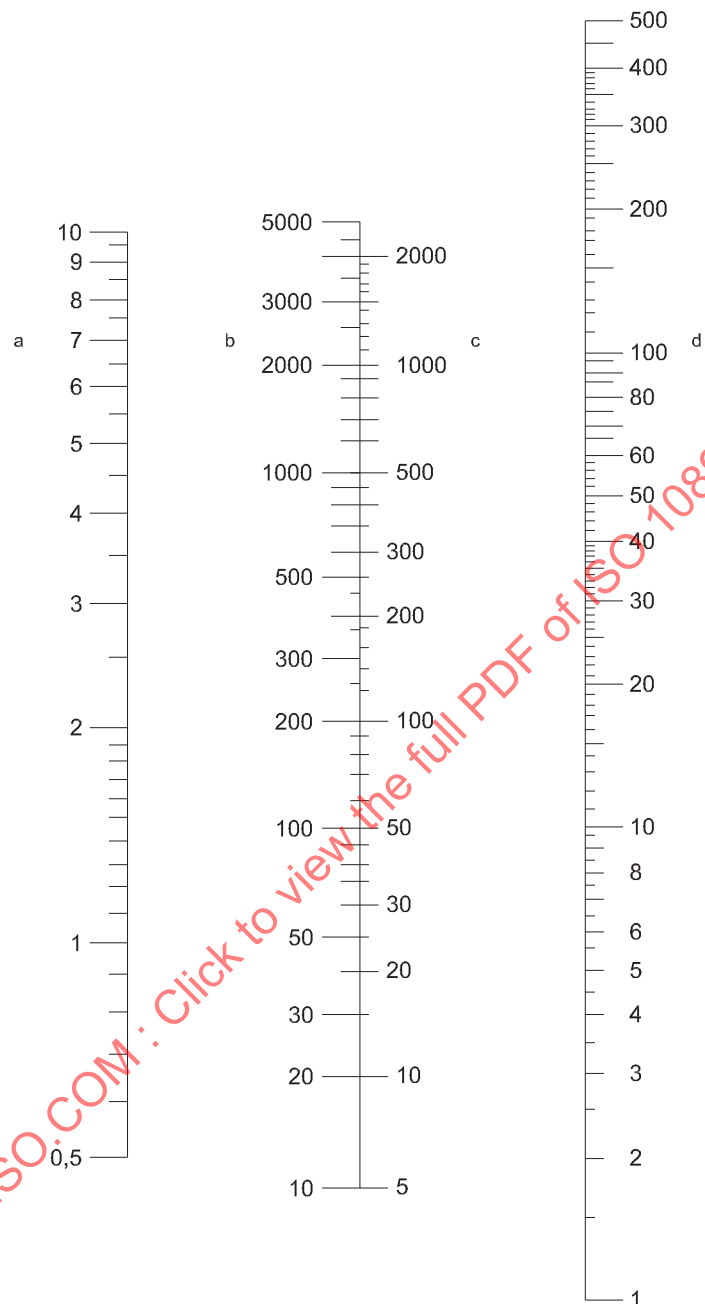
$$\frac{f}{d} \geq 15 \times b^{2/3} \quad (2)$$

where b is the specified wall thickness in the direction of the radiation beam plus separation between the film and the surface remote from the radiation source, in millimetres.

NOTE These relationships are presented graphically in [Figure 1](#).

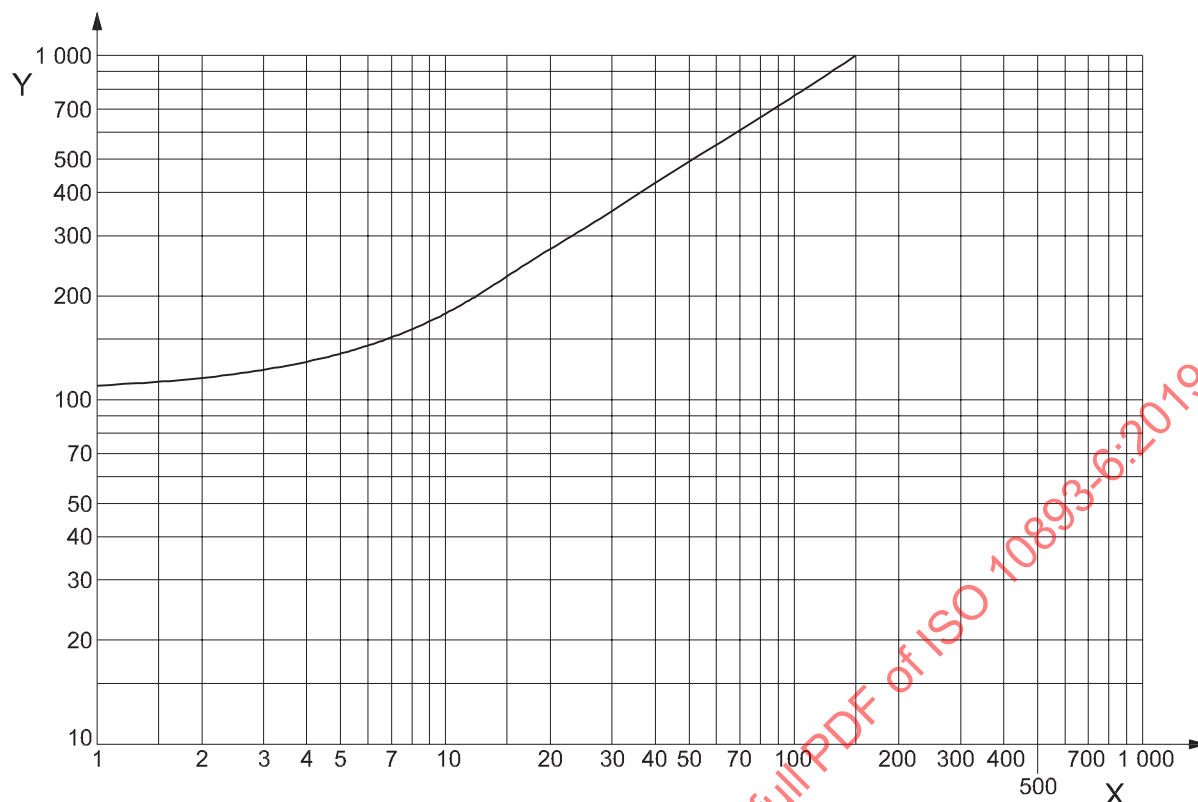
5.11 Exposure conditions shall be such that the density of the radiograph of the sound weld metal in the area under examination is not less than 2,3 for image quality class B and not less than 2,0 for image quality class A. Fog density shall not exceed 0,3. Fog density (for the purposes of this document) is defined as the total density (emulsion and base) of a processed, unexposed film.

5.12 To maintain sufficient sensitivity, the X-ray tube voltage should not exceed the maximum values given in [Figure 2](#).



- a Effective focal spot size, d , in millimetres.
- b Minimum source-to-weld distance, f , for class B, in millimetres.
- c Minimum source to weld distance, f , for class A, in millimetres.
- d Weld-to-film distance, b , in millimetres.

Figure 1 — Nomogram for determination of minimum source-to-weld distance, f , in relation to weld-to-film distance, b , and the effective focal spot size, d

**Key**

X penetrated thickness, in millimetres

Y X-ray voltage, in kilovolts

Figure 2 — Maximum X-ray voltage for X-ray devices up to 1 000 kV as a function of penetrated thickness

6 Image quality

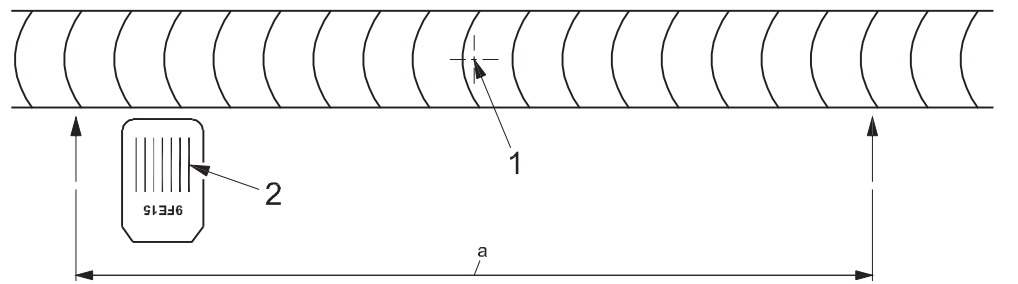
6.1 The image quality shall be determined by the use of a mild steel image quality indicator (IQI) of the type specified in ISO 19232-1 or ISO 19232-2, and agreed on between the manufacturer and the purchaser. The IQI shall be placed on the surface facing the source of radiation, on the parent material adjacent to the weld (see [Figures 3](#) and [4](#)).

The IQI shall only be placed on the film side when the surface facing the radiation source is inaccessible. In these circumstances, a letter "F" shall be placed near the IQI and this procedural change recorded in the test report.

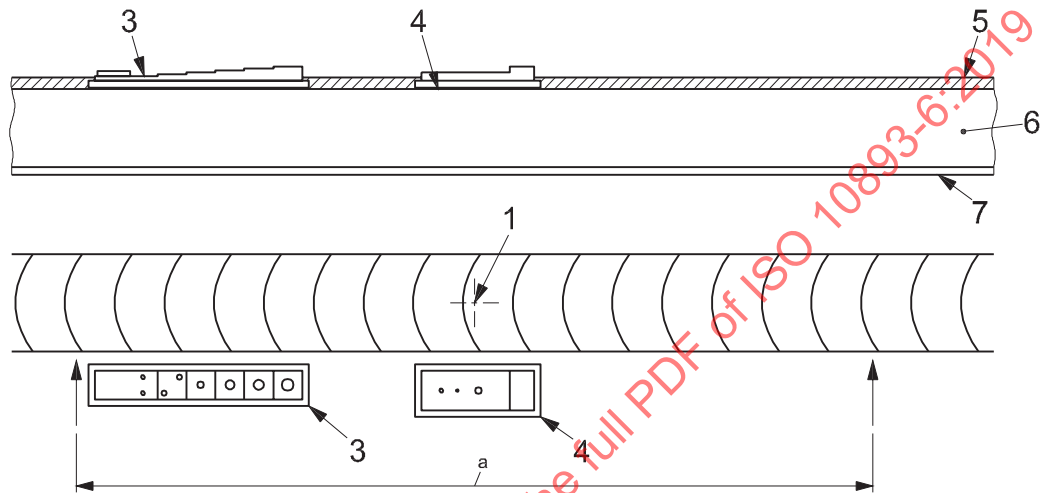
Film-side positions typically show 1 or 2 more wires, or holes, than if the same IQI was on the source side. Customers may ask for a trial exposure to be carried out on a sample piece of pipe, with IQIs placed on both source and film side as a comparison.

When using a wire IQI, the wires shall be directed perpendicular to the weld. The location shall be such that an acceptable image of the wire can be obtained. The image of a wire shall be acceptable if a continuous length of at least 10 mm is clearly visible in a section of uniform optical density, which is normally in the parent metal adjacent to the weld. If necessary, additional or longer IQI shall be placed across the weld.

NOTE For further details, see ISO 19232-1, ISO 19232-2, ISO 17636-1 and ISO 3183.



a) Wire type

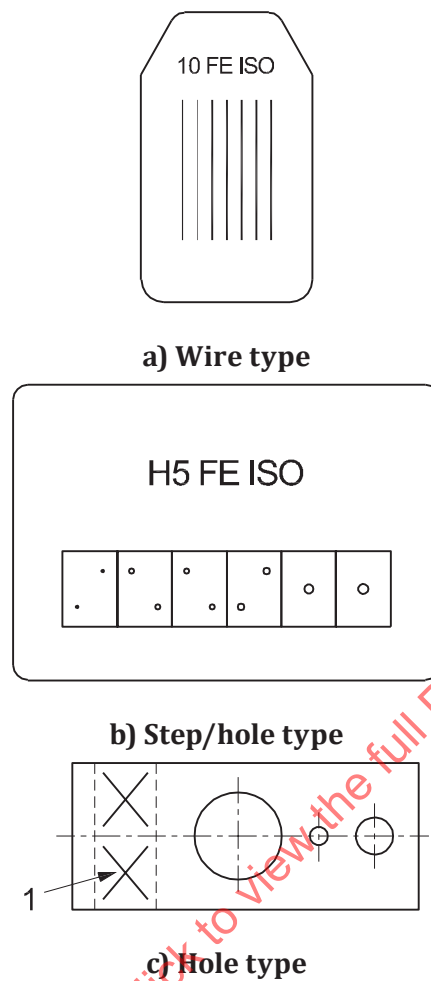


b) Step/hole and hole types

Key

- 1 centre of beam
- 2 wire type IQI, thinnest wire away from the centre of the beam
- 3 step/hole type IQI, thinnest step away from the centre of the beam
- 4 hole type IQI if necessary with shim stock
- 5 outer weld reinforcement
- 6 tube wall
- 7 inner weld reinforcement
- a Diagnostic length.

Figure 3 — Positioning of IQIs (basic requirements)



Key

1 place identification number here

NOTE [Figure 4](#) c) is a hole-type IQI of ASTM E1025.

Figure 4 — Types of image quality indicator

6.2 The two image quality classes are defined in [Tables 1](#) to [4](#).

6.3 For the double wall penetration technique, the image quality value that shall be used shall be taken as that corresponding to twice the specified wall thickness.

Table 1 — Wire IQI

Image quality class A	
Specified thickness, T mm	IQI value
$T \leq 1,2$	W 18
$1,2 < T \leq 2$	W 17
$2 < T \leq 3,5$	W 16
$3,5 < T \leq 5$	W 15
$5 < T \leq 7$	W 14
$7 < T \leq 10$	W 13
$10 < T \leq 15$	W 12
$15 < T \leq 25$	W 11
$25 < T \leq 32$	W 10
$32 < T \leq 40$	W 9
$40 < T \leq 55$	W 8
$55 < T \leq 85$	W 7
$85 < T \leq 150$	W 6
$150 < T \leq 250$	W 5
$250 < T$	W 4

Table 2 — Step/hole IQI

Image quality class A	
Specified thickness, T mm	IQI value
$T \leq 2$	H 3
$2,0 < T \leq 3,5$	H 4
$3,5 < T \leq 6$	H 5
$6 < T \leq 10$	H 6
$10 < T \leq 15$	H 7
$15 < T \leq 24$	H 8
$24 < T \leq 30$	H 9
$30 < T \leq 40$	H 10
$40 < T \leq 60$	H 11
$60 < T \leq 100$	H 12
$100 < T \leq 150$	H 13
$150 < T \leq 200$	H 14
$200 < T \leq 250$	H 15
$250 < T \leq 320$	H 16
$320 < T \leq 400$	H 17
$400 < T$	H 18

Table 3 — Wire IQI

Image quality class B	
Specified thickness, T mm	IQI value
$T \leq 1,5$	W 19
$1,5 < T \leq 2,5$	W 18
$2,5 < T \leq 4$	W 17
$4 < T \leq 6$	W 16
$6 < T \leq 8$	W 15
$8 < T \leq 12$	W 14
$12 < T \leq 20$	W 13
$20 < T \leq 30$	W 12
$30 < T \leq 35$	W 11
$35 < T \leq 45$	W 10
$45 < T \leq 65$	W 9
$65 < T \leq 120$	W 8
$120 < T \leq 200$	W 7
$200 < T \leq 350$	W 6
$350 < T$	W 5

Table 4 — Step/hole IQI

Image quality class B	
Specified thickness, T mm	IQI value
$T \leq 2,5$	H 2
$2,5 < T \leq 4$	H 3
$4 < T \leq 8$	H 4
$8 < T \leq 12$	H 5
$12 < T \leq 20$	H 6
$20 < T \leq 30$	H 7
$30 < T \leq 40$	H 8
$40 < T \leq 60$	H 9
$60 < T \leq 80$	H 10
$80 < T \leq 100$	H 11
$100 < T \leq 150$	H 12
$150 < T \leq 200$	H 13
$200 < T \leq 250$	H 14

7 Processing of film

ISO 11699-2 or other equivalent rules may be used to control the reliability or quality of the image development process. The radiographs shall be free from imperfections due to processing or other defects that could interfere with interpretation.

8 Viewing conditions for radiographs

Radiographs shall be viewed using an industrial radiographic illuminator in accordance with ISO 5580. The minimum luminance of the illuminated radiograph shall be 30 cd/m² for densities less than or equal to 2,5 and 10 cd/m² for densities greater than 2,5.

9 Classification of indications

9.1 All indications found on the radiograph shall be classified as weld imperfections or defects as described in [9.2](#) and [9.3](#).

9.2 Imperfections are discontinuities in the weld seam detectable by the radiographic testing method described in this document. Imperfections with a size and/or population density within the specified acceptance limits are considered to have no practical implications on the intended use of the tubes.

9.3 Defects are imperfections with a size and/or population density greater than the specified acceptance limits. Defects are considered to adversely affect or limit the intended use of the tubes.

10 Acceptance limits

10.1 The acceptance limits specified in the applicable product standard for the material or fabrication standard for the component shall apply. In cases where an acceptance criteria is not specified, the acceptance limits for radiographic examination of the weld seam, as specified in [10.2](#) to [10.6](#), shall apply.

10.2 Cracks, incomplete penetration and lack of fusion are not acceptable.

10.3 Individual circular slag inclusions and gas pockets up to 3,0 mm or $T/3$ in diameter (T = specified wall thickness), whichever is the smaller, are acceptable.

The sum of the diameters of all such permitted individual imperfections in any 150 mm or $12T$ of weld length, whichever is the smaller, shall not exceed 6,0 mm or $0,5T$, whichever is the smaller, where the separation between individual inclusions is less than $4T$.

10.4 Individual elongated slag inclusions up to 12,0 mm or T in length, whichever is the smaller, or up to 1,5 mm in width are acceptable.

The accumulated length of such permitted individual imperfections in any 150 mm or $12T$ of weld length, whichever is the smaller, shall not exceed 12,0 mm where the separation between individual inclusions is less than $4T$.

NOTE For information, the criteria specified in [10.3](#) and [10.4](#) are shown diagrammatically in [Annex A](#).

10.5 Individual undercuts of any length having a maximum depth of 0,4 mm and not encroaching on the minimum wall thickness are acceptable.

Individual undercuts of a maximum length of $T/2$ having a maximum depth of 0,5 mm and not exceeding 10 % of the specified wall thickness are acceptable, provided there are not more than two such undercuts in any 300 mm of the weld length, and all such undercuts are dressed out.

10.6 Undercuts on the inside and outside welds, which are coincident in the longitudinal direction, are not acceptable.

11 Acceptance

11.1 Any tubes not showing indications in excess of that permitted by the corresponding acceptance limits shall be deemed to have passed the test.

11.2 Any tubes showing indications in excess of that permitted by the corresponding acceptance limits shall be deemed suspect.

11.3 For suspect tubes, one or more of the following actions shall be taken, subject to the requirements of the product standard.

- a) The suspect area shall be removed by dressing. Complete removal of the defect shall be verified by either liquid penetrant or magnetic particle testing, and the dressed area shall be retested by radiography. The remaining wall thickness shall be measured by an appropriate technique to verify conformity with the specified tolerances.
- b) The suspect area shall be repaired by welding carried out to an approved welding procedure. The repaired area shall then be subject to radiographic examination in accordance with the requirements of this document and the product standard.
- c) The suspect area shall be cropped off. The remaining length of the tube shall be measured to verify conformity with the specified tolerances.
- d) The tube shall be rejected.

12 Test report

The manufacturer shall record at least the following information. In addition, if specified, the manufacturer shall submit a test report including the following information, unless otherwise agreed by contracting parties:

- a) reference to this document, i.e. ISO 10893-6;
- b) statement of conformity;
- c) any deviation, by agreement or otherwise, from the procedures specified;
- d) product designation by steel grade and size;
- e) radiation source, type and effective focal spot size and equipment used;
- f) selected film systems, screens and filters;
- g) tube voltage and current;
- h) time of exposure and source-to-film distance;
- i) type and position of image quality indicator (IQI);
- j) IQI reading and minimum film density;
- k) the image quality class achieved;
- l) date of exposure and report;
- m) operator identification (e.g. code, ID, name/surname), qualification/certification (based on scheme ISO 11484, ISO 9712 or equivalent), level and signature.