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Submerged arc-welded steel tubes for pressure purposes — Radiographic testing of the weld seam for the detection of imperfections

Tubes en acier soudés à l'arc immergé pour service sous pression — Contrôle radiographique du cordon de soudure pour la détection des imperfections

Reference number
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12096 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 19, *Technical delivery conditions for steel tubes for pressure purposes.*

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Submerged arc-welded steel tubes for pressure purposes — Radiographic testing of the weld seam for the detection of imperfections

1 Scope

This International Standard specifies requirements for radiographic testing of the longitudinal or spiral weld seam of submerged arc-welded steel tubes for the detection of imperfections using the X-ray film technique.

One set of acceptance criteria is considered, together with two image quality classes R1 and R2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1027:1983, *Radiographic image quality indicators for non-destructive testing — Principles and identification.*

ISO 2504:1973, *Radiography of welds and viewing conditions for films — Utilization of recommended patterns of image quality indicators (I.Q.I.).*

ISO 5576:—[1], *Non-destructive testing — Industrial radiology — Vocabulary.*

ISO 5579:1985, *Non-destructive testing — Radiographic examination of metallic materials by X- and gamma rays — Basic rules.*

ISO 7004:1987, *Photography — Industrial radiographic film — Determination of ISO speed and average gradient when exposed to X- and gamma-radiation.*

ISO 11484:1994, *Steel tubes for pressure purposes — Qualification and certification of non-destructive testing (NDT) personnel.*

3 General requirements

3.1 For the purpose of this International Standard, the definitions given in ISO 5576 shall apply.

3.2 The radiographic inspection covered by this International Standard is usually carried out on tubes after completion of all the primary production process operations.

These activities shall be carried out by NDT personnel trained and qualified in accordance with ISO 11484, as nominated by the manufacturer. In the case of third-party inspection, this shall be agreed between the purchaser and manufacturer.

3.3 The tubes to be tested shall be sufficiently straight to ensure the validity of the test. The surfaces of the weld seam and adjacent parent metal shall be sufficiently free from foreign matter and surface irregularities which could interfere with the interpretation of the radiographs.

1) To be published.

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

3.4 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, so that its position can be identified on the radiograph.

3.5 Identification symbols, usually in the form of lead letters, shall be placed on each section of the weld being radiographed so that the images of these symbols appear in the radiograph to ensure unequivocal identification of the section.

3.6 Permanent markings shall be provided on the tube surface to provide reference points for the accurate relocation of the position of each radiograph. Where the nature of the material and/or its intended service conditions render stamping impossible, other suitable means shall be provided for relocating the radiographs, for example, by paint marking or by reference to accurate sketches.

3.7 When radiographing a continuous length of weld with separate films, adjacent films shall overlap by at least 10 mm to ensure that no portion of the weld length remains unexamined.

4 Test method

4.1 The weld of longitudinally or spirally welded tube shall be radiographically tested using the X-ray film technique.

By agreement between the purchaser and manufacturer, the use of fluoroscopic methods is permitted but only when the manufacturer can demonstrate equivalence to the X-ray film technique.

4.2 Two image quality classes are specified:

class R1: X-ray examination technique with enhanced sensitivity;

class R2: X-ray examination technique with standard sensitivity.

NOTE 1 Most applications are covered by the use of image quality class R2.

Image quality class R1 is intended for more important and difficult applications where image quality class R2 may be insufficiently sensitive to reveal all the imperfections to be detected. Image quality class R1 requires the use of fine-grain films and lead screens and, therefore, generally requires a longer exposure time. The required image quality class will be stated in the relevant product standard.

4.3 The films shall be at least fine-grain for image quality class R1 and shall be at least medium-grain for image quality class R2 (see ISO 5579 and ISO 7004).

The front intensifying screen, for both image quality class R1 and image quality class R2, 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, the intermediate screen, when used, shall also be within the thickness range specified for the front intensifying screen.

4.4 Salt intensifying screens shall not be used.

4.5 No back-scattered or internally scattered X-ray radiation shall reach the film.

If there is any doubt regarding the adequacy of protection from back-scattered X-ray radiation, a characteristic symbol (typically a 3,2 mm thick letter B) shall be attached to the back of the cassette or film holder, and a radiograph made in the normal manner. If 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.

4.6 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.

4.7 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 R1 or by more than 20 % for image quality class R2, provided that the conditions specified in 4.11 and clause 7 are not compromised.

4.8 The single-wall penetration technique shall be used. If this technique is impractical because of the dimensions, the use of the double-wall penetration technique is permitted.

4.9 The distance between the film and the weld surface shall be as small as possible.

4.10 The minimum source-to-specimen distance, d, shall be chosen such that the ratio of this distance to the effective dimension of focal spot f, i.e. d/f, conforms to the values given by the following equations.

For image quality class R1

$$d/f > 15x^{2/3}$$

For image quality class R2

$$d/f > 7{,}5x^{2/3}$$

where x is the specimen thickness, in the direction of the radiation beam, plus the separation between the film and the surface remote from the radiation source.

These relationships are shown graphically in figure 1.

4.11 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 2,0 for image quality class R1 and not less than 1,7 for image quality class R2.

NOTE 2 For image quality class R2, the minimum density may be reduced to 1,5, by special agreement between the purchaser and manufacturer.

Fog density, defined as the total density (emulsion and base) of a processed unexposed film, shall not exceed 0,3.

4.12 To maintain sufficient sensitivity, the voltage of the X-ray tube shall be as low as possible and the maximum values given in figure 2 shall not be exceeded.

5 Image quality

5.1 The image quality shall be determined using a mild steel image quality indicator (I.Q.I.) of the type specified in ISO 1027 and agreed between the purchaser and manufacturer. This I.Q.I. shall be placed on the surface facing the source of radiation, either adjacent to the weld or, in the case of wire type I.Q.I.'s, across the weld. The I.Q.I. 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 I.Q.I. and this procedural change recorded in the test report.

For further details, refer to ISO 2504.

5.2 The two image quality classes specified within this International Standard are defined in table 1.

5.3 To determine the required image quality value for the double-wall penetration technique, the steel thickness referred to in table 1 shall be twice the penetrated nominal thickness.

6 Processing of film

The radiographs shall be free from imperfections due to processing or other defects that could interfere with interpretation.

7 Viewing conditions for radiographs

The minimum luminance of the illuminated radiograph shall be 30 cd/m^2 for densities less than or equal to 2,5 and 10 cd/m^2 for densities greater than 2,5.

8 Acceptance

8.1 All indications found on the radiograph shall be classified as weld imperfections or defects as defined in 8.1.1 or 8.1.2.

8.1.1 Imperfections are discontinuities in the weld seam detectable by the radiographic testing method described in this International Standard. Imperfections with a size and/or population density that are within the acceptance criteria defined in the relevant product standard are considered to have no practical implications on the intended use of submerged arc-welded tubes for pressure purposes.

8.1.2 Defects are imperfections with a size and/or population density equal to or greater than the acceptance criteria defined in the relevant product standard. Defects are considered to adversely affect or limit the intended use of submerged arc-welded tubes for pressure purposes.

8.2 Acceptance limits for radiographic examination of the weld seam are given below. These limits shall be used unless alternative requirements are specified in product standards.

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

8.2.2 Individual circular slag inclusion and gas pockets up to 3,0 mm or $T/3$ in diameter (T is the 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 $4T$.

8.2.3 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 maximum 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 $4T$.

8.2.4 Individual undercuts of any length having a maximum depth of 0,4 mm 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 that there are not more than two such undercuts in any 300 mm of the weld length. All such undercuts are dressed out.

8.2.5 Any undercuts exceeding the above limits shall be repaired, the suspect area cropped off or the pipe rejected.

8.2.6 Any undercuts on the inside and outside welds, of any length and depth, which are coincident in the longitudinal direction on the same side of the weld are not acceptable.

8.3 Actions to be taken on tubes containing defects.

Tubes containing weld seam defects shall be subjected to one or more of the actions described in 8.3.1 to 8.3.4.

8.3.1 Defects shall be removed by grinding, chipping or machining, provided that the remaining wall thickness is within specified limits. The dressed area shall be checked for complete removal of the defect by either the magnetic particle or liquid penetrant test method.

8.3.2 Should the removal of the defect reduce the wall thickness below the specified limit, the weld area shall be repaired by welding carried out in accordance with an approved welding procedure. The repaired area shall then be subject to radiographic examination in accordance with the requirements of this International Standard.

8.3.3 The section of tube containing the defective weld area shall be cut off within the limits of the requirements placed on minimum tube length.

8.3.4 The entire tube shall be rejected.

9 Test report

When specified, the manufacturer shall submit to the purchaser a test report that includes, at least, the following information:

a) reference to this International Standard;

b) the type and details of the inspection technique;

c) any deviation, by agreement or otherwise, from the test method;

d) the type of X-ray equipment, the tube voltage applied and the anodic current intensity;

e) the time of exposure, type of film and screen, and source-to-specimen distance;

f) the system of marking used;

g) the film processing technique;

h) the weld geometry, wall thickness and welding process used;

i) the following geometric relationship:

- focal spot size,
- focal-film distance,
- object-film distance,
- radiation angle with respect to weld and film,
- sketch;

j) the image quality class;

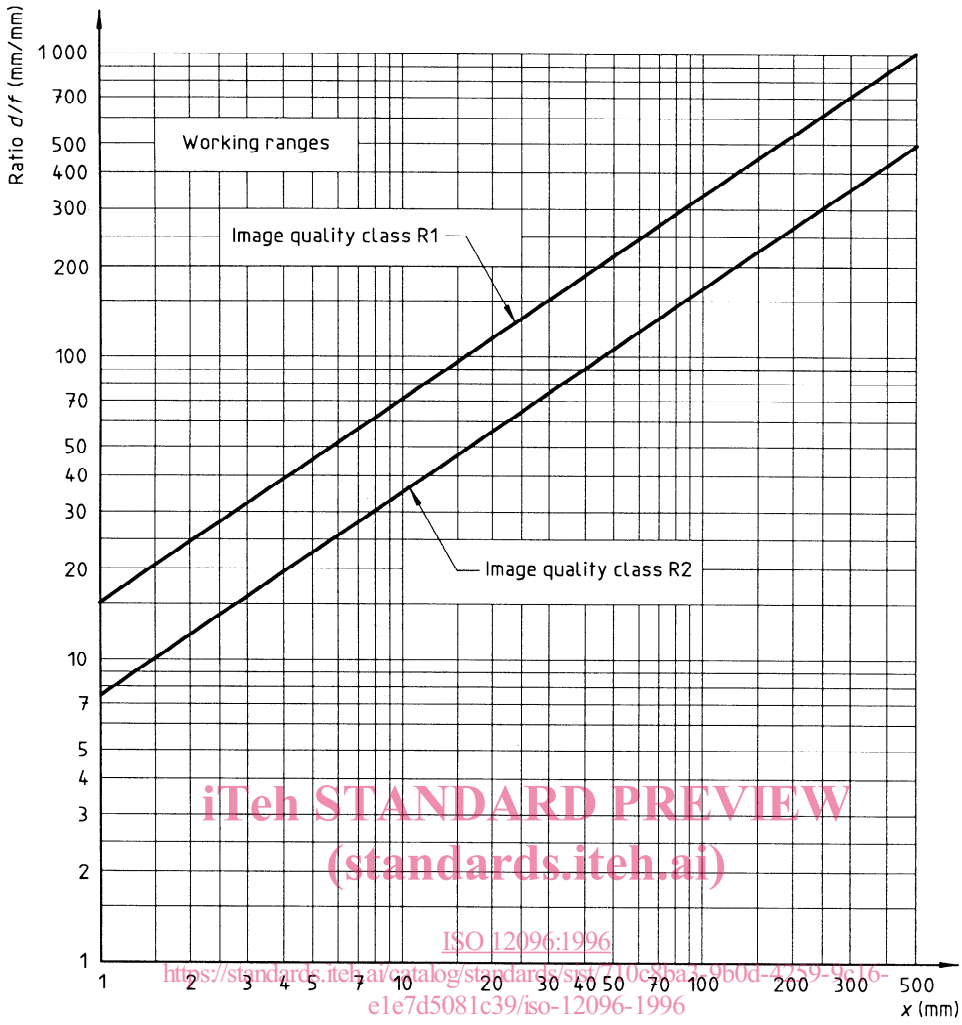
k) results of the radiographic examination and the statement of conformity;

l) the date of the examination and the endorsement by the inspector.

Table 1 — Image quality classes

Steel thickness[1] mm		Visibility			
		Image quality class R1		Image quality class R2	
greater than	less than or equal to	hole diameter mm	wire diameter mm	hole diameter mm	wire diameter mm
4,5	10	0,40	0,16	0,50	0,20
10	16	0,50	0,20	0,63	0,25
16	25	0,63	0,25	0,80	0,32
25	32	0,80	0,32	1,00	0,40
32	40	1,00	0,40	1,25	0,50
40	60	1,25	0,50	1,60	0,63

1) The steel thickness refers to the overall weld thickness.



Key

d Distance between the source of radiation and the surface of the weld seam facing the source of radiation.

f Effective size of the source of radiation

x Specimen thickness, in the direction of the radiation beam, plus the separation between the film and the surface remote from the radiation source

Figure 1 — Required minimum values of ratio d/f as a function of distance, x

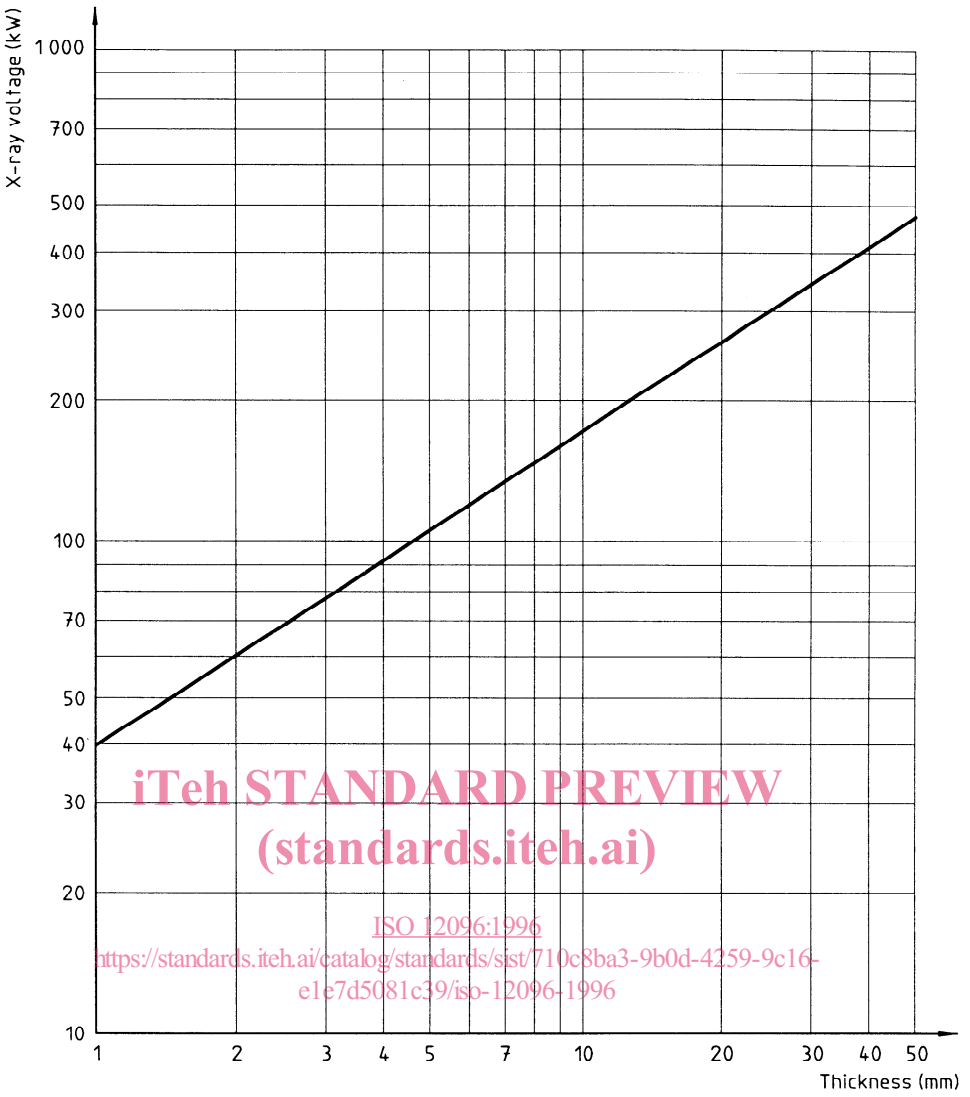


Figure 2 — Permissible maximum X-ray tube voltage as a function of specified nominal wall thickness