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Non-destructive testing of welds — Radiographic testing —

Part 1: X- and gamma-ray techniques with film

Essais non destructifs des assemblages soudés — Contrôle par radiographie —

Partie 1: Techniques par rayons X ou gamma à l'aide de film

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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.

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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This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 17636-1:2013), which has been technically revised.

The main changes are as follows:

— the normative references have been updated;

— the Figures have been updated;

— references to Figures 1 to 19 have been updated throughout the document;

— in 6.7 the use of ASTM wires and other image quality indicators (IQIs) by agreement of contracting parties has been added;

— in 6.7 a) the acceptance of a shorter wire visibility than 10 mm for pipes with an external diameter < 50 mm has been added;

— in 6.7, 6.8 and 6.9 a clarification for the IQI usage for the double-wall double-image (DWDI) technique has been added;

— in 6.9 and 7.2.2 the lower thickness limit for Se 75 applications has been deleted;

— measurement of optical density in the root of the weld has been clarified;

— IQI use for the DWDI technique has been clarified.

A list of all parts in the ISO 17636 series can be found on the ISO website.

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. Official interpretations of ISO/TC 44 documents, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

Non-destructive testing of welds — Radiographic testing —

Part 1:
X- and gamma-ray techniques with film

1 Scope

This document specifies techniques of radiographic testing of fusion-welded joints in metallic materials using industrial radiographic film techniques with the object of enabling satisfactory and repeatable results. The techniques are based on generally recognized practice and fundamental theory of the subject.

It applies to the joints of plates and pipes in metallic materials. Besides its conventional meaning, "pipe" as used in this document covers other cylindrical bodies, such as tubes, penstocks, boiler drums and pressure vessels.

This document does not specify acceptance levels for any of the indications found on the radiographs. The ISO 10675 series provides information on acceptance levels for weld evaluation.

If contracting parties apply lower test criteria, it is possible that the quality achieved will be significantly lower than when this document is strictly applied.

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

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

ISO 11699-2, *Non-destructive testing — Industrial radiographic films — Part 2: Control of film processing by means of reference values*

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*

ISO 19232-4, *Non-destructive testing — Image quality of radiographs — Part 4: Experimental evaluation of image quality values and image quality tables*

ASTM E 747, *Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*

EN 12543 (all parts), *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing*

EN 12679, *Non-destructive testing — Radiographic testing — Determination of the size of industrial radiographic gamma sources*

JIS Z2306, *Radiographic image quality indicators for non-destructive testing*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
nominal thickness
t
thickness of the parent material only where manufacturing tolerances do not have to be considered

3.2
penetration thickness change
Δt
change of *penetrated thickness* (3.3) relative to the *nominal thickness* (3.1) due to beam angle

3.3
penetrated thickness
w
thickness of material in the direction of the radiation beam calculated on the basis of the *nominal thicknesses* (3.1) of all penetrated walls

3.4
object-to-film distance
b
distance between the radiation side of the radiographed part of the test object and the film surface, measured along the central axis of the radiation beam

Note 1 to entry: The abbreviated term OFD can also be used.

3.5
source size
d
size of the radiation source or focal spot size

Note 1 to entry: See the EN 12543 series or EN 12679.

3.6
source-to-film distance
SFD
distance between the source of radiation and the film, measured in the direction of the beam

Note 1 to entry: $SFD = f + b$

where

f is *source-to-object distance* (3.7);

b is *object-to-film distance* (3.4).

3.7
source-to-object distance
f
distance between the source of radiation and the source side of the test object, measured along the central axis of the radiation beam

Note 1 to entry: The abbreviated term SOD can also be used.

3.8
external diameter
D_e
nominal diameter of the outer surface of the pipe

3.9
weld area to evaluate
WAE
area to be evaluated on the radiograph, which contains the weld and the *heat-affected zone* (3.11) on both sides

3.10
area of interest
AoI
minimum area which should be evaluated on the radiograph and which contains the weld, the *heat-affected zone* (3.11) on both sides and all lead letters, markers and image quality indicators (IQIs)

3.11
heat-affected zone
HAZ
area beside the weld influenced by the heating and cooling process of the welding

Note 1 to entry: This is considered to be the two areas beside the weld, each with the same width as the weld cap but with at least 10 mm to be considered for evaluation.

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 apply.

Table 1 — Symbols and abbreviated terms

Symbol or abbreviated term	Definition
AoI	area of interest
b	object-to-film distance
b'	object-to-film distance perpendicular to test object
d	source size, focal spot size (see EN 12679 and the EN 12543 series)
D_e	external diameter
d_f	value of the diagonal extension of the film, used for testing
DWDI	double-wall double-image
DWSI	double-wall single-image
f	source-to-object distance
f'	source-to-object distance perpendicular to test object
F	film
f_{min}	minimum source-to-object distance
NOTE The source-to-detector-distance (SDD), as used in digital radiography (see ISO 17636-2), is equivalent to SFD in film radiography.	

Table 1 *(continued)*

Symbol or abbreviated term	Definition
HAZ	heat-affected zone
IQI	image quality indicator
S	radiation source
SFD	source-to-film distance
t	nominal thickness
Δt	penetration thickness change
w	penetrated thickness
WAE	weld area to evaluate
β	opening angle of source window or collimator to central beam
NOTE The source-to-detector-distance (SDD), as used in digital radiography (see ISO 17636-2), is equivalent to SFD in film radiography.	

5 Classification of radiographic techniques

The radiographic techniques are divided into two testing classes:

— testing class A: basic techniques;

— testing class B: improved techniques.

Testing class B techniques are used when testing class A techniques are insufficiently sensitive.

Radiographic techniques providing higher sensitivity than testing class B are possible and may be agreed between the contracting parties by specification of all appropriate test parameters.

The choice of radiographic technique shall be agreed between the contracting parties.

If, for technical or industrial reasons, it is not possible to meet one of the conditions specified for testing class B, such as the type of radiation source or the source-to-object distance, *f,* it may be agreed by contracting parties that the condition selected can be that specified for testing class A. The loss of sensitivity shall be compensated by an increase of minimum density to 3,0 or by selection of a better film system testing class with a minimum optical density of 2,6. The other conditions for testing class B remain unchanged, especially the image quality achieved (see Tables B.1 to B.12 and 6.9). Because of the better sensitivity than testing class A, the test specimen may be regarded as being tested to testing class B. This does not apply if the special SFD reductions as described in 7.6 for test arrangements 7.1.4 and 7.1.5 (Figures 5 to 10) are used.

6 General preparations and requirements

6.1 Protection against ionizing radiation

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 health and safety requirements shall be applied.

NOTE Local, national and international regulations and safety precautions provide additional information.

6.2 Surface preparation and stage of manufacture

In general, surface preparation is not necessary, but where surface imperfections or coatings can cause difficulty in detecting defects, the surface shall be ground smooth or the coatings shall be removed.

Unless otherwise specified, radiography shall be carried out after the final stage of manufacture, for example after grinding or heat treatment.

6.3 Location of the weld in the radiograph

Where the radiograph does not show the weld, high-density markers shall be placed on both sides of the weld outside the WAE.

6.4 Identification of radiographs

Symbols shall be affixed to each section of the object being radiographed. The images of these symbols shall appear in the radiograph outside the WAE where possible and shall ensure unambiguous identification of the section. Another identification system may be part of the contract agreement.

6.5 Marking

Permanent markings on the object to be tested shall be made in order to accurately locate the position of each radiograph, for example zero-point, direction, identification, measure.

Where the nature of the material and/or its service conditions do not permit permanent marking, the location may be recorded by means of accurate sketches or photographs.

6.6 Overlap of films

When radiographing an area with two or more separate films, the films shall overlap sufficiently to ensure that the complete WAE is radiographed. This shall be verified by a high-density marker on the surface of the object which is to appear on each film.

6.7 Types and positions of image quality indicators (IQIs)

The quality of images shall be verified by the use of IQIs in accordance with ISO 19232-1 or ISO 19232-2. IQIs according to ASTM E 747 or JIS Z2306 may be used, instead, if their material group fits better to the test object or component. Tables for the conversion of wire numbers of ASTM E 747, JIS Z2306 and ISO 19232-1 can be found in these documents. By agreement between contracting parties, other IQIs with the same radiographic attenuation as the test object and the same dimensions as defined in ISO 19232-1 or ISO 19232-2 may be used.

The single wire or step hole IQIs used shall be placed on the source side of the test object at the centre of the AoI on the parent metal beside the weld. The identification symbols and, when used, the lead letter F shall not be in the WAE, except when geometric configuration makes it impractical. The IQI shall be in close contact with the surface of the object. Its location shall be made in a section of uniform thickness characterized by a uniform optical density on the film.

According to the IQI type used, cases a) and b) shall be considered.

a) When using a wire IQI, the wires shall be directed perpendicular to the weld and its location shall ensure that at least 10 mm of the wire length shows in a section of uniform optical density, which is normally in the parent metal adjacent to the weld. For exposures in accordance with 7.1.6 and 7.1.7 (Figures 11 and 12), the IQI should be placed with the wires across the pipe axis and they should not be projected into the image of the weld. The visible wire length may be shorter than 10 mm for external pipe diameters smaller than 50 mm. In this case, the visible wire length shall be ≥ 20 % of the external pipe diameter.

b) When using a step hole IQI, it shall be placed in such way that the required hole is placed close to the weld.

For single-wall exposures in accordance with 7.1.4 and 7.1.5 (Figures 5 to 10), the IQI type used may be placed either on the source side (use Tables B.1 to B.4) or on the film side. If the IQIs cannot be placed at the source side, the IQIs are placed on the film side and the image quality shall be determined at least

once from comparison exposure, with one IQI placed at the source side and one at the film side under the same conditions.

For double-wall exposures in accordance with 7.1.6 and 7.1.7 (Figures 11 to 12), the IQI type used shall be placed on the source side (use Tables B.5 to B.8). By agreement between contracting parties, the IQI may be placed on the film side (use Tables B.9 to B.12).

For double-wall exposures in accordance with 7.1.8 (Figures 13 to 16), the IQI type used may be placed on the film side. When the IQI is placed on the film side, refer to Tables B.9 to B.12.

Where the IQIs are placed on the film side, the letter F shall be placed near the IQI and shall be visible in the radiographic image and this shall be stated in the test report.

If steps have been taken to guarantee that radiographs of similar test objects and regions are produced with identical exposure and processing techniques, and no differences in the image quality value are likely, the image quality does not need to be verified for every radiograph. The extent of image quality verification should be subject to agreement between the contracting parties.

For exposures of pipes with the source centrally located, at least three IQIs should be placed equally spaced at the circumference. The films showing IQI images are then considered representative for the whole circumference.

6.8 Evaluation of image quality

The films shall be viewed in accordance with 7.10.

From the evaluation of the image of the IQI on the radiograph, the number of the smallest wire or hole which can be discerned shall be determined. The image of a wire is accepted if a continuous length of at least 10 mm is clearly visible in a section of uniform optical density, typically in the HAZ near the weld [see 6.7 a) for pipes with smaller diameters]. In the case of the step hole type IQI, if there are two holes of the same diameter, both shall be discernible in order that the step be considered as visible. See also 6.7 a), for the exception of DWDI evaluation of small pipes.

The IQI value obtained shall be indicated in the test report of the radiographic testing. In each case, the type of indicator used shall be clearly stated, as shown on the IQI.

6.9 Minimum image quality values

The minimum image quality values given in Annex B shall be used. Tables B.1 to B.12 show the minimum IQI values for metallic materials. For other materials, these requirements or corresponding requirements may be agreed upon by contracting parties and shall be noted in the report. The requirements shall be determined in accordance with ISO 19232-4.

In cases where Ir 192 or Se 75 sources are used for copper-based alloys, steel or nickel-based alloys, IQI values poorer than the ones listed in Tables B.1 to B.12 may be accepted exceptionally as follows. This shall be noted in the report.

For DWDI techniques, values shown in Tables B.5 to B.12, both testing class A and testing class B ($w = 2t$):

— 10 mm < w ≤ 25 mm: one wire value fewer or one step hole value more for Ir 192;

— w ≤ 12 mm: one wire value fewer or one step hole value more for Se 75.

For single-wall single-image and double-wall ($w = 2t$) single-image techniques, values shown in Tables B.1, B.2, B.9 and B.10, testing class A:

— 10 mm < w ≤ 24 mm: two wire values fewer or two step hole values more for Ir 192;

— 24 mm < w ≤ 30 mm: one wire value fewer or one step hole value more for Ir 192;

— $w \leq 24$ mm: one wire value fewer or one step hole value more for Se 75.

For single-wall single-image and double-wall single-image techniques, values shown in Tables B.3, B.4, B.11 and B.12, testing class B:

— 10 mm < $w \leq 40$ mm: one wire value fewer or one step hole value more for Ir 192;

— $w \leq 20$ mm: one wire value fewer or one step hole value more for Se 75.

For Se 75 and penetrated thicknesses less than 12 mm, it can be difficult to achieve the IQI values required for testing class B. In this particular case, the minimum optical density shall be increased to 3,0 and at least one film system class better shall be used than required in Table 3 or Table 4.

If the IQI values for Se 75 and penetrated thicknesses less than 12 mm cannot be achieved as described, the required IQI values and test conditions shall be agreed by the contracting parties based on ISO 19232-4.

6.10 Personnel qualification

Personnel performing non-destructive testing in accordance with this document shall be certified in radiographic testing in accordance with ISO 9712 or an equivalent internationally or nationally accepted certification scheme to an appropriate level in the relevant industrial sector.

7 Recommended techniques

7.1 Test arrangements

7.1.1 General

Radiographic techniques in accordance with 7.1.2 to 7.1.9 (Figures 1 to 19) shall be used, if possible. Films shall be placed as close as possible to the object.

The elliptical technique (double-wall and double-image) in accordance with Figure 11 should only be used for $D_e \leq 100$ mm, wall thickness $t \leq 8$ mm and weld width $\leq D_e/4$. Two 90° displaced images are sufficient if $t/D_e < 0{,}12$; otherwise, three elliptical images are needed. The distance between the two projected weld images shall be about one weld width.

When it is not possible to carry out an elliptical testing for $D_e \leq 100$ mm, the perpendicular technique in accordance with 7.1.7 (Figure 12) may be used. In this case, three exposures 120° or 60° apart are required, depending on the access around the pipe.

For test arrangements in accordance with Figures 13 and 14, the inclination of the beam shall be kept as small as possible and be such as to prevent superimposition of the two images. The source-to-object distance, f', shall be kept as small as possible for the technique shown in Figures 13 and 14, in accordance with 7.6. The IQI shall be placed on the film side close to the film with a lead letter F.

Radiographic techniques other than those in 7.1.2 to 7.1.9 (Figures 1 to 19) may be agreed by the contracting parties when it is useful, for example for reasons such as the geometry of the piece or differences in material thickness. In 7.1.9 (Figures 17 to 19) an example of such a case is presented. Additionally, thickness compensation with the same material may be applied. Multi-film techniques shall not be used to reduce exposure times on uniform sections.

If radiation protection is a major concern, a maximum of two films may be exposed during one exposure by agreement of contracting parties.

In Annex A, the minimum number of radiographs required is given in order to obtain an acceptable radiographic coverage of the total circumference of a butt weld in pipe.

NOTE Unless otherwise noted, definitions of the symbols used in Figures 1 to 21 and in the annexes can be found in Clause 4.