INTERNATIONAL STANDARD

ISO 17636-2

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Non-destructive testing of welds — Radiographic testing —

Part 2: X- and gamma-ray techniques with digital detectors

Contrôle non destructif des assemblages soudés — Contrôle par radiographie —

Partie 2: Techniques par rayons X ou gamma à l'aide de détecteurs numériques

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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.

ISO 17636-2 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition, together with ISO 17636-1, cancels and replaces ISO 17636:2003, of which it constitutes a technical revision.

ISO 17636 consists of the following parts, under the general title *Non-destructive testing of welds — Radiographic testing*:

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

— *Part 2: X- and gamma-ray techniques with digital detectors*

The main changes are that:

— the normative references have been updated;

— the document has been divided into two parts — this part of ISO 17636 is applicable to radiographic testing with digital detectors;

— X-ray devices up to 1 000 kV have been included;

— Annex C on determination of basic spatial resolution has been added;

— Annex D on determination of minimum grey values for CR practice has been introduced;

— Annex E with general remarks on grey values has been added;

— the text has been editorially revised.

Requests for official interpretations of any aspect of this part of ISO 17636 should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Introduction

This International Standard specifies fundamental techniques of radiography with the object of enabling satisfactory and repeatable results to be obtained economically. The techniques are based on generally recognized practice and fundamental theory of the subject, inspection of fusion welded joints with digital radiographic detectors.

Digital detectors provide a digital grey value image which can be viewed and evaluated with a computer only. The practice describes the recommended procedure for detector selection and radiographic practice. Selection of computer, software, monitor, printer and viewing conditions are important but are not the main focus of this part of ISO 17636.

The procedure specified in this part of ISO 17636 provides the minimum requirements and practice which permits exposure and acquisition of digital radiographs with equivalent sensitivity for detection of imperfections as film radiography, specified in ISO 17636-1.

Non-destructive testing of welds — Radiographic testing —

Part 2:
X- and gamma-ray techniques with digital detectors

1 Scope

This part of ISO 17636 specifies fundamental techniques of digital radiography with the object of enabling satisfactory and repeatable results to be obtained economically. The techniques are based on generally recognized practice and fundamental theory of the subject.

This part of ISO 17636 applies to the digital radiographic examination of fusion welded joints in metallic materials. It applies to the joints of plates and pipes. Besides its conventional meaning, “pipe”, as used in this International Standard, covers other cylindrical bodies such as tubes, penstocks, boiler drums, and pressure vessels.

NOTE This part of ISO 17636 complies with EN 14784-2.[6]

This part of ISO 17636 specifies the requirements for digital radiographic X- and gamma-ray testing by either computed radiography (CR) or radiography with digital detector arrays (DDA) of the welded joints of metallic plates and tubes for the detection of imperfections.

Digital detectors provide a digital grey value (GV) image which can be viewed and evaluated using a computer. This part of ISO 17636 specifies the recommended procedure for detector selection and radiographic practice. Selection of computer, software, monitor, printer and viewing conditions are important, but are not the main focus of this part of ISO 17636. The procedure specified in this part of ISO 17636 provides the minimum requirements for radiographic practice which permit exposure and acquisition of digital radiographs with equivalent sensitivity for detection of imperfections as film radiography, as specified in ISO 17636-1.

This part of ISO 17636 does not specify acceptance levels for any of the indications found on the digital radiographs.

If contracting parties apply lower test criteria, it is possible that the quality achieved is significantly lower than when this part of ISO 17636 is strictly applied.

2 Normative references

The following referenced documents are indispensable for the application 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 16371-1:2011, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 1: Classification of systems*

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

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

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

ISO 19232–5, *Non-destructive testing — Image quality of radiographs — Part 5: Image quality indicators (duplex wire type) — Determination of image unsharpness value*

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 — Determination of the size of industrial radiographic sources — Radiographic method*

3 Terms and definitions

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

3.1
computed radiography
CR
storage phosphor imaging plate system
complete system comprising a storage phosphor imaging plate (IP) and a corresponding read-out unit (scanner or reader), which converts the information from the IP into a digital image

3.2
storage phosphor imaging plate
IP
photostimulable luminescent material capable of storing a latent radiographic image of a material being examined and, upon stimulation by a source of red light of appropriate wavelength, generates luminescence proportional to radiation absorbed

NOTE When performing computed radiography, an IP is used in lieu of a film. When establishing techniques related to source size or focal geometries, the IP is referred to as a detector, i.e. source-to-detector distance (SDD).

3.3
digital detector array system
DDA system
electronic device converting ionizing or penetrating radiation into a discrete array of analogue signals which are subsequently digitized and transferred to a computer for display as a digital image corresponding to the radiologic energy pattern imparted upon the input region of the device

3.4
structure noise of imaging plate
structure noise of IP
structure due to inhomogeneities in the sensitive layer (graininess) and surface of an imaging plate

NOTE 1 After scanning of the exposed imaging plate, the inhomogeneities appear as overlaid fixed pattern noise in the digital image.

NOTE 2 This noise limits the maximum achievable image quality of digital CR images and can be compared with the graininess in film images.

3.5
structure noise of digital detector array
structure noise of DDA
structure due to different properties of detector elements (pixels)

NOTE After read-out of the exposed uncalibrated DDA, the inhomogeneities of the DDA appear as overlaid fixed pattern noise in the digital image. Therefore, all DDAs require, after read-out, a software based calibration (software and guidelines are provided by the manufacturer). A suitable calibration procedure reduces the structure noise.

3.6
grey value
GV
numeric value of a pixel in a digital image

NOTE This is typically interchangeable with the terms pixel value, detector response, analogue-to-digital unit, and detector signal.

3.7
linearized grey value
GV_{lin}
numeric value of a pixel which is directly proportional to the detector exposure dose, having a value of zero if the detector was not exposed

NOTE This is typically interchangeable with the terms linearized pixel value, and linearized detector signal.

3.8
basic spatial resolution of a digital detector
$SR_b^{detector}$
corresponds to half of the measured detector unsharpness in a digital image and corresponds to the effective pixel size and indicates the smallest geometrical detail, which can be resolved with a digital detector at magnification equal to one

NOTE 1 For this measurement, the duplex wire IQI is placed directly on the digital detector array or imaging plate.

NOTE 2 The measurement of unsharpness is described in ISO 19232-5, see also ASTM E2736[13] and ASTM E1000.[8]

3.9
basic spatial resolution of a digital image
SR_b^{image}
corresponds to half of the measured image unsharpness in a digital image and corresponds to the effective pixel size and indicates the smallest geometrical detail, which can be resolved in a digital image

NOTE 1 For this measurement, the duplex wire IQI is placed directly on the object (source side).

NOTE 2 The measurement of unsharpness is described in ISO 19232-5, see also ASTM E2736,[13] and ASTM E1000.[8]

3.10
signal-to-noise ratio
SNR
ratio of mean value of the linearized grey values to the standard deviation of the linearized grey values (noise) in a given region of interest in a digital image

3.11
normalized signal-to-noise ratio
SNR_N
signal-to-noise ratio, SNR, normalized by the basic spatial resolution, SR_b, as measured directly in the digital image and/or calculated from the measured SNR, $SNR_{measured}$, by

$$SNR_N = SNR_{measured} \frac{88{,}6\ \mu m}{SR_b}$$

3.12
contrast-to-noise ratio
CNR
ratio of the difference of the mean signal levels between two image areas to the averaged standard deviation of the signal levels

NOTE The contrast-to-noise ratio describes a component of image quality and depends approximately on the product of radiographic attenuation coefficient and SNR. In addition to adequate CNR, it is also necessary for a digital radiograph to possess adequate unsharpness or basic spatial resolution to resolve desired features of interest.

3.13
normalized contrast-to-noise ratio
CNR_N
contrast-to-noise ratio, CNR, normalized by the basic spatial resolution, SR_b, as measured directly in the digital image and/or calculated from the measured CNR, i.e.

$$CNR_N = CNR \times \frac{88{,}6\ \mu m}{SR_b}$$

3.14
aliasing
artefacts that appear in an image when the spatial frequency of the input is higher than the output is capable of reproducing

NOTE Aliasing often appears as jagged or stepped sections in a line or as moiré patterns.

3.15
cluster kernel pixel
CKP
bad pixel which does not have five or more good neighbourhood pixels

NOTE See ASTM E2597[11] for details on bad pixels and CKP.

3.16
nominal thickness
t
thickness of the parent material only where manufacturing tolerances do not have to be taken into account

3.17
penetration thickness change
Δt
change of penetrated thickness relative to the nominal thickness due to beam angle

3.18
penetrated thickness
w
thickness of material in the direction of the radiation beam calculated on the basis of the nominal thicknesses of all penetrated walls

3.19
object-to-detector distance
b
largest (maximum) distance between the radiation side of the radiographed part of the test object and the sensitive layer of the detector along the central axis of the radiation beam

3.20
source size
d
size of the radiation source or focal spot size

NOTE See EN 12679 or EN 12543.

3.21
source-to-detector distance
SDD
distance between the source of radiation and the detector, measured in the direction of the beam

NOTE SDD = $f + b$

where

f source-to-object distance

b object-to-detector distance

3.22
source-to-object distance
f
distance between the source of radiation and the source side of the test object, most distant from the detector, measured along the central axis of the radiation beam

3.23
external diameter
D_e
nominal external diameter of the pipe

3.24
geometric magnification
v
ratio of source-to-detector distance SDD to source-to-object distance, *f*

4 Symbols and abbreviated terms

For the purposes of this standard, the symbols given in Table 1 apply.

Table 1 — Symbols and abbreviated terms

Symbol	Term
b	object-to-detector distance
b'	object-to-detector distance perpendicular to test object
d	source size, focal spot size
D_e	external diameter
f	source-to-object distance
f'	source-to-object distance perpendicular to test object
SNR	signal-to-noise ratio

SNR_N	normalized signal-to-noise ratio
t	nominal thickness
Δt	penetration thickness change
u_G	geometric unsharpness
u_i	inherent unsharpness of the detector system, excluding any geometric unsharpness, measured from the digital image with a duplex wire IQI adjacent to the detector
u_{im}	required image unsharpness measured in the digital image at the object plane with a duplex wire IQI
u_T	total image unsharpness, including geometric unsharpness, measured in the digital image at the detector plane with a duplex wire IQI at the object plane
v	geometric magnification
w	penetrated thickness
CKP	cluster kernel pixel
CNR	contrast-to-noise ratio
CNR_N	normalized contrast-to-noise ratio
CR	computed radiography
D	detector
DDA	digital detector array
IP	storage phosphor imaging plate
IQI	image quality indicator
S	radiation source
SDD	source-to detector-distance
SR_b	basic spatial resolution as determined with a duplex wire IQI adjacent to the detector
$SR_b^{detector}$	basic spatial resolution of a digital detector
SR_b^{image}	basic spatial resolution as determined with a duplex wire IQI on the source side of the object

5 Classification of radiographic techniques and compensation principles

5.1 Classification

The radiographic techniques are divided into two classes:

— Class A: basic techniques;

— Class B: improved techniques.

Class B techniques are used when class A might be insufficiently sensitive.

Better techniques compared to class B are possible and may be agreed between the contracting parties by specification of all appropriate test parameters.

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

Nevertheless, the visibility of flaws using film radiography or digital radiography is equivalent when using class A and class B techniques, respectively. The visibility shall be proven by the use of IQIs according to ISO 19232-1 or ISO 19232-2 and ISO 19232-5.

If, for technical reasons, it is not possible to meet one of the conditions specified for class B, such as the type of radiation source or the source-to-object distance, f, it may be agreed between the contracting parties that the condition selected may be that specified for class A. The loss of sensitivity shall be compensated by an increase of minimum grey value and SNR_N for CR or SNR_N for the DDA-technique (recommended increase of SNR_N by a factor >1,4). Because of the better sensitivity compared to class A, the test specimen may be regarded as being examined to class B, if the correct IQI sensitivity is achieved. This does not apply if the special SDD reduction as described in 7.6 for test arrangements 7.1.4 and 7.1.5 are used.

5.2 Compensation principles, CP I, CP II or CP III

5.2.1 General. Three rules (see 5.2.2 to 5.2.4) are applied in this part of ISO 17636 for radiography with digital detectors to achieve a sufficient contrast sensitivity.

Application of these rules requires the achievement of a minimum contrast-to-noise ratio, CNR_N, normalized to the detector basic spatial resolution per detectable material thickness difference Δw. If the required normalized contrast-to-noise ratio (CNR_N per Δw) cannot be achieved due to an insufficient value of one of the following parameters, this can be compensated by an increase in the SNR.

5.2.2 CP I. Compensation for reduced contrast (e.g. by increased tube voltage) by increased SNR (e.g. by increased tube current or exposure time).

5.2.3 CP II. Compensation for insufficient detector sharpness (the value of SR_b higher than specified) by increased SNR (increase in the single IQI wire or step hole value for each missing duplex wire pair value).

5.2.4 CP III. Compensation for increased local interpolation unsharpness, due to bad pixel correction for DDAs, by increased SNR.

5.2.5 Theoretical background. These compensation principles are based on the following approximation for small flaw sizes ($\Delta w << w$):

$$\frac{CNR_N}{\Delta w} = c \frac{\mu_{eff} SNR}{SR_b}$$

where

c is a constant;

μ_{eff} is the effective attenuation coefficient, which is equivalent to the specific material contrast;

CNR_N is the normalized CNR, as measured in the digital image.

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 legal requirements shall be applied.

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

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, digital radiography shall be carried out after the final stage of manufacture, e.g. after grinding or heat treatment.

6.3 Location of the weld in the radiograph

Where the digital radiograph does not show the weld, high density markers shall be placed on either side of the weld.

6.4 Identification of radiographs

Symbols shall be affixed to each section of the object being digitally radiographed. The images of these symbols shall appear in the digital radiograph outside the region of interest where possible and shall ensure unambiguous identification of the section.

6.5 Marking

Permanent markings on the object to be examined shall be made in order to accurately locate the position of each digital radiograph (e.g. 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 digital images

When digitally radiographing an area with two or more separate detectors (imaging plates), they shall overlap sufficiently to ensure that the complete region of interest is digitally radiographed. This shall be verified by a high density marker on the surface of the object which is to appear on each digital image. If the radiographs are taken sequentially, the high density marker shall be visible on each of the radiographs.

6.7 Types and positions of image quality indicators

The quality of image shall be verified by use of image quality indicators (IQIs) in accordance with ISO 19232-5 and ISO 19232-1 or ISO 19232-2.

Following the procedure outlined in Annex C, a reference image is required for the verification of the basic spatial resolution of the digital detector system. The basic spatial resolution or duplex wire value shall be determined to verify whether the system hardware meets the requirements specified as a function of the penetrated material thickness in Tables B.13 and B.14. In this case, the duplex wire IQI shall be positioned directly on the digital detector. The use of a duplex wire IQI (ISO 19232-5) for production radiographs is not compulsory. The requirement for using a duplex wire IQI additionally to a single wire IQI for production radiographs may be part of the agreement between the contracting parties. For use on production radiographs, the duplex wire IQI shall be positioned on the object. The measured basic spatial resolution of the digital image (SR_b^{image}) (see Annex C), shall not exceed the maximum values specified as a function of the penetrated material thickness (Tables B.13 or B.14). For single image inspection, the single wall thickness is taken as the penetrated material thickness. For double wall double image inspection (Figures 11 or 12), with the duplex wire on the source side of the pipe, the penetrated material thickness is taken as the pipe diameter for determination of the required basic spatial resolution (SR_b^{image}) from Tables B.13 and B.14. The basic spatial resolution of the detector ($SR_b^{detector}$) for double wall double image inspection shall correspond to the values of Tables B.13 and B.14 chosen on the basis of twice the nominal single wall thickness as the penetrated material thickness.

If the geometric magnification technique (see 7.7) is applied with $v > 1,2$, then the duplex wire IQI (ISO 19232-5) shall be used on all production radiographs.

The duplex wire IQI shall be positioned tilted by a few degrees (2° to 5°) to the digital rows or columns of the digital image. If the IQI is positioned at 45° to the digital lines or rows the obtained IQI number shall be reduced by one.

The contrast sensitivity of digital images shall be verified by use of IQIs, in accordance with the specific application as given in Tables B.1 to B.12 (see also ISO 19232-1 or ISO 19232-2).

The single wire or step hole IQIs used shall be placed preferably on the source side of the test object at the centre of the area of interest on the parent metal beside the weld. The IQI shall be in close contact with the surface of the object. Its location shall be in a section of uniform thickness characterized by a uniform grey value (mean) in the digital image.

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

a) When using a single 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 grey value or SNR_N, which is normally in the parent metal adjacent to the weld. For exposures in accordance with 7.1.6 and 7.1.7, the IQI can be placed with the wires across the pipe axis and they should not be projected into the image of the weld.

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

For exposures in accordance with 7.1.6 and 7.1.7, the IQI type used can be placed either on the source or on the detector side. If the IQIs cannot be placed in accordance with the above conditions, the IQIs are placed on the detector 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 detector side under the same conditions. If filters are used in front of the detector, the IQI shall be placed in front of the filter.

For double wall exposures, when the IQI is placed on the detector side, the above test is not necessary. In this case, refer to the correspondence tables (Tables B.9 to B.14).

Where the IQIs are placed on the detector side, the letter F shall be placed near the IQI and it shall be stated in the test report.

The identification numbers and, when used, the lead letter F, shall not be in the area of interest, except when geometric configuration makes it impractical.

If steps have been taken to guarantee that digital 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 need not be verified for every digital radiograph. The extent of image quality verification should be subject to agreement between the contracting parties.

For exposures of pipes with diameter 200 mm and above with the source centrally located at least three IQIs should be placed equally spaced at the circumference. The IQI images are then considered representative for the whole circumference.

6.8 Minimum image quality values

Tables B.1 to B.14 show the minimum quality values for metallic materials. For other materials these requirements or corresponding requirements may be agreed upon by contracting parties. The requirements shall be determined in accordance with ISO 19232-4.

In the case where Ir 192 or Se 75 sources are used, IQI values worse than the ones listed in Tables B.1 to B.12 may be accepted by agreement of contracting parties as follows:

Double wall, double image techniques, both class A and B ($w = 2t$):

— 10 mm $< w \leq$ 25 mm 1 wire or step hole value less for Ir 192;

— 5 mm $< w \leq$ 12 mm 1 wire or step hole value less for Se 75.

