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

*Essais non destructifs 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

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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).

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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 17636-2:2013), which has been technically revised.

The main changes are as follows:

— the normative references have been updated;

— the figures have been updated;

— manual and automated inspection with DDAs has been considered in 6.6, 6.7, and 7.8;

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

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

— in 6.7.1, the use of ASTM wires and other IQIs by agreement of the contracting parties has been added;

— 6.8, "Evaluation of image quality" for digital radiography has been added;

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

— in 6.8, 6.9 and 7.3.1, a clarification for the IQI usage for DWDI technique has been added;

— permission to reduce $SNR_N$ if the tube voltage is reduced or energy-resolving detectors are used to < 80 % of the values given in Figure 20 has been added in 7.3.1;

- in 7.3.2, the compensation principle II (CP II) has been extended to three wire pairs without the agreement of the contracting parties;
- Annex C has been shortened to avoid duplication with ISO 19232-5;
- in D.2, a new note on fading has been added;
- a new Annex F has been added;
- a new Annex G has been added.

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

## 1 Scope

This document specifies techniques of digital radiography with the object of enabling satisfactory and repeatable results. The techniques are based on generally recognized practice and fundamental theory of the subject.

This document applies to the digital radiographic testing 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 document, covers other cylindrical bodies such as tubes, penstocks, boiler drums and pressure vessels.

This document specifies the requirements for digital radiographic X- and gamma-ray testing by either computed radiography (CR) or radiography with digital detector arrays (DDAs) of the welded joints of metallic plates and tubes for the detection of imperfections. It includes manual and automated inspection with DDAs.

Digital detectors provide a digital grey value image which can be viewed and evaluated using a computer (Annex E). This document 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 document. The procedure specified in this document provides the minimum requirements for radiographic practice which permits exposure and acquisition of digital radiographs with equivalent sensitivity for the detection of imperfections as film radiography (specified in ISO 17636-1).

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

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 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: 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*

ISO 19232-5, *Non-destructive testing — Image quality of radiographs — Part 5: Determination of the image unsharpness and basic spatial resolution value using duplex wire-type image quality indicators*

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*

ASTM E747, *Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*

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**
**computed radiography**
**CR**
complete system comprising a *storage phosphor imaging plate* (IP) (3.2) 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 tested and which, upon stimulation by a source of red light of appropriate wavelength, generates luminescence proportional to radiation absorbed

Note 1 to entry: When performing *computed radiography* (3.1), an IP is used in lieu of a film. When establishing techniques related to *source size* (3.20) or focal geometries, the IP is referred to as a detector, i.e. *source-to-detector distance* (3.21).

**3.3**
**digital detector array**
**DDA**
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**
<imaging plate> local sensitivity variations due to inhomogeneities in the sensitive layer (structure, graininess) and surface of an imaging plate

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

Note 2 to entry: 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**
<digital detector array> local sensitivity variations due to different properties of detector elements (pixels)

Note 1 to entry: After read-out of the exposed uncorrected *digital detector array* (DDA) (3.3) image, 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 image correction (software and guidelines are provided by the manufacturer). A suitable correction procedure reduces the structure noise.

Note 2 to entry: The image correction is also called "calibration" in other documents.

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

Note 1 to entry: This is typically interchangeable with the terms "pixel value", "detector response", "analogue-to-digital unit" and "detector signal".

Note 2 to entry: For further information, see Annex E.

**3.7**
**linearized grey value**
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 1 to entry: This is typically interchangeable with the terms "linearized pixel value" and "linearized detector signal".

**3.8**
**basic spatial resolution of a digital detector**
$SR_b^{detector}$
half of the measured detector unsharpness in a digital image, which 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 to entry: For this measurement, the duplex wire IQI is placed directly on the *digital detector array* (3.3) or imaging plate.

Note 2 to entry: The measurement of unsharpness is described in ISO 19232-5. See also ASTM E1000 and ASTM E2736.

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

Note 1 to entry: For this measurement, the duplex wire IQI is placed directly on the object (source side).

Note 2 to entry: The measurement of unsharpness is described in ISO 19232-5. See also ASTM E1000 and ASTM E2736.

**3.10**
**signal-to-noise ratio**
**SNR**
ratio of mean value of the *linearized grey values* (3.7) to the standard deviation of the linearized grey values (noise) in a given *region of interest* (3.25) in a digital image

**3.11**
**normalized signal-to-noise ratio**
**$SNR_N$**
*signal-to-noise ratio* (3.10) normalized by the *basic spatial resolution of a digital image*, $SR_b^{image}$, (3.9) and calculated from the measured signal-to-noise ratio by:

$$SNR_N = SNR \cdot \frac{88{,}6}{SR_b^{image}}$$

Note 1 to entry: If the duplex wire IQI is positioned directly on the detector without a test object, $SR_b^{image}$ is equal to the measured $SR_b^{detector}$, which can be used instead of $SR_b^{image}$.

**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 1 to entry: Signal levels are measured in *grey values* (3.6) or *linearized grey values* (3.7).

Note 2 to entry: 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* (3.12) normalized by the basic spatial resolution of a digital image, $SR_b^{image}$, (3.9), as measured directly in the digital image with the duplex wire IQI on the object side and calculated from the measured contrast-to-noise ratio, CNR, i.e.



$$CNR_N = CNR \cdot \frac{88{,}6}{SR_b^{image}}$$

**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 1 to entry: Aliasing often appears as jagged or stepped sections in a line or as moiré patterns.

**3.15**
**cluster kernel pixel**
**CKP**
*bad pixel* (3.29) which does not have five or more good neighbourhood pixels

Note 1 to entry: See ASTM E2597 for details of bad pixels and CKP.

**3.16**
**nominal thickness**
$t$
thickness of the parent material only where manufacturing tolerances do not have to be considered

**3.17**
**penetration thickness change**
$\Delta t$
change of *penetrated thickness* (3.18) relative to the *nominal thickness* (3.16) 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* (3.16) 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, measured along the central axis of the radiation beam

Note 1 to entry: The abbreviated term ODD is used in other documents.

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

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

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



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

where

$f$ is *source-to-object distance* (3.22);

$b$ is *object-to-detector distance* (3.19).



**3.22**
**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 is used in other documents.

**3.23**
**external diameter**
$D_e$
nominal value of the external diameter of the pipe

**3.24**
**geometric magnification**
*v*
ratio of *source-to-detector distance* (3.21) to *source-to-object distance* (3.22)

**3.25**
**region of interest**
**RoI**
defined group of pixels from which measurements or statistics, or both, can be derived

**3.26**
**weld area to evaluate**
**WAE**
area to be evaluated on the radiograph, which contains the weld and the *heat-affected zone* (3.30) on both sides

**3.27**
**area of interest**
**AoI**
minimum area which should be evaluated on the radiograph and which contains the weld, the *heat-affected zone* (3.30) on both sides and all lead letters, markers and image quality indicators (IQIs)

**3.28**
**raw image**
image acquired with *digital detector arrays* (3.3) or computed radiography (3.1) systems after image correction, if a correction has been performed

**3.29**
**bad pixel**
underperforming detector element (pixel) of a *digital detector array* (3.3)

Note 1 to entry: Bad pixels are described in ASTM E2597.

**3.30**
**heat affected zone**
**HAZ**
area beside the weld influenced by the heating and cooling process of the welding, which is considered as the two areas beside the weld, each with the same width as the weld cap but at least 10 mm width 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 |
|---|---|
| $\alpha$ | angle subtended by half of the circumferential length of the AoI at the pipe centre, see Figure 22 a) |
| AoI | area of interest |
| $\beta$ | opening angle of source window or collimator to central beam |
| $b$ | object-to-detector distance |
| $b'$ | object-to-detector distance perpendicular to test object |
| $b_{ed}$ | maximum distance from the object surface nearest to the planar detector to the object surface most distant to the detector in the weld area to evaluate (WAE) of the pipe, see Figures 2 b), 8 b), 13 b), 14 b) and 22 |
| $b_{gap}$ | distance between the radiation sensitive layer of the detector and the outer pipe surface, see Figures 2 b) and 22 |
| $C_i$ | factor to correct $f_{min}$ for using planar detectors for curved objects, if $b > t$ |
| CKP | cluster kernel pixel |
| CNR | contrast-to-noise ratio |
| $CNR_N$ | normalized contrast-to-noise ratio |
| CR | computed radiography |
| $d$ | source size, focal spot size (see the EN 12543 series and EN 12679) |

**Table 1** *(continued)*

| Symbol or abbreviated term | Definition |
|---|---|
| D | detector |
| $D_e$ | external diameter |
| DDA | digital detector array |
| DWDI | double-wall double-image |
| DWSI | double-wall single-image |
| $f$ | source-to-object distance |
| $f_{min}$ | minimum source-to-object distance |
| $f^*_{min}$ | minimum source-to-object distance for testing of curved objects with planar detectors |
| $f'$ | source-to-object distance perpendicular to test object |
| GV | grey value |
| HAZ | heat-affected zone |
| IP | storage phosphor imaging plate |
| IQI | image quality indicator |
| $r_e$ | external radius |
| $r_i$ | internal radius |
| RoI | region of interest |
| S | radiation source |
| SDD | source-to-detector distance |
| SNR | signal-to-noise ratio |
| $SNR_N$ | normalized signal-to-noise ratio |
| $SR_b$ | basic spatial resolution which can be $SR_b^{image}$ or $SR_b^{detector}$ |
| $SR_b^{detector}$ | basic spatial resolution of a digital detector |
| $SR_b^{image}$ | basic spatial resolution of a digital image |
| $t$ | nominal thickness |
| $\Delta t$ | penetration thickness change |
| $u_G$ | geometric unsharpness |
| $u_d$ | inherent unsharpness of the detector system, excluding any geometric unsharpness, measured from the digital image with a duplex wire IQI adjacent to the detector |
| $U_{Im}$ | 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 |
| $v_o$ | optimum magnification |
| $w$ | penetrated thickness |
| WAE | weld area to evaluate |



NOTE The source-to-detector-distance (SDD), as used in digital radiography, is equivalent to SFD (see ISO 17636-1) in film radiography.

# 5 Classification of radiographic techniques and compensation principles

## 5.1 Classification

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 digital radiographic technique shall be agreed between the contracting parties.

The visibility of flaws using film radiography or digital radiography is equivalent when using testing class A and testing 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 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 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 than that of testing class A, the test specimen may be regarded as being tested to testing 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 (Figure 5 to Figure 10) are used.



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

### 5.2.1 General

Three compensation principles (see 5.2.2 to 5.2.4) are applied in this document for radiography with digital detectors to achieve a sufficient contrast sensitivity.

Application of these principles requires the achievement of a minimum contrast-to-noise ratio, $CNR_N$, normalized to the detector basic spatial resolution per detectable material thickness difference $\Delta w$. If the required normalized contrast-to-noise ratio ($CNR_N$ per $\Delta w$) 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 Compensation principle I (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 Compensation principle II (CP II)

Compensation for insufficient detector sharpness (the value of $SR_b$ is higher than specified) by increased SNR (increase in the single IQI wire or step-hole value for each missing duplex wire pair value). $SR_b$ is $SR_b^{detector}$ for detector selection (IQI on the detector without object) or $SR_b^{image}$ for image quality evaluation of a production radiograph with the IQI on the source side of the object.

### 5.2.4 Compensation principle III (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 approximation given in Formula (1) for small flaw sizes ($\Delta w << w$):

$$\frac{CNR_N}{\Delta w} = c \cdot \frac{\mu_{\text{eff}} \cdot SNR}{SR_b^{\text{image}}} \tag{1}$$

where

| | |
|---|---|
| c | is a constant (0,088 6 mm); |
| $\mu_{\text{eff}}$ | is the effective attenuation coefficient, which is equivalent to the specific material contrast, in $mm^{-1}$; |
| $CNR_N$ | is the normalized CNR, as measured in the digital image; |
| $SR_b^{\text{image}}$ | is the basic spatial image resolution, in mm. |

## 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, 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 both sides of the weld outside the weld area to evaluate (WAE).

### 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 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 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 or from automated positioning systems.