

**ISO/TC 85/SC 6 N**

Date: 2015-03-06

**ISO/WD -6**

ISO/TC 85/SC 6/WG 3

Secretariat: AFNOR

## **In-service inspections for primary coolant circuit components of light water reactors — Radiographic testing**

*Contrôles périodiques des composants du circuit primaire des réacteurs à eau légère — Contrôle par radiographie*

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Document type: International Standard

Document subtype:

Document stage: (20) Preparatory

Document language: E

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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.

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ISO -6 was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 6, *Reactor technology*.

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

ISO consists of the following parts, under the general title *In-service inspections for primary coolant circuit components of light water reactors — Radiographic testing*:

- *Part 1: Automated ultrasonic testing*
- *Part 2: Magnetic particle and penetrant testing*
- *Part 3: Hydrostatic testing*
- *Part 4: Visual testing*
- *Part 5: Eddy current testing of steam generator heating tubes*
- *Part 6: Radiographic testing*



# In-service inspections for primary coolant circuit components of light water reactors — Radiographic testing

## 1 Scope

This standard is applicable for in-service inspections by radiographic testing conducted on components in the reactor coolant circuit of light water reactors. This standard is also applicable to other components of nuclear installations.

Test systems for the validation of inhomogeneities (surface and volume) and requirements for test personnel, test devices, the preparation of test and device systems, the implementation of the testing as well as the recording are defined.

An in-service radiographic test in respect to corrosion and wall thickness abrasion of base material areas is not an object of this standard.

NOTE Data concerning the test section, test scope, test time, test interval and evaluation of indications is defined in the applicable national nuclear safety standards.

## 2 Normative references

The following documents quoted in this document, partly or in full, are indispensable for the application of this document. For dated references, only the edition to which reference is made is applicable. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

ISO 8596, *Ophthalmic optics — Visual acuity testing — Standard optotype and its presentation*

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

ISO 11699-1, *Non-destructive testing — Industrial radiographic films — 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 14096-1, *Non-destructive testing — Qualification of radiographic film digitisation systems — Part 1: Definitions, quantitative measurements of image quality parameters, standard reference film and qualitative control*

ISO 14096-2, *Non-destructive testing — Qualification of radiographic film digitisation systems — Part 2: Minimum requirements*

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

ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

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

EN 12543-1, *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing — Part 1: Scanning method*

EN 12543-2, *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing — Part 2: Pinhole camera radiographic method*

EN 12543-3, *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing — Part 3: Slit camera radiographic method*

ISO 16526-1, *Non-destructive testing — Measurement and evaluation of the X-ray tube voltage — Part 1: Voltage divider method*

ISO 16526-3, *Non-destructive testing — Measurement and evaluation of the X-ray tube voltage — Part 3: Spectrometric method*

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

EN 1330-3:1997-10, *Non-destructive testing — Terminology — Part 3: Terms used in industrial radiographic testing; Trilingual version EN 1330-3:1997*

ISO 16371-1, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 1: Classification of systems;*

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

ASTM E 2737, *Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability*

DGZfP-D2, *Recommendation for the Dark Room Processing of Industry X-ray Films<sup>1)</sup>*

ENIQ report nr. 31, *European Methodology For Qualification Of Non- Destructive Testing<sup>2)</sup>*

### 3 Terms, symbols and abbreviations

#### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-3 and the following apply.

##### 3.1.1

###### **Evaluation**

<Radiographic testing> Inspection of the test data in respect to completeness and analysis capacity, localisation and registration of indications according to defined criteria, representation of the test results

[SOURCE: ISO xx-1:2015-03, 3.4]

##### 3.1.2

###### **Basic spatial resolution of a digital detector**

$S R_b$  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 and ASTM E1000.

[SOURCE: ISO 17636-2:2013, 3.8]

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1) Deutsche Gesellschaft für Zerstörungsfreie Prüfung e.V. (DGZfP), Max-Planck-Straße 6, 12489 Berlin

2) Luxemburg, Office for Official Publications of the European Communities, 2007. ISSN 1018-5593



**3.1.3****Basic spatial resolution of a digital image****SR<sub>b</sub> 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 and ASTM E1000.

[SOURCE: ISO 17636-2:2013, 3.9]

**3.1.4****Evaluation**

comparison of the analysed measured data with specified criteria

**3.1.5****Image evaluator**

Qualified RT inspector, who evaluates radiographic images in respect to the achieved image quality and characterisation of indications

Note 1 to term: Traditionally, the image evaluator is referred to as film evaluator when using X-ray films.

**3.1.6****Cluster kernel pixel****CKP**

bad pixel which does not have five or more good neighbourhood pixels

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

[SOURCE: ISO 17636-2:2013, 3.15]

**3.1.7****Computed radiography****Cstorage phosphor imaging plate system (CR)**

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

[SOURCE: ISO 17636-2:2013, 3.1]

Note 1 to term: The storage phosphor imaging plate system also includes the data logging and analysis software as well as the device setting.

**3.1.8****Detector**

Device for detecting an X-ray image which is either an X-ray film, a storage phosphor imaging plate or a digital detector array

Note 1 to term: Detector middle refers to the centre of an X-ray film, a storage phosphor imaging plate or a digital matrix detector.

**3.1.9****Digital matrix detector 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

[SOURCE: ISO 17636-2:2013, 3.3]

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### 3.1.10

#### **X-ray image**

Developed X-ray film or digital image

### 3.1.11

#### **Grey value**

#### **GW**

Numeric value of a pixel in a digital image

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

[SOURCE: ISO 17636-2:2013]

### 3.1.12

#### **Component**

A part of a system delimited according to structural or functional aspects, which can still implement independent sub-functions

### 3.1.13

#### **Contrast**

#### **$\Delta D$**

#### **$\Delta GW$**

Difference in the optical density of two adjoining areas on the X-ray film ( $\Delta D$ ) or difference in the mean grey values of two adjoining areas in a digital image ( $\Delta GW$ )

### 3.1.14

#### **Normalised 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

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

[SOURCE: ISO 17636-2:2013, 3.11]

Note 1 to term: The measurement of  $SNR_N$  is described in detail in ISO 163 71-1.

### 3.1.15

#### **Optical density**

#### **$D$**

measure for the attenuation of the light by the developed film

$$D = \lg \left( \frac{L_0}{L_f} \right)$$

Whereby

$L_0$  is the luminance in front of the film;

$L_f$  is the luminance behind the film in the direction of the observer.

Note 1 to term: The optical density  $D$  of the film corresponds to the old term film blackening.

Note 2 to term: The concrete conditions for measurement of the optical density are described in ISO 5-2.

### 3.1.16

#### **Test section**

part of the test range

[SOURCE: ISO xx-2:2015-03, 3.5]

### 3.1.17

#### **Test supervisor**

responsible for application of the test method and for the individual details of the test implementation including monitoring of the activities for preparation and implementation of the test as well as analysis of the test results

[SOURCE: ISO xx-1:2015-03, 3.22]

### 3.1.18

#### **Test area**

area of the test object to be tested

[SOURCE: ISO xx-2:2015-03, 3.7]

### 3.1.19

#### **Test object**

Part of a component to be tested

[SOURCE: ISO xx-2:2015-03, 3.9]

### 3.1.20

#### **Phosphor storage 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).

[SOURCE: ISO 17636-2:2013, 3.2]

### 3.1.21

#### **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

[SOURCE: ISO 17636-2:2013, 3.10]

Note 1 to term: The measurement of SNR is described in detail in ISO 13671-1.

### 3.1.22

#### **Structural noise of the 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.

[SOURCE: ISO 17636-2:2013, 3.4]

### 3.1.23

#### **Structural noise of the 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.

[SOURCE: ISO 17636-2:2013, 3.5]

### 3.1.24

#### Distortion angle

$\beta$   
angle between the radiographic beam direction and the surface normal of the test object

## 3.2 Symbols and abbreviated terms

The symbols and abbreviations according to Table 1 apply for the application of this document.

**Table 1 — Symbols and abbreviations**

Formula symbol	Designation	Unit
$a$	Distance from the position test indicator to the weld seam centre	mm
$A$	Deviation in the position of the radiation source according to Figure A.2	mm
$A'$	Distance from the vertical irradiation point to the position test indicator	mm
$b$	Distance from the detector to the surface of the test object near to the radiation source (see Figure 1 and Figure 2) in the test area	mm
(BPK) IQI	Image quality indicator	—
$C_r$	Reference value for the contrast index, specified by the manufacturer	—
$D$	Optical density of the X-ray film (see 3.1.15)	—
$\Delta D$	Image contrast in X-ray films (see 3.1.13)	—
$D_a$	External diameter of the tube-shaped test object	mm
$d$	Focal spot size or size of the gamma source	mm
$d_f$	Lead foil thickness	mm
$d_s$	Diameter of the position test indicator	mm
GW	Numerical grey level of a pixel in the digital image (see 3.1.11)	—
$\Delta GW$	Contrast in digital images (see 3.1.13)	—
FDA	Distance from the radiation source to the detector <sup>a</sup>	mm
$f$	Distance from the radiation source to the surface of the test object near to the radiation source (see Figure 1 and Figure 2) in the test area	mm
$h$	Height of the position test indicator	mm
$N$	Minimum number of exposures	—
$s$	Distance between the windings of the lead foil of the position test indicator	mm
$S_r$	Reference value for the sensitivity index, specified by the manufacturer	—
$S_i$	Measured value of the sensitivity index	—
$SNR$	Signal-to-noise ratio (see 3.1.21)	—
$SNR_N$	Normalised signal-to-noise ratio (see 3.1.14)	—
$SR_b^{\text{detector}}$	Basic spatial resolution (see 3.1.3) measured with IQI on the detector	—
$SR_b^{\text{image}}$	Basic spatial resolution measured in the radiography image with IQI on the object	—
$t$	Wall thickness of the test object	mm

$\Delta t$	Change to the radiographic wall thickness of the test object	mm
$U$	Tube voltage (high voltage value set at the X-ray generator)	kV
$w$	Penetrated thickness	mm
$\alpha$	Angular deviation from the vertical inclination of the X-ray beam according to Figure 1 or Figure 2 (see Figure A.2)	°
$\beta$	Distortion angle (see 3.1.24)	°
a In the past, the term film-focus distance FFA was used for film radiography.		

## 4 Test systems

### 4.1 Preliminary remark

The suitability of the test technique and the test device shall be validated corresponding to the requirements of the applicable national nuclear safety standards. The procedure for the qualification is described in ENIQ report nr. 31.

**NOTE** The radiographic testing methods discussed in this part of the standard series ISO xx involves a standardised testing method whose application is realised based on standard test procedures relating to nuclear power plants. A qualification as above can be necessary in individual cases if there are significant deviations from the specifications from the standard test procedures.

### 4.2 General

The testing classes B-NF (testing class B-Nuclear, Film) and B-ND (testing class B-Nuclear, Digital) are introduced for radiographic testing. These include the definitions of testing class B according to ISO 17636-1 for film radiography or ISO 17636-2 for digital radiography and additional requirements. These are, in particular:

- a) Test arrangements as per 4.3;
- b) Minimum number of exposures as per 4.3;
- c) Verification of the radiation source position as per 4.4.2;
- d) Test personnel as per 5.1;
- e) Test object as per 5.2;
- f) Radiation sources as per 5.3;
- g) Film system class as per 5.4;
- h) Maximum tube voltage of X-ray tubes for steel in relation to the penetrated thickness as per 7.2 (Figure 6);
- i) Documentation in accordance with clause 8.

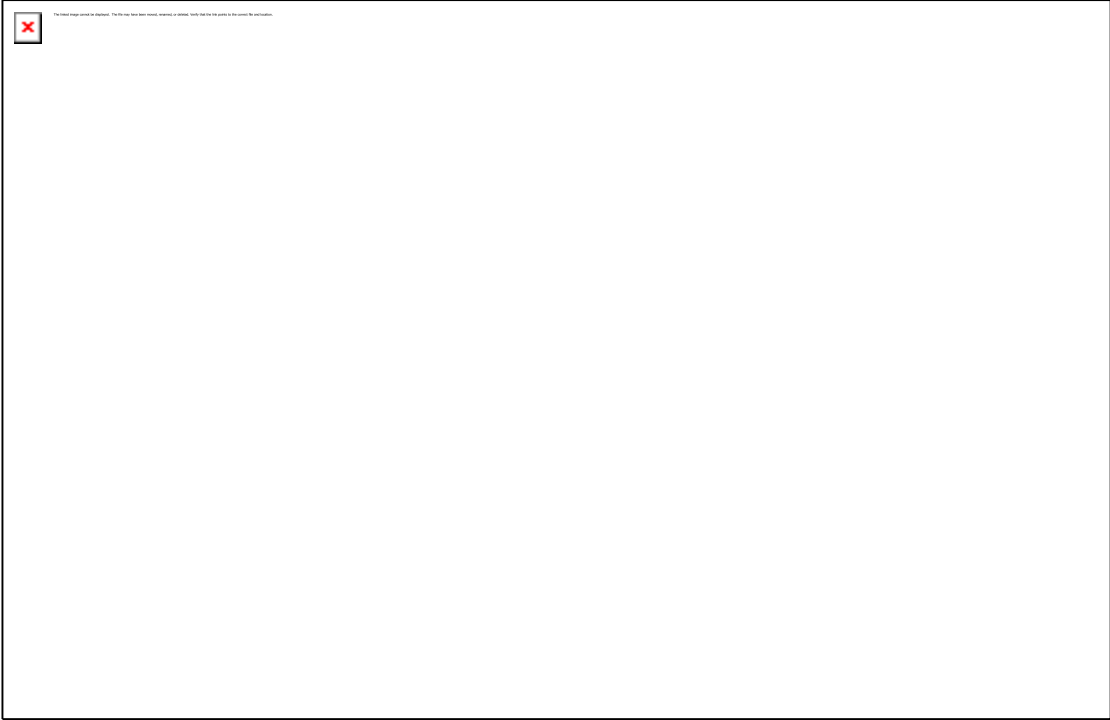
If digital radiography is used, its suitability corresponding to the requirements according to 5.5.2 and 5.5.3 shall be validated.

### 4.3 Test arrangements

For the detection of defects oriented vertically to the surface, the radiation source shall basically be located in the weld level in case of greater than or equal to DN 80 divergent from ISO 17636-1:2013, Figure 13, for class B-NF or from ISO 17636-2:2013, Figure 13, for class B-ND (vertical inclination of beam, see Figure 1 for film radiography or flexible imaging plates and Figure 2 for digital radiography with cassettes or DDA). If the

geometry and accessibility of this test arrangement are not possible, exceptional regulations shall be agreed. The angular deviation  $\alpha$  during the vertical inclination of the beam may not exceed  $\pm 5^\circ$ .

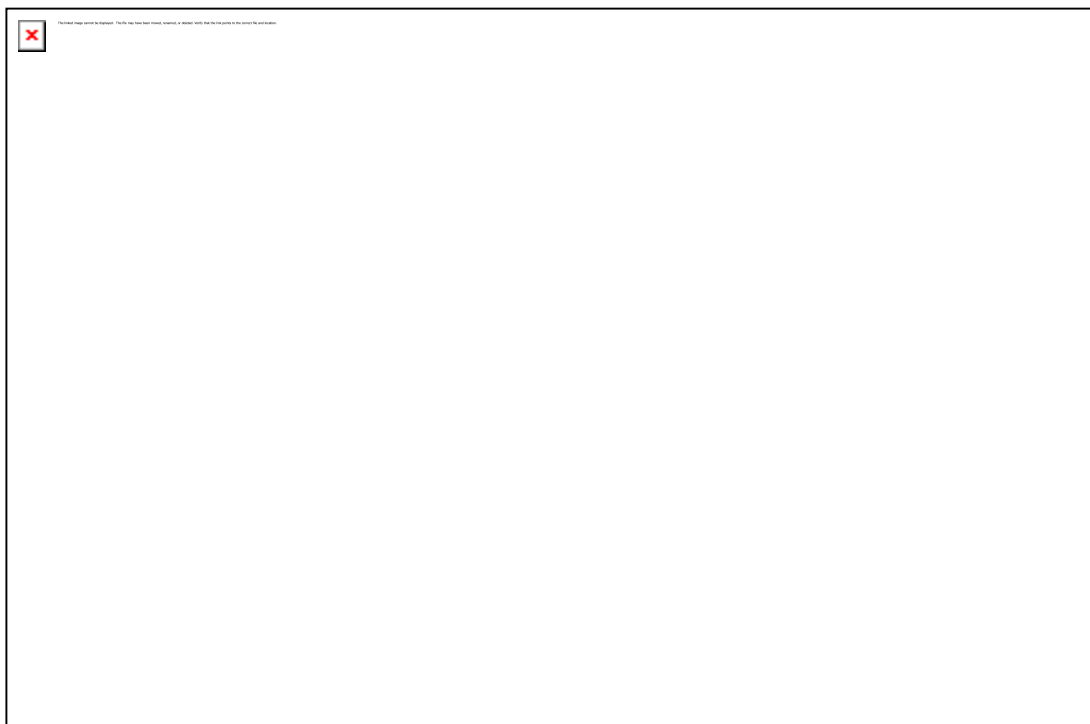
The testing of pipes smaller than DN 80 shall be conducted according to ISO 17636-1:2013, Figure 12, or ISO 17636-2:2013, Figure 12. A deviation  $\alpha$  from the vertical beam inclination of max.  $\pm 5^\circ$  is permissible. Three exposures offset by  $120^\circ$  shall be made. After agreement with the operator and person responsible, three exposures offset by  $60^\circ$  may also be made instead of three exposures offset by  $120^\circ$  if accessibility is restricted.



**Key**

- 1 Radiation source
- 2 Flexible detector

**Figure 1 — Test arrangement for double-wall penetration (single image) with film or flexible imaging plate for testing the wall near to the detector (vertical penetration) with radiation source (focus) at a distance to the tube surface, also in case of surface-mounted X-ray tube**



#### Key

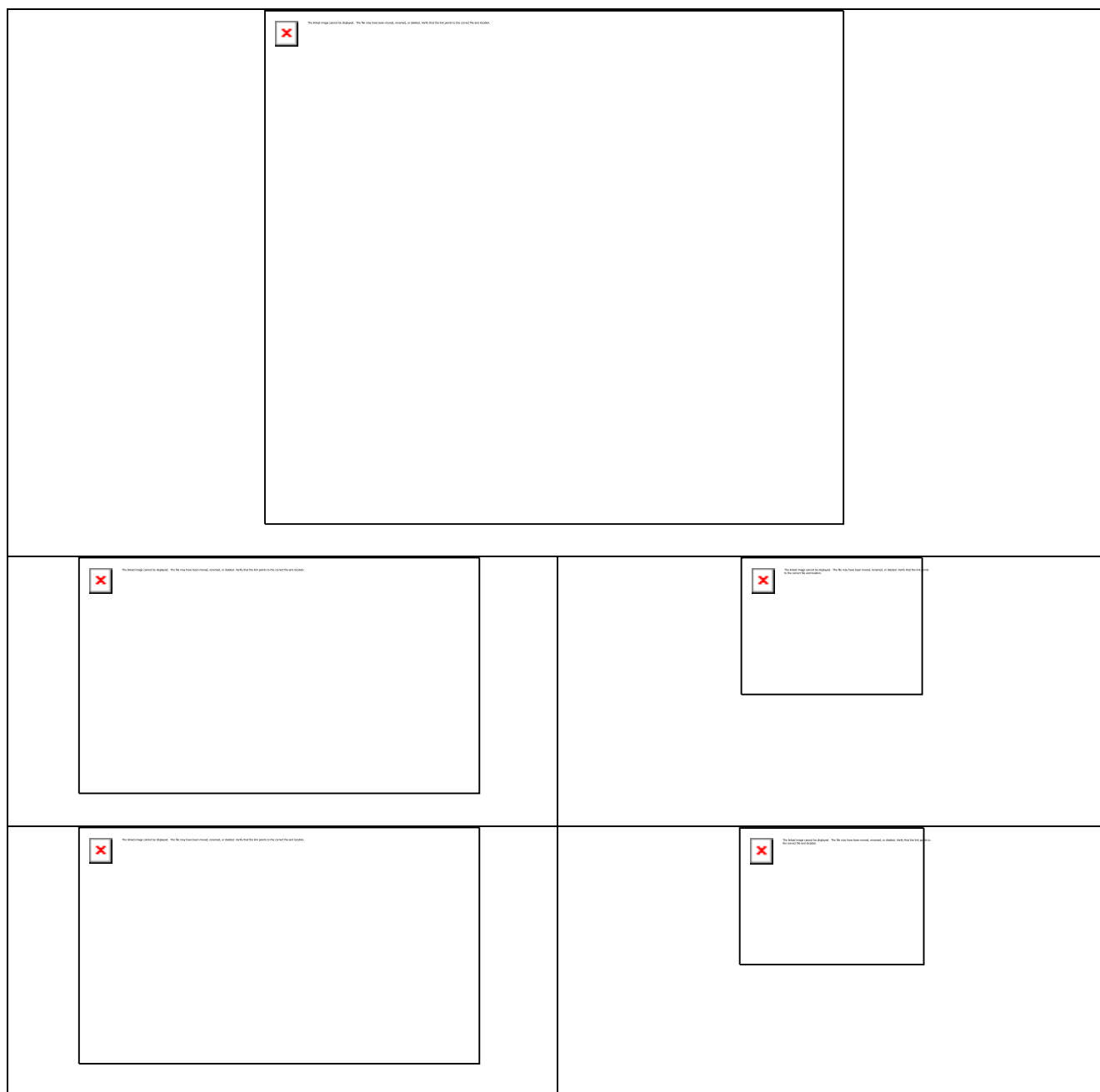
- 1 Radiation source
- 2 Planar detector, cassette

**Figure 2 — Test arrangement for double-wall radiography (single image) for testing the wall near to the detector with digital detector or cassette (vertical penetration) with radiation source (focus) at a distance to the tube r surface, also in case of surface-mounted X-ray tube**

For radiography of girth welds larger than or equal to DN 80 according to Figure 1 or Figure 2, the minimum number of exposures  $N$  according to Figure 3 or Figure 4 shall be determined. The line for the maximum distortion angle  $\beta = \pm 15^\circ$  (see Figure 1 and Figure 2) shall be selected for determination of the minimum number of exposures  $N$ .

If testing is targeted for transversal flaw indications, the line for the maximum distortion angle  $\beta = \pm 10^\circ$  in Figure 3 or Figure 4 shall be selected for the determination of the minimum number of exposures  $N$ .

When determining the minimum number of exposures  $N$  according to Figure 3 or Figure 4, the value shall be rounded up to the next whole number. If additional exposures are required for optimised testing of indication areas, these areas shall be mapped in the centre of the detector.



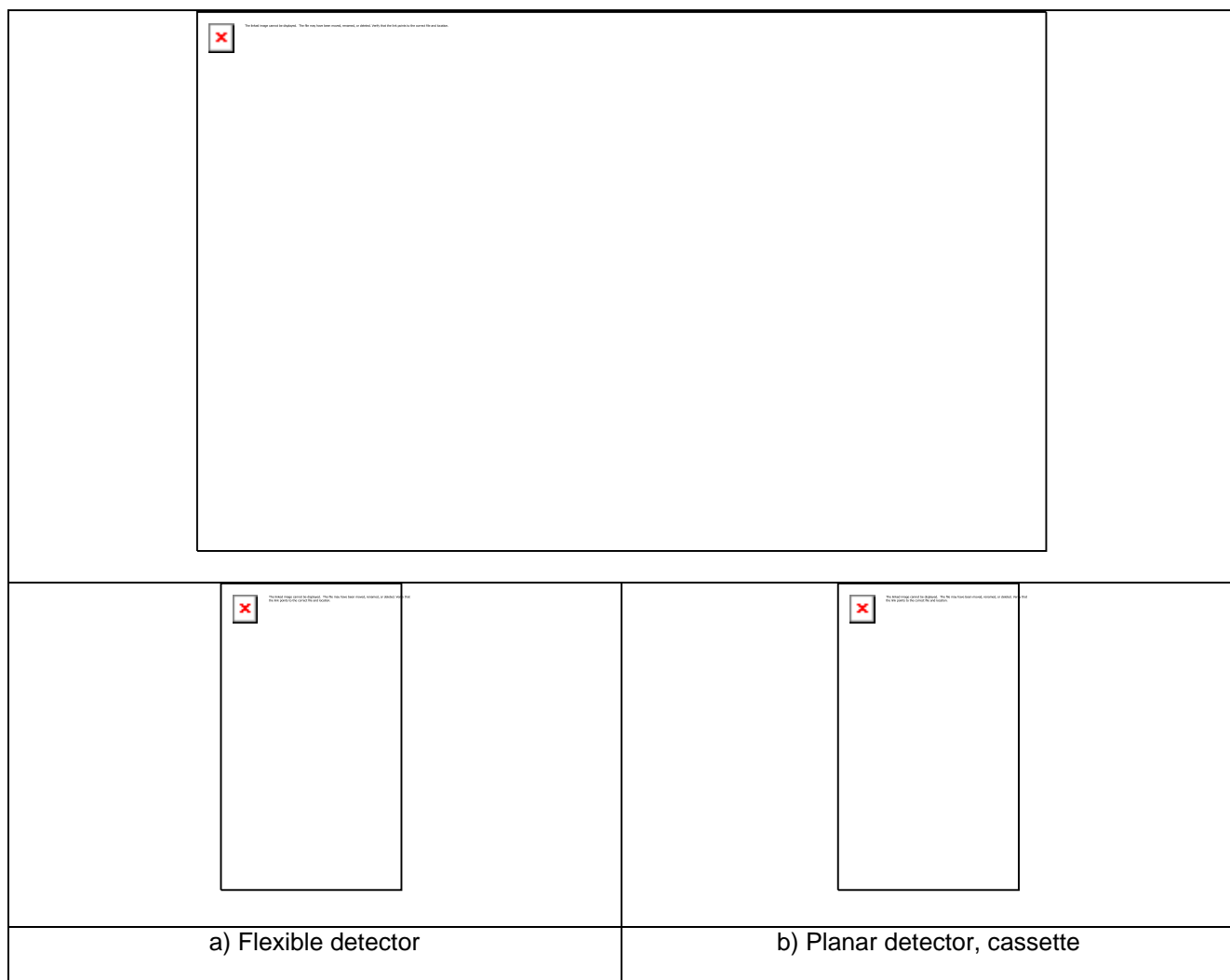
**Key**

1 maximum distortion angle  $\beta = \pm 10^\circ$

2 maximum distortion angle  $\beta = \pm 15^\circ$

**Figure 3 — Minimum number of exposures N for single wall penetration with source inside as well as double wall penetration in relation to the ratio of tube external diameter  $D_a$  to the FDA and the maximum distortion angle  $\beta$**





**Key**

- 1 maximum distortion angle  $\beta = \pm 10^\circ$
- 2 maximum distortion angle  $\beta = \pm 15^\circ$

**Figure 4 — Minimum number of exposures  $N$  for single wall penetration from outside to inside in relation to the ratio of tube external diameter  $D_a$  to the distance  $f$  and the maximum distortion angle  $\beta$**

**4.4 Quality insurance methods**

**4.4.1 Image quality**

Image quality indicators (IQIs) according to ISO 19232-1 shall be used. The analysis of the image quality and specification of the minimum image quality numbers are conducted in accordance with ISO 17636-1 or ISO 17636-2 for image quality class B. This also applies for the type and position of the image quality indicator. The wire is regarded as detected if it is visible contiguously at least over a range of 10 mm in the base material.

**4.4.2 Position of the radiation source and marking of the test area**

To trace the position of the radiation source, the recording setup for girth welds on pipes shall be documented in suitable form, e.g. by photographing the test setup. In case of pipes larger than or equal to DN 150, measuring tapes with position test indicators may be used. The application and detailed setup of these position test indicators are described in Annex A.

The location of the individual test sections shall basically correspond to the positions of the previous radiographic testing. In the case of the initial in-service testing or in justified exceptional cases, it is possible to deviate from this, whereby the number of minimum exposures  $N$  according to Figure 3 or Figure 4 shall be complied with in any case.

### 4.5 Evaluation methods

#### 4.5.1 General

The analysis of the radiography testing is conducted:

- a) based on X-ray films on the illuminator or
- b) based on digitised X-ray films on the monitor of the image processing system or
- c) based on radiographic images of imaging plate systems or digital matrix detectors on the monitor of the image processing system.

#### 4.5.2 Film evaluation at the illuminator

The X-ray films shall be analysed by the image evaluator (see 5.1).

The X-ray films shall be analysed in a darkened room on an illuminator with adjustable luminance according to ISO 5580. The background lighting in the evaluation room should be adjustable and may not glare during evaluation. It is practical to not fully darken the environment. Reflections due to ambient lighting on the surface of the X-ray film are to be avoided. The film area to be inspected should be covered apart from the test section.

An adaptation time for the eye of at least 5 minutes shall be complied with after entering the darkened evaluation room and after glaring.

Thin cotton gloves should be worn when evaluating X-ray films.

To prevent dazzling, areas not to be evaluated and areas with a contrast of  $\Delta D > 1.5$  shall be covered by masks.

The X-ray films shall be evaluated at an angle of about  $90^\circ$  to the field of illumination and at a distance of about 30 cm.

NOTE The use of magnifying glasses with a magnification up to three times is advisable.

The daily evaluation time at the illuminator should not exceed 4 hours. Sufficient rest intervals shall be kept by the image evaluator after every hour.

Calibrated Densitometers shall be used for measuring the optical density. The device calibration of the densitometer shall be checked daily before starting the evaluation. The densitometer is calibrated if the deviation of the measured values from the values of the density step is within  $D \pm 0.1$ . The certified density step tablet used for calibration shall be recertified every 5 years at the latest. No damage shall be discernible at the density step tablet.

#### 4.5.3 Evaluation with image processing system

##### 4.5.3.1 General

Image processing systems may be used for the analysis of digital radiographs. For this, the radiographic X-ray film shall be digitised using a qualified scanner of class DB or class DS according to ISO 14096-2 or a digital radiographic image according to ISO 17636-2 shall be provided.

The digital radiographic images shall be digitised with minimum 12 Bit. The image processing system shall be able to process 16 bit grey value images. It is not permissible to analyse images compressed to 8 Bit.

The digital radiographic images are visualised on the high-resolution monitor. A quantitative determination of the characteristic values of radiographic indications (length, width, contrast) can be performed via profile plots (grey value in relation to its position on a line) from the digital image data.

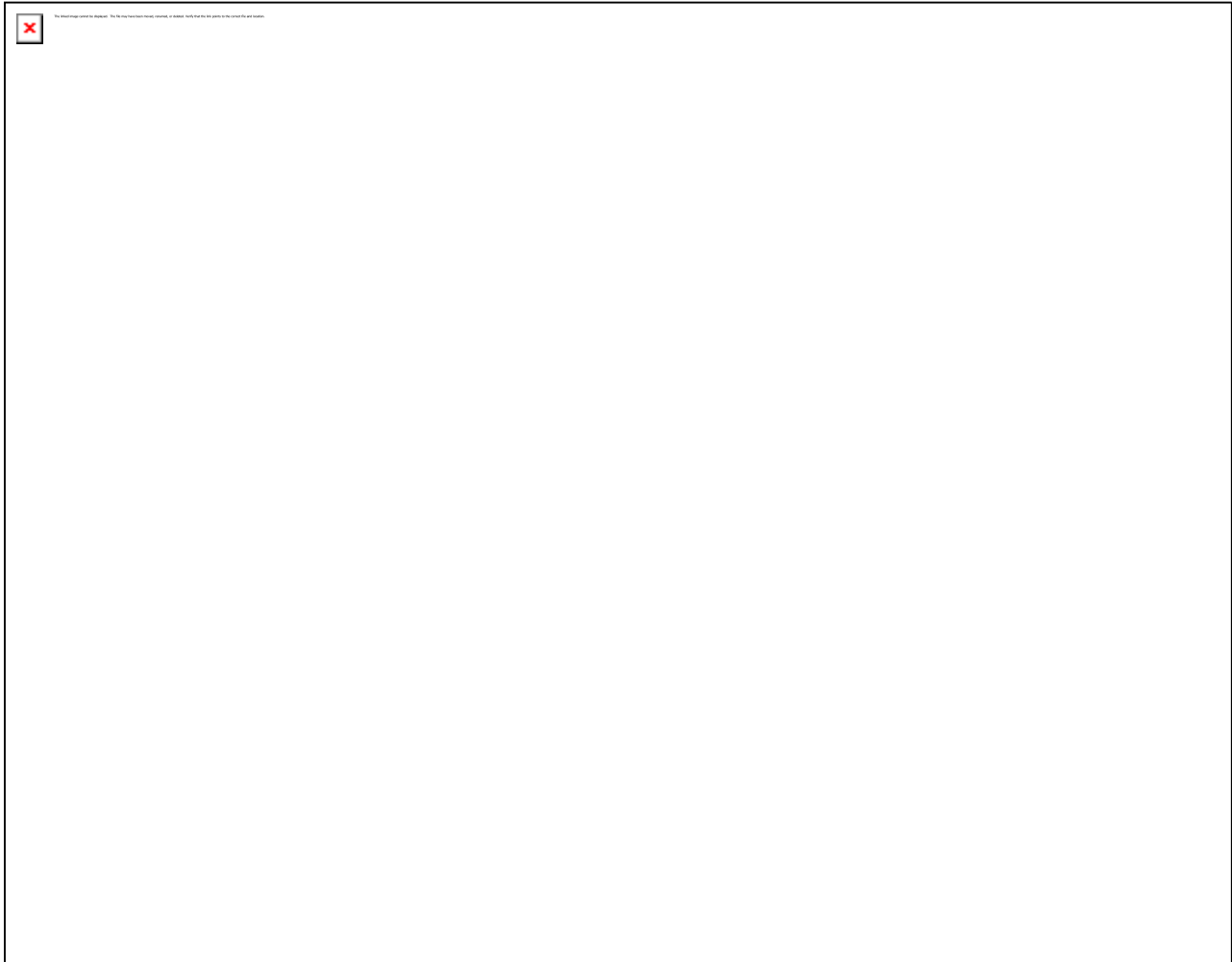
The use of digital image processing (e.g. magnification, brightness adjustment, contrast stretching, signal filtering, edge enhancement) makes it possible to improve the recognition of indications.

#### **4.5.3.2 Viewing conditions at the monitor**

The digital radiographic images shall be evaluated in a darkened room with background lighting. This may not glare during the Evaluation. Reflections by background lighting on the surface of the monitor have to be avoided. The monitor setting shall be verified with a suitable test image. Here the following requirements shall be fulfilled as a minimum:

1. A Grey level contrast 0 % to 5 % shall be clearly discernible.
2. A Grey level contrast 95 % to 100 % shall be clearly discernible.
3. The visualisation of 256 continuously rising grey values (gray wedge) shall be recognisable without any steps.

The settings of the graphics card or the monitor may be optimised for this. The image evaluation may only be carried out after positive tests. The tests shall be conducted before and after the evaluation session and at least once a day. The result shall be documented. Figure 5 shows an example of a monitor test image. The daily analysis time at the monitor should not exceed 4 hours. Sufficient rest intervals shall be complied with by the image evaluator after every hour.



**Key**

- 1 Test for the grey level contrast 0 % to 5 %
- 2 Test for the grey level contrast 95 % to 100 %
- 3 Test for the step-free visualisation of 256 grey levels (neutral wedge).

**Figure 5 — Example of a test image for testing the minimum requirements of the monitor**

**4.5.3.3 Image processing**

The digital data of the radiographic detector (raw data) shall be evaluated using the linearised grey values representation, in which the grey values are proportional to the radiation dose and which is suitable for determination of the *SNR* or the *SNR<sub>N</sub>* as well as the image quality. For an optimum image reproduction it shall be possible to set contrast and brightness interactively. Optional filter functions, profile plots and an *SNR/SNR<sub>N</sub>* tool should be integrated into the software for the image visualisation and analysis. For the critical image analysis, the evaluator shall view the image with a magnification factor between 1:1 (i.e. one pixel of the digital radiograph is visualised by one monitor pixel) and 1:2 (i.e. one pixel of the digital radiograph is visualised by four monitor pixels).

Further image processing functions applied to the saved raw data (e.g. high-pass filtering for image display) shall be documented and repeatable.

**5 Requirements**

**5.1 Test personnel**

The test personnel comprises the test team, image evaluator and test supervisor.

The test supervisor and image evaluator shall have the knowledge required for their tasks as well as know the application options and limits of the testing methods and have knowledge about the characteristic appearances of operation-induced flaws. Indications above the evaluation threshold shall be evaluated by a test supervisor, who has the required experience in respect to the test object, test assignment, testing method and test device.

The test team shall have the skills to perform the work they are to carry out. In particular, they shall have adequate experience in the implementation of radiographic testing and knowledge about the test object in respect to this.

The qualifications of the test personnel shall be confirmed according to Table 2.

**Table 2 — Requirements for the test personnel**

Test personnel	Qualification for RT-Film	Additional qualification for RT-Digital
Test team	A test team comprises at least two inspectors, whereby one inspector shall be qualified with level 2 as a minimum and all others with level 1 as a minimum in accordance with ISO 9712	At least one inspector qualified in RT-Digital level 2
Image evaluator <sup>a</sup>	Certified with level 2 as a minimum in accordance with ISO 9712 and additional experience of 100 h in the evaluation of radiographic images of welds in nuclear systems	Qualified in RT-Digital level 2
Test supervisor	Certified with level 3 according to ISO 9712	Qualified in RT-Digital level 2
<sup>a</sup> The image evaluator shall be authorised by the employer.		

The test personnel shall provide annual validation of their visual abilities, which has been determined by an ophthalmologist, optician or other medically recognised person. The following requirements shall be fulfilled:

- a) The visual acuity testing shall be conducted using standard symbols according to ISO 8596 or equivalent. Here a near vision of 1.0 at 0.33 m test distance with at least one eye, with or without vision aid shall be validated;
- b) The ability to distinguish visually between grey shades shall be validated. The validation can typically be conducted with the help of the "shades of grey test".

If disorders in the adaptability are determined, these shall be considered.

## 5.2 Test object and test area

### 5.2.1 Test object

The pipes to be tested shall be emptied. In justified cases (e.g. pipes that cannot be emptied for reasons of safety or plant-relevant reasons), this rule can be exempted from if it is demonstrated through reference exposures that the image quality value is attained according to ISO 17636-1:2013, Table B.11, for film radiography or according to ISO 17636-2:2013, Table B.11, for digital radiography. ISO 17636-2:2013, Table B.14, shall be complied with when evaluating the maximum total image unsharpness with film radiography and digital radiography.

### 5.2.2 Test area

The surfaces shall be in such a state that the analysis of the radiographic images is not affected. If necessary, the surfaces shall be grinded. The external surface of welds shall be machined notch free and more or less

level with the tube. Visible surface defects (e.g. grooves, notches, impurities) shall be eliminated before the radiographic testing.

### 5.3 Radiation sources

#### 5.3.1 General

Constant potential X-ray systems shall be used. In particular cases (e.g. single-wall radiography with a pig source, thick-walled components), the use of gamma sources may be agreed with the operation agency and third party. X-ray systems shall be certified in respect to their properties (focal spot size, position of the focal spot and X-ray tube voltage). Gamma sources shall be certified in respect to the physical source dimensions, its activity and the location of the source capsules (marking on the move-out rod).

#### 5.3.2 X-ray systems

##### 5.3.2.1 Focal spot

The focal spot size is defined and measured in accordance with EN 12543-1, EN 12543-2 or EN 12543-3. The focal spot size and position of the focal spot shall be certified by the manufacturer or by a testing laboratory upon delivery of the X-ray system. Only X-ray systems may be used, which have a certificate concerning the measurement of the focal spot size in accordance with EN 12543-1, EN 12543-2 or EN 12543-3. A new measurement including certificate of the focal spot is necessary after every repair. The focal spot size (d) indicated in the certificate shall be used for determining the exposure parameters. If two dimensions are indicated in the certificate for a focal spot, the larger one shall be used.

The use of X-ray tubes is approved if the corrected deviation of the focal spot from the centre position (corrected deviation = measured deviation from the detector centre divided by the magnification of the pin-hole camera) is less than or equal to 5 mm.

##### 5.3.2.2 Voltage of the X-ray system

The voltage of the X-ray system shall be measured in accordance with ISO 16526-1 or in accordance with ISO 16526-3. The deviation between the actual value and the set target value shall not exceed 5 % in the mains voltage range indicated. The measured deviation shall be certified by the manufacturer or by a testing laboratory.

Only stabilised constant potential X-ray systems for which a certificate concerning the voltage measurement is available may be used. A new calibration and certification is required if interventions have been made to the electronic control during repairs.

#### 5.3.3 Gamma sources

##### 5.3.3.1 Dimensions of the gamma sources

The dimensions of the gamma source can be found in the manufacturer certificate. On request, the source size shall be measured and presented in accordance with EN 12679. The certificate is valid over the entire utilisation period of the gamma source. The dimensions indicated in the certificate shall be used for determining the exposure parameters. If two dimensions are indicated in the certificate for a source, the larger one shall be used.

##### 5.3.3.2 Activity of the gamma source

The activity of the gamma source is certified by the manufacturer upon delivery of the gamma source. The certificate is valid over the entire utilisation period of the gamma source.

##### 5.3.3.3 Position of the gamma source

The position of the gamma source shall be marked permanently on the move-out tip by the manufacturer.

## 5.4 Film system

Only film systems may be used, which are classified in accordance with ISO 11699-1 and which belong to film system class C3 and better. A certificate concerning the classification of the film system used showing the complete data according to ISO 11699-1 shall be provided. The film processing shall be conducted according to the recommendations of the manufacturer and shall be monitored and documented in accordance with ISO 11699-2 (see Annex B).

## 5.5 Analysis system

### 5.5.1 Illuminator

Film illuminators according to ISO 5580 shall be used. The maximum luminance of the illuminator shall be measured and recorded annually and after any lamp replacement. The maximum optical density of the radiograph which can be analysed shall be defined in accordance with ISO 5580 for every illuminator and indicated on this illuminator. The uniform illumination of the illuminator screen shall be checked each time just after putting the illuminator into operation. Defective lamps shall be replaced.

### 5.5.2 Systems of digital radiography

The requirements in respect to film digitisation systems shall be complied with corresponding to EN 14096-2, system class DS or DB. The system class DS shall be used for the digital archiving of films.

If other systems of digital radiography are used to generate digital images, the requirements according to ISO 17636-2 shall be complied with. If the digital detectors do not fulfil the requirements according to ISO 17636-2:2013, Table B.14, only these systems may be used that fall below the required duplex wire detection by maximum one duplex wire pair, whereby the single wire detection according to ISO 17636-2:2013, Table B.11 shall be increased by one single wire respectively (compensation principle).

**NOTE** The compensation principle according to ISO 17636-2:2013-, 6.3.2, is limited to one duplex wire pair. This means that, insofar as the required values D10 and W13 (for a penetrated thickness of 20 mm, class B-ND) cannot be attained simultaneously for a definite detector setting, for example, the values D9 and W14 provide an equivalent detection sensitivity.

When using magnification, the duplex wire visibility according to ISO 17636-2:2013-05, Table B.14 shall be validated. The required duplex wire detection shall be qualified by a reference exposure according to Annex C. The testing shall be performed with this qualified test arrangement.

### 5.5.3 Image processing systems

The requirements in respect to image processing systems shall be complied with according to ISO 17636-2. The monitor for the image evaluation shall fulfil the following minimum requirements:

- a) Minimum luminance of 250 cd/m<sup>2</sup>;
- b) Display with minimum 256 grey levels;
- c) Minimum visualised luminance ratio of 1:250;
- d) Reproduction of minimum 1 Megapixel with a pixel size < 0.3 mm.

The original images of the test area shall be saved in the full resolution provided by the detector system. Before saving this raw data, only image processing may be applied, which is associated with the detector calibration (e.g. offset correction, gain calibration for the detector calibration and bad pixel correction acc. to ASTM E 2597), in order to provide artefact-free detector raw images.

The data storage shall be redundant and assisted by suitable backup strategies to ensure a lossless data storage.

## 5.6 Storage media

Storage media shall be designed in such way that

- a) they enable a labelling for identification;
- b) an unintentional overwrite is prevented;
- c) the suitability of storage is ensured.

It shall be ensured that stored raw data can be read and processed at least until the next in-service testing.

NOTE Operating system or hardware modifications might render it necessary to transfer raw data to other data carrier types.

## 6 Standard test procedures

The standard test procedures shall contain:

- a) Scope of validity;
- b) Jointly applicable regulations, standards and instructions;
- c) Test objective;
- d) Personnel qualifications;
- e) Data on the test object and possibly data on the test scope and test time;
- f) Data on test preconditions;
- g) Test system;
- h) Data on the test implementation and analysis as well as the evaluation of indications;
- i) Type and scope of the recording and documentation.

## 7 Testing

### 7.1 Preparations

#### 7.1.1 General

The test personnel shall be instructed in the special test assignment, the appearance of operational errors and the present test boundary conditions, such as component geometry, impeded accessibility, work carried out with respiratory protection and radiation expositions.

Before conducting mechanised radiographic testing in areas exposed to radiation, training for rapid assembly and disassembly shall be realised for reducing the time personnel remain in such areas. The training shall be documented and, if necessary, validated by the test service provider.

All requisite documents, such as test procedures, drawings or piping isometries necessary for conducting the testing shall be made available to the test personnel. Data on the radiographic parameters and test arrangement of the previous test shall be provided in the documents, in order to obtain a reproducible radiographic image. If the radiographic conditions have been optimised, this shall be documented. The inspection equipment and film development systems shall be checked in respect to functionality before commencing work.

It shall be ensured that the test areas are adequately accessible.



The identity of the weld intended for testing shall be ensured by verification of the marking. The zero point and counting direction shall be unique and distinctive (see Annex E).

The preparation and implementation of the test shall be documented in suitable form. A control sheet according to Annex F should be used.

## **7.1.2 Performance verification of the equipment**

### **7.1.2.1 Radiation sources**

X-ray systems and gamma emitters shall be checked for completeness of the equipment and presence of the certificates required in accordance with 5.3.2 or 5.3.3 before every test application or upon delivery.

If mechanical damage is discernible on the tube head, an on-site test should be performed. A focal spot exposure according to EN 12543-2 should be carried out during an on-site test for this X-ray system. In addition to the focal spot size, the deviation of the focal spot (see 5.3.2.1) from the centre position (in relation to the axis tube collimator centre — pinhole aperture — detector centre) shall be determined and both values shall be recorded. The measured data focal spot width, focal spot length, exposure time, pinhole aperture diameter, magnification of the pinhole camera and deviation from the centre position as well as date of the measurements shall be recorded and enclosed in the test reports.

The larger of the two values for the focal spot size (determined value or value indicated in the certificate) shall be used.

### **7.1.2.2 Film processing**

The film processing shall be conducted as specified by the manufacturer. The correspondence of the film processing with the film system classification shall be monitored in accordance with ISO 11699-2 with certified film strips. The film processing shall be checked each working day.

The measured results and the values calculated from these shall be entered in a record form. This shall also contain the following data on the processing procedure:

- a) Manual or automated processing;
- b) Cycle time;
- c) Developer temperature;
- d) Immersion time of the film in the developer;
- e) Manufacturer name, designation of the chemicals;
- f) Manufacturer name and identification of the certified film strips.

The residual thiosulphate test (thio test) shall be performed as specified by the manufacturer to monitor the archiving capacity of the X-ray films. This test shall be carried out each working day and after every new mixing of the fixing bath on an unexposed and developed sample of each of the film types to be used. An archiving capacity for at least the service life of the nuclear plant shall be ensured.

The optical density of the fog and base shall be checked for each film batch before use. The same unexposed and developed films shall be used for this. The optical density  $D$  of the fog and base may not exceed 0.3.

### **7.1.2.3 Dark room**

The DGZfP-D2 recommendation for dark room processing of industrial X-ray films shall be complied with.

## **7.1.3 Reference exposure for film radiography**

If the specifications of this standard cannot be complied with, a reference exposure according to Annex C shall be compiled for verification of the test system. For this, the reference exposure shall be performed with a

tube of the same design, same type and same focal spot, as well as with a film system that is used for the planned in-service test. The image quality shall be validated in accordance with ISO 17636-1:2013, Annex B, and in accordance with ISO 17636-2:2013 Table B.14, for film records.

#### 7.1.4 Performance verification of scanners for film digitisation

A test film in accordance with EN 14096-1 shall be used to check whether the film scanner to be used fulfils the requirements according to EN 14096-2 for the required class.

#### 7.1.5 Performance verification of the digital radiographic system

For CR systems, the check is carried out with the user test for validation of the long-term stability according to ISO 16371-1:2011, Annex C. It is necessary to validate at least every six months that the required basic spatial resolution of the imaging plate used,  $SR_b^{\text{detector}}$ , is attained in accordance with ISO 17636-2:2013, Table B.14, and ISO 17636-2:2013, Annex C. After repairs, when using other imaging plates, or if the scanner settings are changed, this validation must be performed before use.

For systems with digital detectors arrays (DDA), the test is conducted according to ASTM E 2737. It is necessary to validate at least once a year that the required basic spatial resolution of the DDA system used,  $SR_b^{\text{detector}}$ , according to ISO 17636-2:2013, Table B.14, and ISO 17636-2:2013, Annex C, is attained. After repairs or changes to the detector settings, this validation shall be performed before use.

The application of digital detector arrays (DDA) requires a mapping of the detector in order to determine the "bad pixel map" (position determination of the defective pixels in the entire detector matrix) corresponding to the instructions of the manufacturer. This "bad pixel map" shall be documented. The interpolation of the defective pixels is permissible and represents an important method for radiography with DDA.

In the case of digital detector arrays, the updating of the "bad pixel map" as well as the detector calibration shall be conducted at least every six months according to the manufacturer's recommendation.

NOTE 1 "Bad pixels" are detector elements with insufficient performance (defective pixels). They are described in ASTM E 2597. Digital detector arrays may not contain any cluster kernel pixels (CKP) as per ASTM E 2597 in the evaluation area.

The calibration of a digital detector array (DDA) shall be carried out so that at least a  $SNR_N > 300$  is attained without test object but at the tube voltage used for the test. A pre-filtration at tube-port for the validation of this  $SNR_N$  is permissible.

NOTE 2 The DDA calibration should be repeated if background images or detector-specific structures are visible. This can occur e.g. at a change to the ambient temperature or the radiographic energy.

#### 7.1.6 Reference exposure for digital radiography

A reference exposure in accordance with Annex C shall be performed for verification of the digital test system. For this, the reference exposure shall be performed with a tube of the same design, same type and same focal spot, as well as with a detector of the same design and same type as for the planned in-service test. For the film digitisation or use of digital detectors, the image quality according to ISO 17636-2:2013, Annex B, (single wire and duplex wire detection) shall be validated in the digital images.

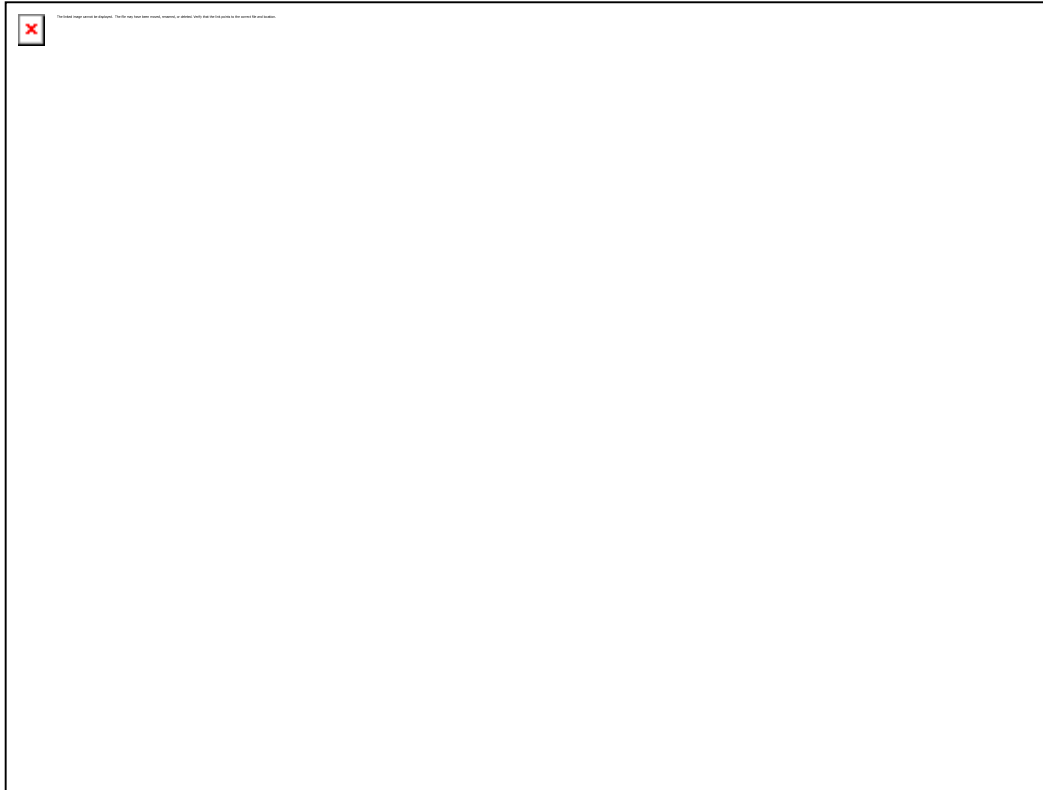
### 7.2 Implementation

#### 7.2.1 Film radiography

The implementation of the radiographic testing shall be carried out in accordance with ISO 17636-1 for testing class B-NF with additional requirements according to 4 to 7.1. The following shall be observed:

- a) The overlapping of the areas to be evaluated shall be sufficient, but should be at minimum 10 mm. The projected weld should be in the centre of the image.
- b) The zero point and numerical direction of the measuring tape shall correspond with the location and direction marking of the zero point of the weld.

- c) The zero point of the weld should be in the centre of the radiograph.
- d) On both sides of the weld, a measured value for the wall thickness shall be recorded and logged distributed every 90° at the circumference.
- e) If required, a film position plan shall be compiled.
- f) Double-wall radiography at pipes large than or equal to DN 80 shall be conducted according to Figure 1. Measuring tapes shall be used, whereby at least three dimensional numbers must be able to be detected in the evaluation area.
- g) The minimum number of required exposures shall be determined according to Figure 3 or Figure 4. In case of dimensions less than DN 150, eight exposures are sufficient. The maximum tube voltage for film radiography is specified according to Figure 6. If the wall thickness range (excess penetration) cannot be complied with locally, the tube voltage may be increased by maximum 50 kV in coordination with the operating agency and the third party.
- h) To determine the exposure parameters, the focal spot size ( $d$ ) indicated in the certificate shall be used. If the length and width are indicated in the certificate, the larger of both values shall be used.
- i) Only film systems according to 5.4 shall be used.
- j) In case of a setup of the radiation source within the test object of evaluation,  $f_{\min}$  (see ISO 17636-1:2013, Figure 21 and 7.6) shall be complied with. Only in case of a test arrangement according to ISO 17636-1:2013, Figure 5, a reduction in the minimum distance focal spot — test object up to 40 % is approved for testing class B.
- k) The optical density of the film in the area to be evaluated (weld material and base material) shall be 2.3 minimum. The maximum optical density may not exceed the certified value of the illuminator used. The maximum value is  $D = 4.5$ .
- l) At a local dose rate  $> 10$  mSv/h in the test area, a potential increase in the optical density of the film base and fog by non-imaging radiation shall be determined based on a test film of the same film type and the minimum required optical density has to be increased by this value.
- m) The tested areas shall be assigned uniquely to the test object and the test area based on the identification. The weld identification shall be exposed using numbers and letters from absorbing material.
- n) In the case of internally and externally processed welds, the weld seam progression shall be identified with markings on both sides next to the area to be inspected. The markings shall be applied on both sides of the test object at the same distance to the weld centre.



**Key**

- U* Tube voltage in kV
- W* Penetrated thickness in mm

**Figure 6 — Maximum tube voltage of X-ray tubes for steel in relation to the penetrated thickness**

**7.2.2 Digital radiography**

The implementation of the radiographic testing shall be carried out according to ISO 17636-2 for testing class B-ND with additional requirements according to 4 to 6.2. The following shall be observed:

- a) The overlapping of the areas to be evaluated shall be sufficient, but should be at minimum 10 mm. The projected weld should be in the centre of the image.
- b) The zero point and numerical direction of the measuring tape shall correspond with the location and direction marking of the zero point of the weld.
- c) The zero point of the weld should be in the centre of the radiograph.
- d) On both sides of the weld, a measured value for the wall thickness shall be recorded and logged distributed every 90° at the circumference.
- e) If required, a detector location plan shall be compiled.
- f) Double wall radiography at pipes greater than or equal to DN 80 shall be performed according to Figure 1 or Figure 2. Measuring tapes shall be used, whereby at least three dimensional numbers must be able to be detected in the evaluation area.
- g) The minimum number of required exposures shall be determined according to Figure 3 or Figure 4. In case of dimensions less than DN 150, eight exposures are sufficient. The maximum tube voltage is recommended according to Figure 6.
- h) Digital detector arrays may also be used at higher tube voltages than indicated in Figure 6, if the required image quality is achieved.

- i) Imaging plates with maximum achievable  $SNR_N < 200$  (large grain) should be used at a X-ray tube voltage reduced by minimum 20 % according to Figure 6. When using imaging plates, the specification of a minimum grey value according to ISO 17636-2:2013, Annex D, testing class B, is recommended.
- j) To specify the exposure parameters, the focal spot size (d) indicated in the certificate shall be used. If the length and width are indicated in the certificate, the larger of both values shall be used.
- k) In case of a setup of the radiation source within the test object of evaluation,  $f_{min}$  (see ISO 17636-2:2013, Figure 21 and 7.6) shall be complied with. Only in case of a test arrangement according to ISO 17636-2:2013, Figure 5, a reduction in the minimum distance focal spot — test object up to 40 % is approved for testing class B.
- l) The  $SNR_N$  in the area to be evaluated (weld material and base material) shall be complied with in accordance with ISO 17636-2:2013, Table 3.
- m) When testing with DDA or rigid (planar) cassettes, the minimum distance between the radiation source and object (f) shall be increased. For this purpose, equations (3) and (4) according to ISO 17636-2 shall be used for calculation instead of the nomogram (see ISO 17636-2:2013, Figure 21) or equations (1) and (2).
- n) At a local dose rate  $> 10$  mSv/h in the test area, a potential increase in the grey value in the digital image by non-imaging radiation based on a test exposure with the same detector shall be performed. The grey values of the digital radiography shall be increased by this determined value. The percentage of grey value increase by the radiation of the test object should not be greater than 25 % of the mean grey value in the area to be evaluated.
- o) The tested areas shall be assigned uniquely to the test object and the test area based on the identification. The weld identification shall be exposed using numbers and letters from absorbing material.
- p) In the case of internally and externally processed welds, the weld seam progression shall be identified with markings on both sides next to the area to be evaluated. The markings shall be applied on both sides of the test object at the same distance to the weld centre.

### 7.3 Finalisation measures

Auxiliary materials attached to the test object (e.g. adhesive tapes, labels) shall be removed to not leave a trace.

If necessary, the test surfaces shall be cleaned after completing the radiographic testing.

### 7.4 Evaluation

#### 7.4.1 Verification of the data in the test report

The data contained in the test report and possibly in the film sleeves concerning the test object and test system shall undergo a plausibility test based on the documents before beginning the evaluation.

#### 7.4.2 Film evaluation at the illuminator

The evaluation of the radiographic films comprises the following steps:

- a) Checking the film identification and assignment to the test object;
- b) Checking the radiographs for plausibility in respect to the test parameters indicated in the test report (e.g. radiation source, test arrangement, film type, film system class, film processing flaws);
- c) Determination of the evaluation areas, completeness, overlapping of the test areas to be evaluated, restrictions to the evaluation (e.g. shape indications from top bead and root, glare due to excessive contrast);
- d) Description of the indications according to ISO 6520-1;

- e) Assessment of the indications;
- f) Comparison with test reports and with records of previous radiographic tests. By signing at the bottom of the test report, the evaluator confirms that these analysis steps are performed and recorded;
- g) Archiving.

#### 7.4.3 Analysis with image processing system

The digital radiographic images are analysed using the test reports, in which the recording parameters of the radiographic images and the digitisation parameters (e.g. resolution, exposure level) are indicated. The analysis at the monitor shall be conducted in a darkened room and comprises the following steps:

- a) The digital radiographic images are checked for possible artefacts at the monitor based on an overview image before applying image processing procedures. The following shall be ensured:
  - 1. the complete coverage of the test area to be analysed in the available grey value range of the digital image (no clipping by saturation or undermodulation),
  - 2. sufficient cover of bright areas of the radiographic image outside the evaluation area to prevent glaring,
  - 3. verification of the evaluation areas in the overview image in respect to completeness of the overlapping and in respect to restrictions in the evaluation capacity;
- b) determination of the areas to be evaluated;
- c) analysis of the digital or digitised exposure by
  - 1. visualisation of the radiographic indication with optimisation of contrast, brightness and zooming factor,
  - 2. application of image processing procedures, for example high-pass filtering, edge enhancement, pseudo-plast filtering, averaging, addition and subtraction of image contents, for presentation of the indication shape,
  - 3. quantitative description (measurement) of the radiographic indication based on grey value profiles transverse to the indication by the contrast and half-width in the area of the indication maximum and at further points along an extended indication. An integration vertical to the profile direction may be implemented for noise suppression. Determination of the indication length as registration length above a contrast threshold value. This threshold value shall be indicated;
- d) Description of the indications according to ISO 6520-1;
- e) Assessment of the indications;
- f) Printout of the image visualisations relevant to the indication assessment. Measuring tape and identification shall be provided on the overview image;
- g) Comparison with test reports and with radiographic records of previous radiography tests.
- h) By signing at the bottom of the test report, the evaluator confirms that these analysis steps are performed and recorded;
- i) Archiving.

#### 7.4.4 Assessment of indications

The assessment of indications shall be conducted corresponding to the specifications of the applicable national safety standards.

#### 7.4.5 Measures in case of unclear assessment of indications

If a unique assessment of the indications is not possible, measures shall be introduced, e.g.:

- a) Change to the exposure conditions (e.g. radiation direction, tube voltage, focal spot, film system class, screen thickness);
- b) Use of image processing;
- c) Use of other testing methods.

## 8 Recording

### 8.1 General

The recording shall include the control sheet of the film processing (8.2), the test report (8.3), also in the case of digital radiography the test report concerning analysis with the image processing system (8.4), as well in case of findings the findings record (8.5).

The test documentation should also be backed up in digital form in addition to paper form.

### 8.2 Control sheet for the film processing

A record with the data according to Annex B shall be used.

### 8.3 Test record and test report

A test record or test report shall be compiled concerning the testing. The following data shall be included as a minimum:

- a) Date of the testing;
- b) Name of the power station;
- c) Test basis (standard test procedure);
- d) Test object, test scope and test section;
- e) Location of the test section (reference point, coordinates);
- f) Surface state (e.g. ground);
- g) Test system;
  - 1. Test arrangement,
  - 2. Radiation source (type and serial number),
  - 3. Focal spot size or gamma source size,
  - 4. FDA,
  - 5. Tube voltage and current or type and activity of the radiation source,
  - 6. Exposure time,
  - 7. Film format, film type, film system class, screen type and screen thickness, or
  - 8. Digital detector, screens and filters, basic spatial resolution of the detector corresponding to the reference exposure,

- i) for CR: Parameters of the scanning system e.g. pixel size, scanning speed, gain setting, laser intensity, laser spot size;
  - ii) for DDA: Gain, single image exposure time (frame time), number of image integrations (frame number), pixel size, basic spatial resolution, calibration method;
- 9. Scattered radiation filter;
  - 10. Type and location of the image quality indicators,
  - 11. Minimum number of exposures,
  - 12. Zero point location on the test object;
- h) Film location plan or detector location plan (insofar as available);
  - i) min./max. of the optical density or the min./max.  $SNR_N$  values for CR and DDA or the min./max. grey values for CR in the area to be analysed;
  - j) Required and achieved image quality value;
  - k) Validation concerning the position of the radiation source and marking of the test area according to 4.3.2;
  - l) Deviations from the specifications of the standard test procedures;
  - m) Test result with designation according to ISO 6520-1:
  - n) Findings record, if necessary;
  - o) Results comparison with the previous test;
  - p) Name of the inspection body;
  - q) Place, date, name, signature, certificate number of the test inspectors or the test team leader, the image evaluators and test supervisors of the operating agency or the test company commissioned by him and the responsible third party.

#### 8.4 Test report concerning analysis with the image processing system

In the case of digital radiography, the analysis with the image processing system shall be described with the following data in addition to the record/test report (see 7.3):

- a) Device systems used;
- b) Device parameters (e.g. resolution, exposure level);
- c) Results checking of the monitor settings;
- d) Overview visualisation of the digital radiographic image with measuring tape and identification;
- e) Visualisation of the examined areas containing the detected indications (each with documentation of the image processing procedures used according to 5.5.3).

#### 8.5 Findings record

A findings record (see Annex D) shall be compiled in the case of findings. The findings record can consist of a drawing and shall be able to recognise the position of the findings in respect to the tested components, the relevant measuring tape positions and lengths of the findings. In addition supplementary data, e.g. operating parameters, results of additional tests, data on the weld, should be indicated in the findings record. The findings record shall be signed by the test supervisor.



## Annex A (normative)

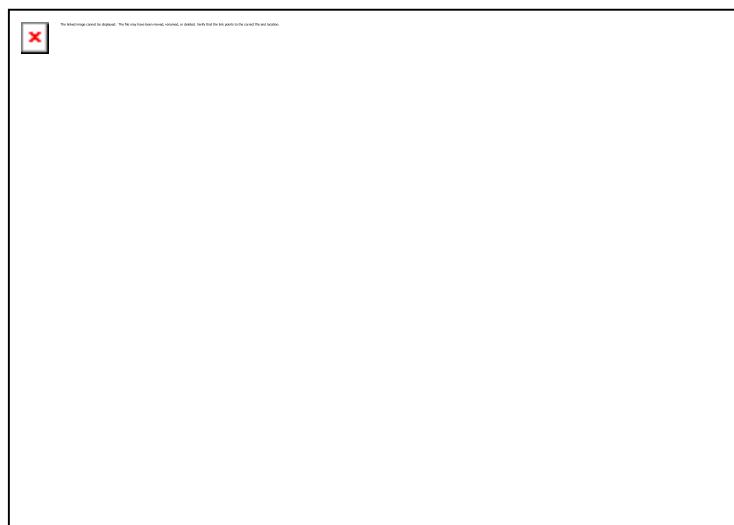
### Position Test Indicator

#### A.1 Use of measuring tapes with position test indicators

When using position test indicators, the position of the radiation source is documented, thus ensuring the reproducibility. The measuring tapes with lead numbers and position test indicators shall be positioned outside the area to be analysed. In case of girth welds, the straight side not curved in the pipe longitudinal direction (e.g. facing away from the bend) shall be selected. If there is no sufficiently long straight area next to the weld, the determination of the position of the radiation source via position test indicators shall be omitted. If position test indicators are not used, the position of the radiation source shall be recorded by the test supervisor in order to ensure reproducibility.

When testing girth welds, the measuring tape with the position test indicators and lead numbers for marking positions of the test area for all exposures shall be left unchanged on the test object. The measuring tape shall be recognisable on all records with at least two lead numbers and several position test indicators at the edge of every exposure (see Figure A. 1).

For pipes smaller than DN 150, a measuring tape without position test indicators can be used for exposures according to the test arrangements Figure 1 or Figure 2.



#### Key

- 1 Girth weld to be tested
- 2 Measuring tape
- 3 Position test indicator
- 4 Lead numbers

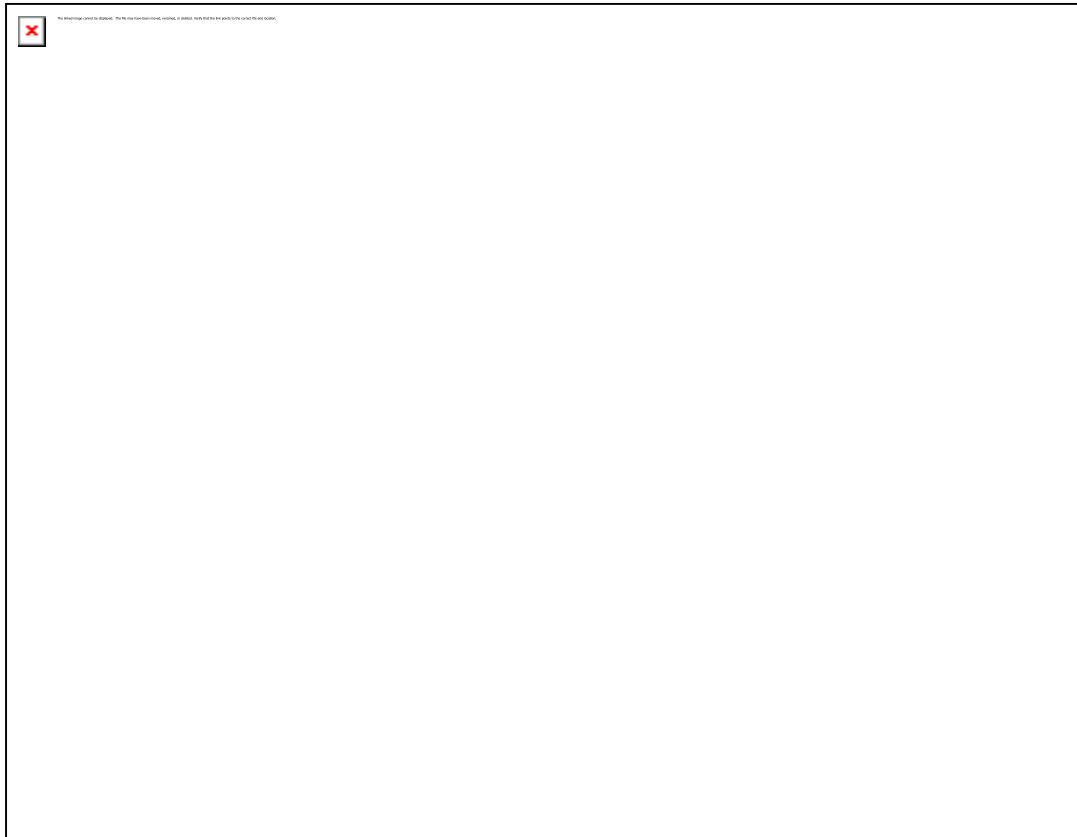
**Figure A.1 — Measuring tape with integrated lead numbers for marking the testing area and with position test indicators for checking the position of the radiation source**

The lead numbers shall be located in the measuring tape at equal distances (2-cm, 5-cm or 10-cm-division), whereby the position test indicators are located between these. These position test indicators should be located at a distance of 2 cm, 2.5 cm or 3.33 cm. The length of the measuring tapes shall correspond to the tube circumference. An overlapping of measuring tape areas is not approved.

The templates according to section A.5 shall be used for analysis of the radiation position. It can be used to determine the distance  $A'$  from the vertical inclination point of the radiation to the position test indicator. The

radiograph can be used to determine the distance  $a$  from the position test indicator to the weld seam centre. As a result, the amount of the angular deviation between the radiation direction and the vertical (permissibility limit) can be determined according to Figure 1 or Figure 2 (see Figure A.2). The maximum angular deviation may not exceed  $5^\circ$ . If working with larger deviations due to the geometry, the measured value  $A$  shall be recorded. The angular deviation shall be calculated according to the equation (A.1).

$$\alpha = \arctan\left(\frac{A}{FDA}\right) \tag{A.1}$$



**Key**

- 1 Girth weld
- 2 Film
- 3 Measuring tape
- 4 Position test indicator
- 5 Lead numbers
- 6 Radiation source

**Figure A.2 — Acceptance limit for the position of the radiation source according to Figure 1 and Figure 2**

The maximum accepted distance of the radiation source position from the vertical is calculated according to Figure A.6 and according to equation (A.2), which results for  $\alpha_{\max} = \pm 5^\circ$  from equation (A.1).

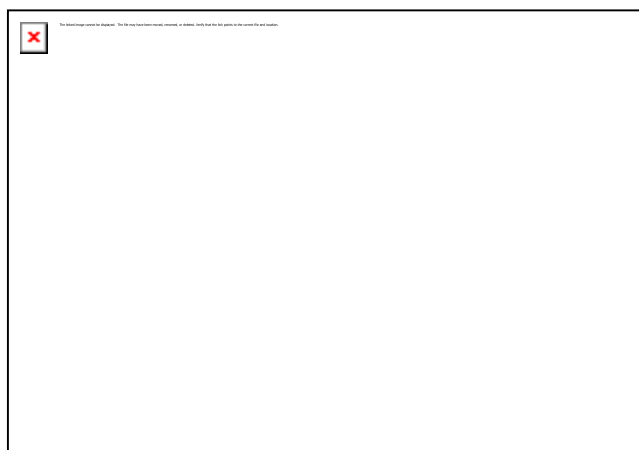
$$A_{\max} = \pm 0,087 \cdot FDA \tag{A.2}$$

**A.2 Composition of the position test indicators**

A position test indicator (BAM snail) according to Figure A.3 consists of a snail-shaped rolled lead foil with a distance foil between the windings of the lead. The application areas and associated dimensions of the position test indicators are shown in Table A.1. The distance  $s$  between the windings of the lead foil shall be defined in relation to the height  $h$  of the position test indicator. The ratio  $h/s = 11.5 \pm 2$  shall be complied with here.

Table A.1 — Dimensions and application areas of the position test indicators

Application area	Height of the position test indicator $h$ mm	Diameter $d_s$ mm	Lead foil thickness $d_f$ $\mu\text{m}$
X-rays 100 kV — 160 kV penetrated thickness $\leq 20$ mm	0.9 to 1.5	5 to 10	20 to 60
X-rays 160 kV — 250 kV penetrated thickness > 20 mm Se-75 penetrated thickness < 20 mm	1.8 to 2.5		50 to 100
Se-75, Ir-192 penetrated thickness $\geq 20$ mm	> 2.5		100 to 200

**Key**

- 1 Lead foil thickness  $d_f$
- 2 distance foil (paper)

Figure A.3 — Principle composition of the position test indicator (BAM snail)

**A.3 Evaluation of the positioning of the radiation source for planar test objects**

In case of planar test objects, the position test indicators or the measuring tapes described in section A.1 shall be positioned outside the area to be tested. Here diameter-like indications are formed imaging the position test indicators in the radiographs. According to Figure A.4, the point of the vertical incidence of the central beam is determined by the intersection point of the vertical to the diameter-like markings.



**Key**

- 1 Point of the vertical incidence of the central beam (vertical inclination point)

**Figure A.4 — Determination of the point of the vertically incident central beam on the radiograph of planar test objects**

**A.4 Analysis of the positioning of the radiation source with templates for girth welds (cylindrical test objects)**

The measurement of the vertical incidence of the central beam is based on the application of special templates that are placed on the radiograph, in the case of cylindrical test objects. Figure A.5 shows a template for analysis of the snail mappings (not true to scale). This template (transparent) is placed over the radiograph on the illuminator according to Figure A.6 so that the pattern of the template and the mapping of the measuring tape correspond to the integrated position test indicators according to Figure A.1. The deviation A (see Figure A.2) can then be read off. A template is required for every set FDA and pipe outer diameter.

The templates contain circles with drawn diameter markings. These diameter markings shall be made to correspond with the diameter-like markings on the position test indicators and mapping of the exposure according to Figure A.6. The distance A' from the point of the vertical incidence of the central beam (vertical radiation inclination point) can be read off on the template.

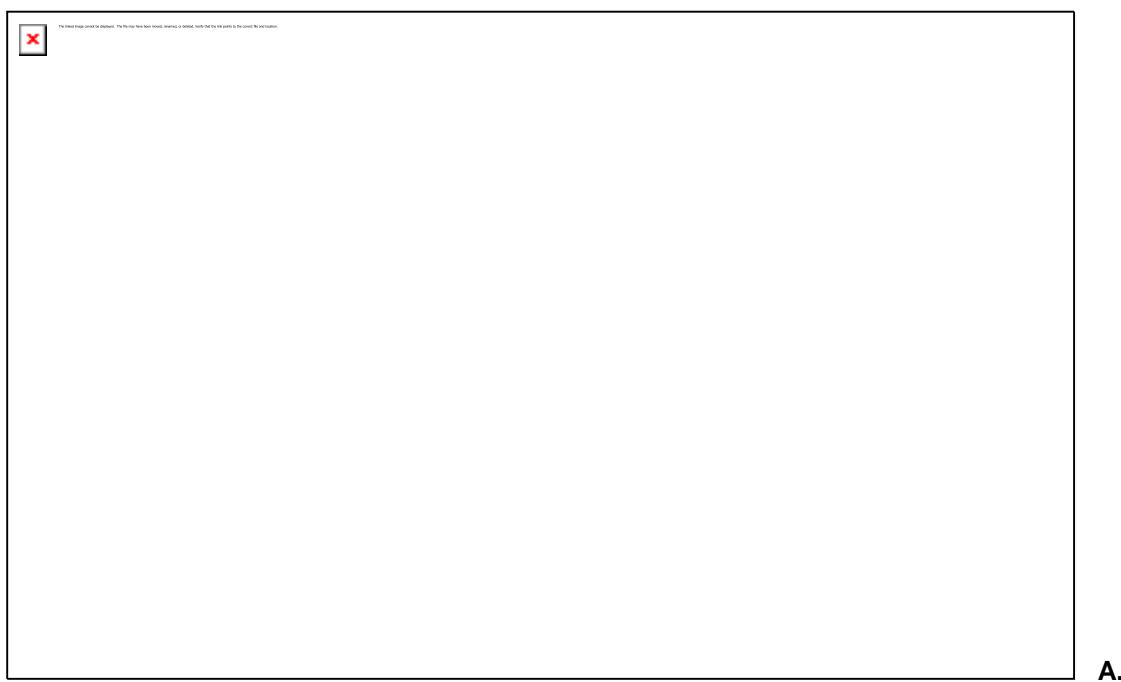
The angles  $\delta$  of the individual diameter markings of the template are calculated according to equation (A.3):

$$\delta = 90^\circ \left\{ \frac{|u|}{u} + \frac{2}{\pi} \cdot \arctan \left[ \frac{w}{\left( \frac{D_a}{2} - FDA \right) \cdot \sin \left( \frac{2u}{D_a} \right)} \right] \right\} \tag{A.3}$$

Whereby

- $u$  is the distance from the snail centre point of the vertical inclination point in the direction of the circumference;
- $w$  is the distance from the snail centre point of the vertical inclination point in the direction of the pipe longitudinal axis.

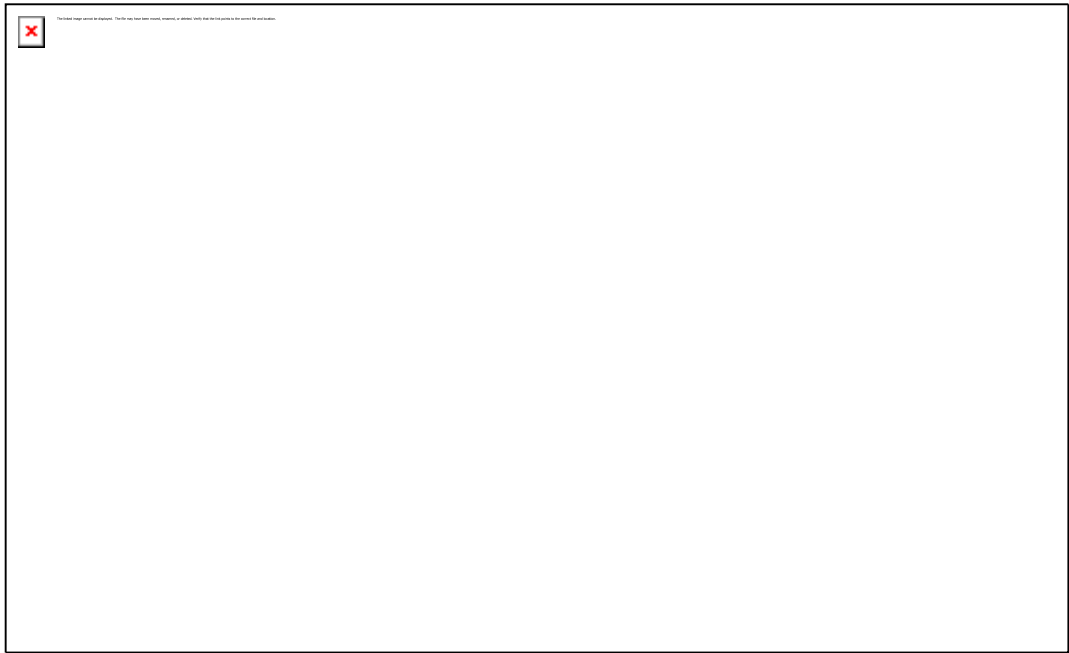
**NOTE** A program for calculating and printing templates (analysis sheets) is available from the BAM Federal Institute for Materials Research and Testing in D-12205 Berlin, Unter den Eichen 87, Division 8.3.

**Key**

Y Distance A' of the vertical inclination point to the snail row, mm

X Longitudinal position, mm

**Figure A.5 — Example of an analysis template for determination of the distance A' according to Figure A.6**



**Key**

X Longitudinal position, mm

**Figure A.6 — Example of the analysis for the mapping of measuring tapes with position test indicators. This is realised by locating the template. Here the vertical inclination point of the central beam is determined to be 30 mm below the position test indicator at tape position 25**

Annex B
(normative)
Control sheet for film processing control

Film processing control according to ISO 11699-2

Table with columns for parameters like Location, Time, Date, and various film processing metrics such as Fog D0, Sensitivity index Sx, Contrast index Cx, and Fixing bath. The table includes checkboxes for different development methods and specific measurement requirements.





## **Annex C** (normative)

### **Reference exposure for qualification of the test equipment, test arrangement and exposure conditions**

A reference exposure is used to validate the required image quality, in order to determine the correct selection and function of the radiation source, the detector (film, film scanner or digital detector) as well as the selected test arrangement (FDA, image quality test indicators etc.) and parameters (kV, mAmin, pixel size, basic spatial resolution ( $SR_b^{\text{detector}}$ ) of digital detectors and in case of film digitisation).

For this, a reference record shall be compiled with a tube of the same design, same type and same focal spot, as well as with a detector of the same design and same type as for the planned in-service test. The image quality shall be validated in accordance with ISO 17636-1:2013, Annex B (Checking contrast sensitivity with wire or step-hole IQI), and in accordance with ISO 17636-2:2013 Table B.14 (Checking the unsharpness with duplex-wire IQI), for film exposures. For the film digitisation or use of digital detectors, the image quality according ISO 17636-2:2013, Annex B, (single wire and duplex wire detection) shall be verified in the digital images.

To perform the reference exposure, two steel plates (austenitic or ferritic steel corresponding to test assignment) shall be used, which are larger than the detector and whose thickness corresponds to the wall thickness to be tested on the test object ( $\pm 10\%$ ).

**NOTE** Instead of the steel plates, a pipe with comparable dimensions (wall thickness and diameter) of the test object ( $\pm 10\%$ ) can also be used. The duplex wire IQI should be located internally parallel to the tube axis. Two exposures with the detector rotated by  $90^\circ$  should be made for this.

On the first plate (close to detector), image quality test indicators (type: wire and duplex-wire according to ISO 19232-1 and ISO 19232-5) according to Figure C.1 and C.2 shall be located close to the source. In the case of a reference exposure for double-wall radiography, a second plate shall be placed over this close to the source. Two wire and duplex-wire IQIs each shall be used offset by  $90^\circ$ , whereby the wires shall be oriented to the row and column direction of the pixels rotated by  $2^\circ$  to  $5^\circ$  when using digital detectors or film digitisation. Instead of a radiographic exposure with four IQIs each, two exposures with the detector rotated by  $90^\circ$  each with a wire and duplex wire IQI can also be made.

The requirements for the test system, arrangement and conditions are complied with if the wire detection is achieved for film exposures according to ISO 17636-1:2013, Annex B, (Contrast sensitivity) and according to ISO 17636-2:2013, Table B.14, (unsharpness) and in case of digital images according to DIN EN ISO 17636-2:2013, Annex B, (contrast sensitivity, unsharpness). Only then are the test system and arrangement as well as the test conditions regarded as qualified for use.

The documentation includes:

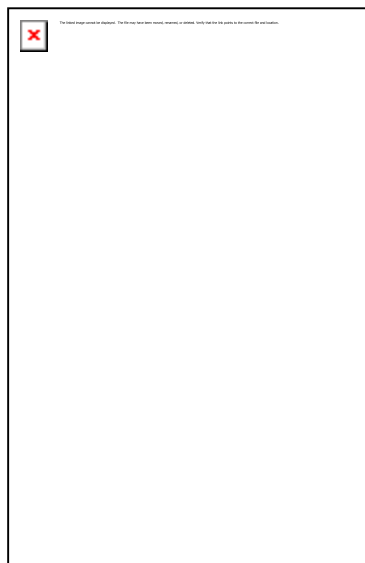
- a) Films or digital images (see example image C.3);
- b) Photograph of the reference exposure setup;
- c) Tube type, and exposure settings
  1. Focal spot size,
  2. FDA,
  3. Test plate thickness and material (or pipe wall thickness, diameter and material),

4. Tube voltage,
  5. Tube current,
  6. Exposure time;
- d) Detector
1. Film type, film system class,
  2. Developer, immersion time, developer temperature,
  3. Imaging plate type,
  4. Imaging plate scanner,
  5. Imaging plate scan data (pixel size, scan time, laser intensity, gain, LUT),
  6. Digital detector array type and exposure parameters,
  7. Digital detector array calibration data or calibration conditions;
- e) Required and achieved wire and duplex-wire number;
- f) Required and achieved optical density of the film;
- g) Required and achieved grey values or  $SNR_N$  at CR;
- h) Required and achieved  $SNR_N$  in case of digital detector arrays;
- i) Date, company, inspector.

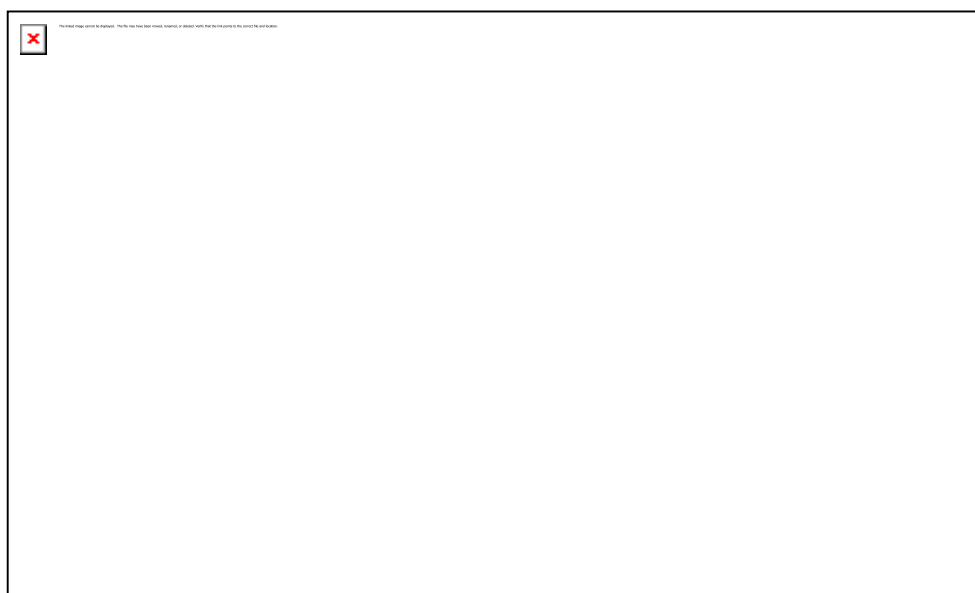
Tube voltages are to be set for radiographic testing, which are equal to or less than the tubes voltages used for the reference exposure, whereby the limit data according to ISO 17636-1 shall be complied with in the case of film exposures.

Film radiographs shall achieve the minimum value of the optical density according to ISO 17636-1. If the reference exposure exhibits a value for the optical density  $> 2.7$ , this value shall be complied with as a minimum value.

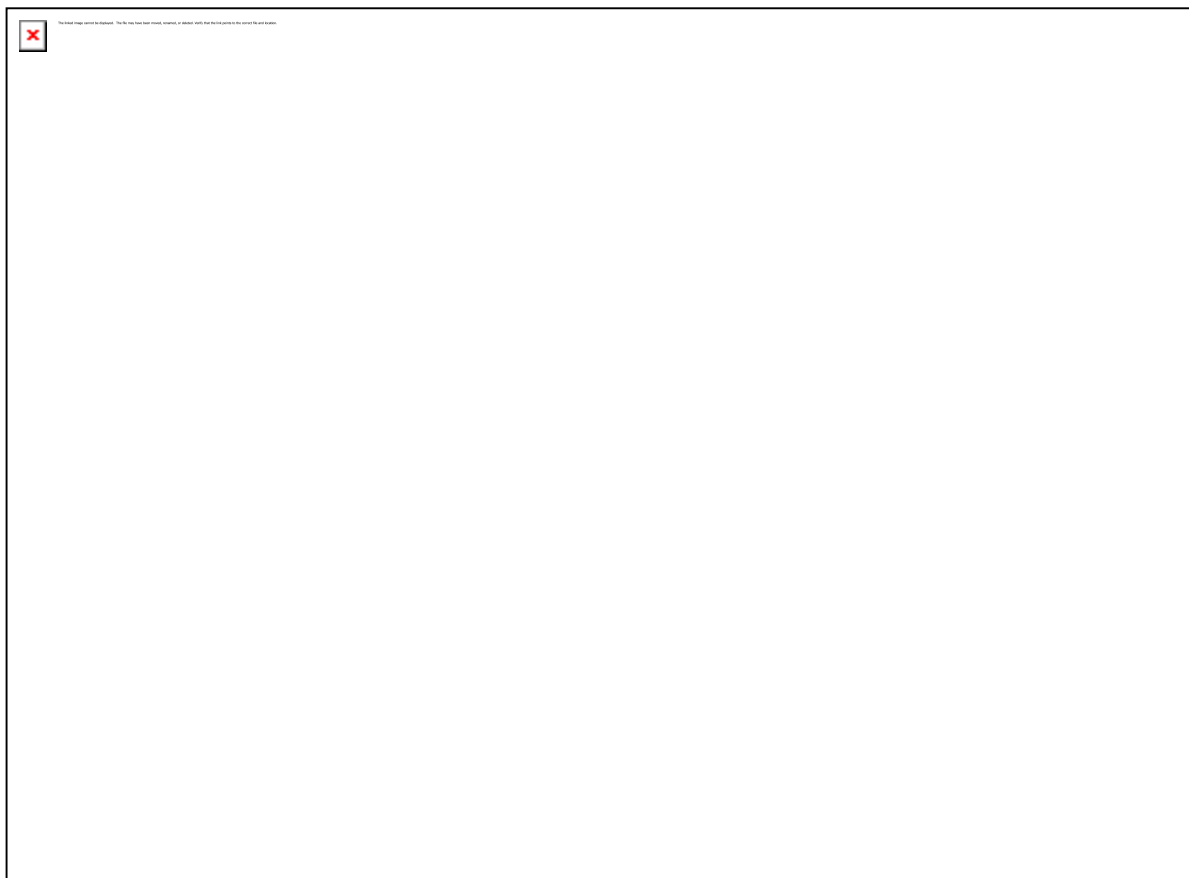
Digital radiographic images shall exhibit an  $SNR_N$  greater than or equal to the requirements according to ISO 17636-2. If these have a greater value than required according to ISO 17636-2, this  $SNR_N$  shall be complied with as a minimum value if it is at least 20 % higher than the value required according to ISO 17636-2. In the case of CR records, the mean grey value in the centre of the reference value record can be used for the in-service test as a minimum value instead of the minimum  $SNR_N$ , if the required  $SNR_N$  was achieved in the reference record.



**Figure C.1 — Example of the arrangement of the image quality test indicators on the first steel plate and for performing a reference exposure**



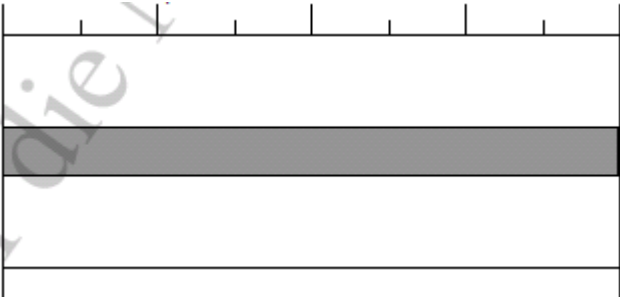
**Figure C.2 — Extract from Figure C.1**



**Figure C.3 — Example of a reference exposure with four image quality indicators**

**Annex D**  
(informative)

**Findings Record**

Plant	<b>Findings record</b>	Record no. Page of
Operating temperature/°C	Plant part	Test procedures
Operating pressure/bar	Identification system for power plants (AKZ/KKS)	Test time point
Material	Isometry no./Drawing no.	Test object
Dimensions (D <sub>a</sub> , t)/mm	Designation of the test point	Testing method
Surface state external	Test area	Test implementation as per
Surface state, internal	Status at the test date (empty/filled)	Evaluation of the test results as per
Indication determined in total <sup>b</sup>	Findings (indication size above evaluation limit) <sup>b</sup>	See also NDT test report no.
<p>Weld handling (top view, not to scale)</p> <div style="display: flex; align-items: flex-start;"> <div style="margin-right: 20px;"> <p><sup>a</sup> Pipe</p> <p>Elbow</p> <p>Fitting</p>   <p>Root area</p> </div>  </div> <p style="margin-left: 150px;"><sup>a</sup> Pipe</p> <p style="margin-left: 150px;">Elbow</p> <p style="margin-left: 150px;">Fitting</p> <p style="margin-left: 150px;">0 →</p> <p style="margin-left: 150px;">Dimension in circumference/ longitudinal direction (mm)<sup>a</sup></p>		
	Findings no.	
	Location	
	Type <sup>b</sup>	
	Location (mm)	
<b>Comments, supplementary notes on the findings description:</b>		
<sup>a</sup> Delete what is not applicable	Place, date	Place, date
<sup>b</sup> Designation according to ISO 6520-1	Signature (operating agency)	Signature (third party)

## Annex E (informative)

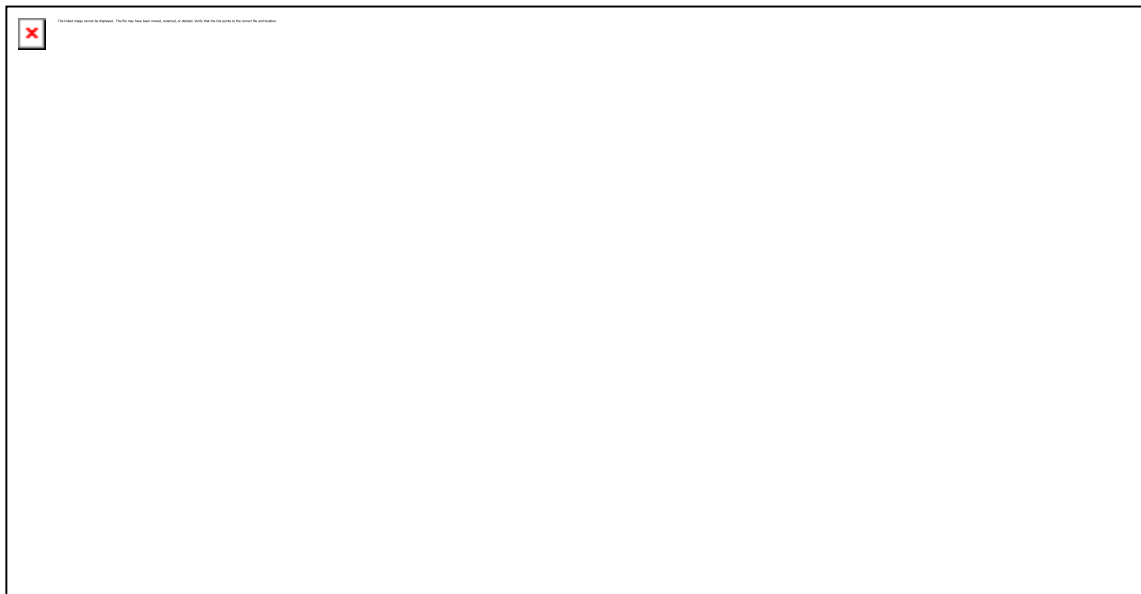
### Coordinate System for Welds

Girth welds (RN) and longitudinal welds (LN) of piping

Zero point: in case of girth welds: (horizontal pipe section) 12:00 o'clock position,  
in case of girth welds: (vertical pipe section) in direction of flow extended 12:00 o'clock position  
of the previous horizontal pipe section,  
in case of longitudinal welds: on T-joint with girth weld.

X dimension: in case of girth welds: measured from the zero point clockwise, viewed in direction of flow,  
in case of longitudinal welds: measured in direction of flow.

Y dimension: measured from the weld centre.



#### Key

- 1 Zero point for longitudinal weld
- 2 Marker of the zero point for girth weld
- 3 Direction of flow
- 4 Zero point for girth weld
- 5 Line of vision = Direction of flow

Figure E.1 — Coordinate system for welds

## Annex F (informative)

### Control Sheets for Test Preparation

#### F.1 Checklist for radiographic testing (testing class B-NF)

General specifications: <span style="float: right;">e.g. test procedures</span> In case of local restrictions, the further procedure with O and A shall be determined. All deviations shall be explained and documented below.	Completed		Control steps																																	
1. Test object: AKZ: <span style="margin-left: 100px;">Isometry:</span> <span style="margin-left: 100px;">Weld no.:</span> Dimensions: <span style="margin-left: 100px;">Material:</span> <span style="margin-left: 100px;">Test area:</span>	Respon sible	Comple ted	Tested O	Tested A																																
<b>2. Specifications for testing:</b> Test as per: <span style="margin-left: 100px;">Film type:</span> <span style="margin-left: 100px;">Film format:</span> Recording setup/Image: <span style="margin-left: 100px;">Screen type:</span>	S																																			
<b>3. Test implementation</b> <b>3.1 Control, accessibility and preparation of the test object</b> <b>3.2 Control, identification, zero point</b> <input type="checkbox"/> present <span style="margin-left: 100px;"><input type="checkbox"/> marked with</span> <span style="margin-left: 100px;"><input type="checkbox"/> newly suggested</span> <b>3.3 Applying the identification of the test area</b> <input type="checkbox"/> with measuring tape <span style="margin-left: 100px;"><input type="checkbox"/> by lead numbers (distance)</span> <b>3.4 Shielding against scattered radiation</b> <input type="checkbox"/> present <span style="margin-left: 100px;"><input type="checkbox"/> extended</span> <b>3.5 Films/Screens used</b> Type and location of the IQI <span style="margin-left: 100px;"><input type="checkbox"/> Close to film</span> <span style="margin-left: 100px;"><input type="checkbox"/> Far from film</span> <b>3.6 Wall thickness in the test area</b> <input type="checkbox"/> measured (mm) <input type="checkbox"/> according to drawing <table style="margin-left: 100px; margin-top: 10px;"> <tr> <td style="border: none;">Location</td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> <td style="border: 1px solid black; width: 20px;"></td> </tr> <tr> <td style="border: none;">before SN</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: none;">on SN</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> <tr> <td style="border: none;">after SN</td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> <td style="border: 1px solid black;"></td> </tr> </table> <b>3.7 Radiation source</b> Type: <span style="margin-left: 100px;">KV/Activity:</span> Focal spot: <span style="margin-left: 100px;">mm</span> <b>3.8 Distance f or FDA (mm):</b> <span style="margin-left: 100px;">f=</span> <span style="margin-left: 100px;">FDA=</span> <input type="checkbox"/> as specified <span style="margin-left: 100px;"><input type="checkbox"/> fallen below on account of</span> <b>3.9 Exposure time:</b> <span style="margin-left: 100px;">min</span>	Location								before SN								on SN								after SN								S S S I I I I I			
Location																																				
before SN																																				
on SN																																				
after SN																																				
<b>4. Positioning of the radiation source ≥ DN 150</b> <b>4.1 Maximum angular deviation (<math>\alpha_{max}</math> 5°) from the vertical</b> <span style="margin-left: 100px;"><input type="checkbox"/> complied with</span> $A_{max} = \pm 0.87 \cdot FDA$ <span style="margin-left: 100px;"><input type="checkbox"/> exceeded</span> <b>4.2 Documented with photo</b> <span style="margin-left: 100px;"><input type="checkbox"/></span>	S																																			
<b>5. Film processing</b> <b>5.1 Checks for the film processing by the test company (as per DIN EN ISO 11699-2)</b> <input type="checkbox"/> Checking the film processing <span style="margin-left: 100px;">State of the equipment:</span> <input type="checkbox"/> Check for archiving capacity <span style="margin-left: 100px;"><input type="checkbox"/> o.k..</span> <input type="checkbox"/> Check for the opt. density of the fog <span style="margin-left: 100px;"><input type="checkbox"/> Measures required</span> <b>5.2 Processing the film</b> <input type="checkbox"/> Free of disturbing film flaws <span style="margin-left: 100px;"><input type="checkbox"/> achieved IQI value:</span> <input type="checkbox"/> opt. density complied with <span style="margin-left: 100px;"><input type="checkbox"/> indications</span>	I  S																																			
<b>6. Checking the film exposure</b> <input type="checkbox"/> Identification complete and correct <span style="margin-left: 100px;"><input type="checkbox"/> Exposures can be used without restrictions</span> <input type="checkbox"/> Test area fully mapped <span style="margin-left: 100px;"><input type="checkbox"/> Requirements not fulfilled, new exposures necessary</span> <input type="checkbox"/> Overlapping sufficient <input type="checkbox"/> Image quality achieved <span style="margin-left: 100px;"><input type="checkbox"/> Supplementary exposures necessary</span> <input type="checkbox"/> Permissible opt. density in the entire range	S																																			
<b>7. Special notes, deviations, diagrams of the test situation:</b>  I inspector    S Test supervisor    O Operating agency    A third party	Test date: Signature I: Signature S: Signature O: Signature A:																																			

F.2 Checklist for radiographic testing (testing class B-ND)

General specifications: e.g. test procedures In case of local restrictions, the further procedure shall be determined with O and A. All deviations shall be explained and documented below.	Completed		Control steps																													
1. Test object: AKZ: Isometry: Weld no.: Dimensions: Material: Test area:	Respon- sible	Comple- ted	Tested O	Tested A																												
<b>2. Specifications for testing:</b> Test as per: Detector: Recording setup/Image: Image format: Filter:	S																															
<b>3. Test implementation</b> <b>3.1 Control, accessibility and preparation of the test object</b> <b>3.2 Control, identification, zero point</b> <input type="checkbox"/> present <input type="checkbox"/> marked with <input type="checkbox"/> newly suggested <b>3.3 Applying the identification of the test area</b> <input type="checkbox"/> with measuring tape <input type="checkbox"/> by lead numbers (distance) <b>3.4 Shielding against scattered radiation</b> <input type="checkbox"/> present <input type="checkbox"/> extended <b>3.5 Metal filter used</b> Type and location of the IQI <input type="checkbox"/> close to detector <input type="checkbox"/> far from detector <b>3.6 Wall thickness in the test area</b> <input type="checkbox"/> measured (mm) <input type="checkbox"/> according to drawing <table border="1" data-bbox="619 902 1070 1003"> <thead> <tr> <th>Location</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> </tr> </thead> <tbody> <tr> <td>before SN</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>on SN</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>after SN</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <b>3.7 Radiation source</b> Type: KV/Activity: Focal spot: mm <b>3.8 Distance f or FDA (mm):</b> f= <input type="checkbox"/> as specified <input type="checkbox"/> fallen below on account of min	Location							before SN							on SN							after SN							S S S I I I I I I			
Location																																
before SN																																
on SN																																
after SN																																
<b>4. Positioning of the radiation source ≥ DN 150</b> <b>4.1 Maximum angular deviation (<math>\alpha_{max}</math> 5°) from the vertical</b> <input type="checkbox"/> complied with $A_{max} = \pm 0.87 \cdot FDA$ <input type="checkbox"/> exceeded <b>4.2 Documented with photo</b> <input type="checkbox"/>	S																															
<b>5. Image processing</b> <b>5.1 Checks of the image processing</b> <input type="checkbox"/> Documentation of the image processing <input type="checkbox"/> Detector calibration <input type="checkbox"/> Checking the monitor settings State of the equipment: <input type="checkbox"/> o.k.. <input type="checkbox"/> Measures required <b>5.2 Checking the raw data</b> <input type="checkbox"/> Free of disturbing image artefacts <input type="checkbox"/> SNR <sub>N</sub> and SR <sub>b</sub> <sup>image</sup> complied with <input type="checkbox"/> achieved image quality value: <input type="checkbox"/> indications	I S																															
<b>6. Checking the radiographic images</b> <input type="checkbox"/> Identification complete and correct <input type="checkbox"/> Test area fully mapped <input type="checkbox"/> Overlapping sufficient <input type="checkbox"/> Image quality achieved <input type="checkbox"/> Permissible grey values or SNR <sub>N</sub> in the entire analysed range <input type="checkbox"/> Images can be used without restrictions <input type="checkbox"/> Requirements not fulfilled, new exposures necessary <input type="checkbox"/> Supplementary exposures necessary	S																															
<b>7. Special notes, deviations, diagrams of the test situation:</b>  I inspector    S Test supervisor    O Operating agency    A third party	Test date: Signature I: Signature S: Signature O: Signature A:																															



## Bibliography

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