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Non-destructive testing — Radiographic testing — Determination of the size of industrial radiographic gamma sources

Essais non destructifs — Contrôle radiographique — Détermination de la dimension des sources de radiographie industrielle gamma

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee CEN/TC 138, *Non-destructive testing* (as EN 12679:2018) and was adopted (without modification other than that (those) given below) by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiographic testing.*

The main changes are as follows:

— revised definitions 3.1, 3.3 and 3.4;

— deleted definition 3.5;

— added Formula (1) defining the geometrical magnification factor;

— updated figures;

— editorial corrections.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Non-destructive testing — Radiographic testing — Determination of the size of industrial radiographic gamma sources

1 Scope

This document specifies a test procedure for determination of the size of industrial radiographic gamma sources of 0,5 mm or greater, made from the radionuclides Iridium 192, Ytterbium 169, Selenium 75 or Cobalt 60, by a radiography method with X-rays. The source size of a gamma radiation source is an important factor which affects the image quality of gamma ray images.

The source size is determined with an accuracy of ±10 % but typically not better than ±0,1 mm.

The source size is provided by the manufacturer as the mechanical dimension of the source insert. A measurement can be required if the manufacturing process is validated or monitored after implementation of the source into the holder.

This document can be used for other radionuclides after validation.

The standard test method ASTM E1114 provides further information on the measurement of the Ir-192 source size, the characterization of the source shape, and its correct assembly and packaging.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ASTM E 2002 - 22, *Standard Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy*

ASTM E 2597/2597M - 22, *Standard Practice for Manufacturing Characterization of Digital Detector Arrays*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
source size
d
maximum dimension of the gamma radiation source

3.2
signal-to-noise ratio
SNR
ratio of mean value of the linearized grey values to the standard deviation of the linearized grey values (noise) in a given region of interest in a digital image

3.3
normalized signal-to-noise ratio
SNR_N
signal-to-noise ratio (3.2) as measured directly in the digital image and normalized by the basic spatial detector resolution, SR_b^{detector}

$$SNR_N = SNR \cdot \frac{c}{SR_b^{\text{detector}}}$$

where

c is a constant (0,088 6 mm);

SR_b^{detector} is the basic spatial detector resolution, in mm.

3.4
basic spatial detector resolution
SR_b^{detector}
smallest degree of visible detail within a digital image, determined, with the duplex wire Image Quality Indicator *(*IQI) according to ISO 19232-5 or ASTM E 2002 located on the detector (Magnification = 1), from the smallest number of the duplex wire pair with less than 20 % modulation depth in a linearized profile, which corresponds to ½ of the inherent detector unsharpness

4 Test procedure

4.1 Test alignment

The X-ray tube shall be placed at a minimum focus-detector-distance of 700 mm for focal spot sizes below 1 mm. The film system class should be at least C3.

The film or the digital detector shall be placed perpendicular to the axis of the central X-ray beam. The gamma source shall be placed on the axis between the X-ray source and the film or digital detector. The gamma source to detector distance *b* shall be 10 % to 20 % of the X- ray source to detector distance, a + b, see Figure 1.

A geometrical magnification factor v is introduced in Formula (1):

$$v = \frac{d'}{d} = \frac{a+b}{a} \quad (1)$$

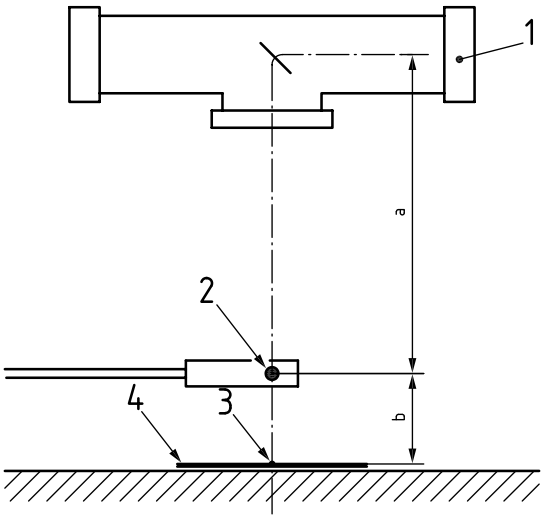
where

d is the diameter of the gamma radiation source, in mm;

d' is the projected size *d'*, in mm;

a is the X-ray source to gamma radiation source distance, in mm;

b is the distance between gamma radiation source and image detector, in mm.



Key

1 X-ray tube

2 size d of the gamma radiation source, in mm

3 projected size d' of the image of the gamma radiation source, in mm

4 image detector

a X-ray source to gamma radiation source distance, in mm.

b Distance between gamma radiation source and image detector, in mm.

Figure 1 — Test alignment

4.2 Test practice

The gamma radiation source shall be brought into the test position and shall not be moved during the measurement. The X-rays should be switched on immediately after the arrival of the gamma source in the exposure position and switched off again simultaneously with the gamma source leaving the exposure position. The source movement time should be minimized to reduce fogging in the radiograph. A reference object with well-defined dimensions (e.g., a steel or tungsten cylinder) shall be positioned in the vicinity of the gamma radiation source for calibration purposes. Alternatively, the known tube diameter of the gamma radiation source guide tube can be used for measurement of the magnification in the gamma radiation source projection (Figure 2). The measured source size in the radiograph shall be corrected by the inverse of the magnification factor.

5 Requirements to digital equipment

5.1 Digital Detectors

Digital detectors, which are either imaging plates or digital detector arrays (DDA), can be used as film replacement. The digital detector shall possess a pixel pitch which is at least 40 times smaller than the nominal source size to measure and shall not exceed 50 µm. The basic spatial detector resolution ($SR_b^{detector}$) shall be smaller than 1/20 of the nominal gamma radiation source size. The basic spatial detector resolution shall be measured in accordance with the procedure in ISO 19232-5 or ASTM E2002 in a reference image or taken from manufacturer's statements normalized to the magnification. In the area of the free beam a detector $SNR_N > 100$ shall be achieved. The measurement procedure of the SNR_N shall be in accordance with the procedure in ASTM E 2597/E 2597 M for DDAs or ISO 16371-1 for CR..

5.2 Test parameters for digital radiography

If the gamma radiation source is located in a guide tube, the known tube diameter should preferably be used to calibrate the image pixel size in the plane of the gamma radiation source (Figure 2). Calibration and analysis of source dimension shall be performed using the corresponding functions of the image processing software, see 6.2. Image integration or averaging for noise reduction of DDAs is recommended.

6 Measurement and determination of size *d* of the radiographic gamma source

6.1 Measurement with film

The film radiograph shall be examined visually on a film illuminator using a magnifying lens with a built-in measurement scale (graticule) with divisions of 0,1 mm for source sizes > 1 mm or with divisions of 0,05 mm for source sizes ≤ 0,5 mm and an optical magnification between 5 and 10. The magnification factor v according Formula (1) shall be taken into account when calculating the actual dimension $d = d'/v$ from the measured values on the film or digitized film. The image of the gamma radiation source shall have sufficient contrast to be easily measured.

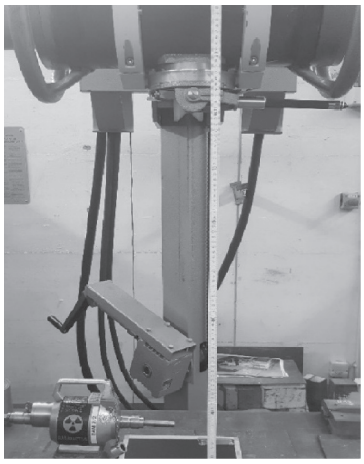
6.2 Measurement with digital detectors

Digital images shall be evaluated using image processing software with contrast, brightness (window levelling), profile, pixel size calibration and zoom function. The digital images shall be magnified at the monitor to a degree that allows the image viewing with at least one pixel of the image at one pixel of the monitor.

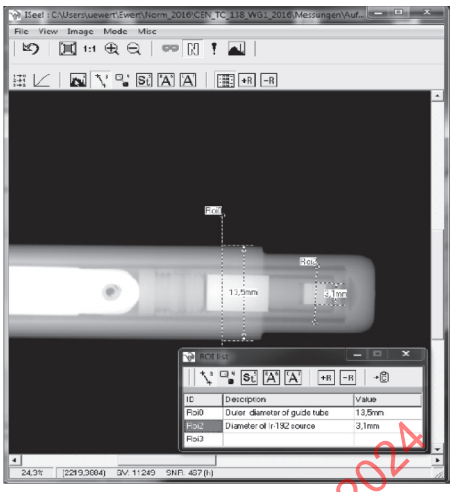
Digital images show the gamma source with a certain magnification factor. It shall be normalized by the magnification factor for measuring the size of the gamma radiation source. The measurement shall consider a known dimension as e.g., the diameter of a reference object (e.g. a steel or tungsten cylinder), or the known diameter of the gamma radiation source guide tube, to determine the overall magnification factor and the real dimensions of the gamma radiation source. The measurement of the size of the gamma radiation source shall be performed with a profile function as shown in Figure 2 e) to achieve sufficient accuracy.

For digital images, the linear grey value difference between the image of the reference object and the image of the envelope surrounding the reference object (contrast) shall be five times larger than the image noise σ. The image noise σ is the calculated standard deviation of the grey value fluctuations in an area of homogeneous exposure, measured in a window of at least 20 $SR_b^{detector}$ x 55 $SR_b^{detector}$ in a homogeneous neighbour area.

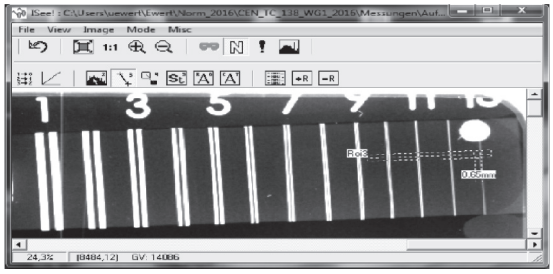
Digital images shall be viewed on a monitor with a brightness of at least 250 cd/m^2. The profile function of the image processing software shall be used for size measurement in digital images after proper brightness and contrast adjustment (Figure 2).



a) Photograph of measurement

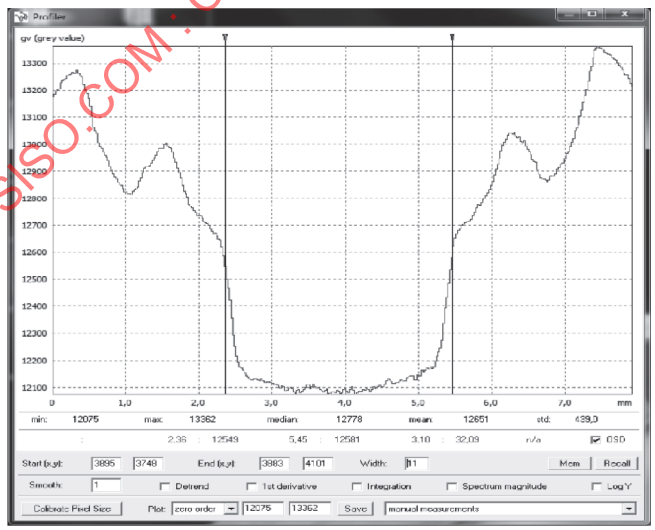


b) Digital image of an Ir-192 gamma radiation source and profile positions at source and guide tube



c) Radiograph of a duplex wire IQI on the detector in the free beam area (1 mm Cu filter in front of X-ray tube)

d) Profile across duplex wire pairs providing SR_b^{detector} = 0,04 mm, taken with CR using a blue high-resolution imaging plate and 25 µm pixel size



e) Measured profile across source projection, determination of source diameter (3,1 mm) between cursor positions

Figure 2 — Measurement of the gamma radiation source size of Ir-192 with digital computed radiography (CR)