BRITISH STANDARD

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Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing

Part 2: Pinhole camera radiographic method

ICS 19.100

National foreword

This British Standard is the UK implementation of . It supersedes BS EN 12543-2:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

Essais non destructifs - Caractéristiques des foyers émissifs des tubes radiogènes industriels utilisés dans les essais non destructifs - Partie 2: Méthode radiographique par sténopé

Zerstörungsfreie Prüfung - Charakterisierung von Brennflecken in Industrie-Röntgenanlagen für die zerstörungsfreie Prüfung - Teil 2: Radiographisches Lochkamera-Verfahren

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Foreword

This document (EN 12543-2:2008) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2009, and conflicting national standards shall be withdrawn at the latest by January 2009.

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This document supersedes EN 12543-2:1999.

EN 12543-2 is part of a series of European Standards under the general title *Non-destructive testing – Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing*; the other Parts are the following:

EN 12543-1: *Part 1: Scanning method;*

EN 12543-3: *Part 3: Slit camera radiographic method*;

EN 12543-4: *Part 4: Edge method;*

EN 12543-5: *Part 5: Measurement of the effective focal spot size of mini and micro focus X-ray tubes*.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

In order to cover the different requirements for focal spot size measurement, five different methods are described in EN 12543-1 to EN 12543-5.

The scanning method (EN 12543-1) is dedicated to those applications where quantitative values for the intensity distribution and spot size are needed, i.e. calibration and image processing purposes.

The radiographic methods (EN 12543-2 and EN 12543-3) describe the traditional techniques and are dedicated for certification purposes and for field applications. A digital detector not only provides focal spot length and width, but also the user with quantitative values for intensity distribution. The digital method may be used as a reference method as in EN 12543-1

Where no pinhole or slit cameras are available in the field, the edge method (EN 12543-4) may be applied. It represents a very simple method for field application.

For micro focus systems, see EN 12453-5.

1 Scope

This European Standard specifies a method for the measurement of focal spot dimensions above 0,2 mm of X-ray systems up to and including 500 kV tube voltage by means of the pinhole camera radiographic method. The voltage applied for this measurement is restricted to 200 kV for visual film evaluation.

The image quality and the resolution of X-ray images depend highly on the characteristics of the focal spot, in particular the size and the two dimensional intensity distribution.

For the characterisation of commercial X-ray tube types (i.e. for advertising or trade) the specific values of Table A.1 are used.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 462-5, *Non-destructive testing — Image quality of radiographs — Part 5: Image quality indicators (duplex wire type), determination of image unsharpness value*

EN 584-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography*

EN 12543-1:1999, *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing — Part 1: Scanning method*

3 Terms and definitions

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

3.1
focal spot
X-ray emitting area on the anode of the X-ray tube as seen from the measuring device

[EN 12543-1:1999]

4 Test equipment

4.1 Essential characteristics of the pinhole

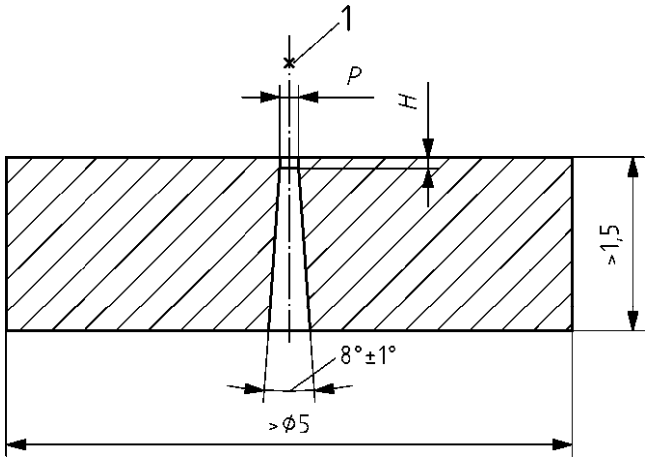
The pinhole camera shall consist of a diaphragm with a pinhole having the following dimensions according to Table 1 dependent from the actual focal spot size:

Table 1 — Dimensions of the pinhole

Focal spot size mm	**Diameter** P µm	**Height** H µm
0,2 to 1,0	30 ± 5	75 ± 10
> 1,0	100 ± 5	500 ± 10

The dimensions P and H are given in Figure 1.

Dimensions in millimetres



Key

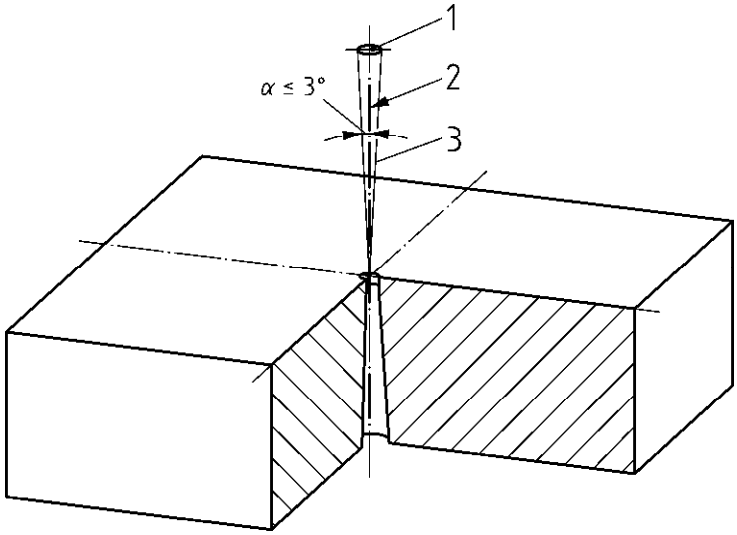
1 focal spot

Figure 1 — Essential dimensions of a pinhole diaphragm

The pinhole diaphragm shall be made of tungsten or of a similar absorbant material.

4.2 Alignment and position of the pinhole camera

The angle between the beam direction and the pinhole axis (see Figure 2) shall be smaller than 3°. When deviating from Figure 2, the direction of the beam shall be indicated.



Key

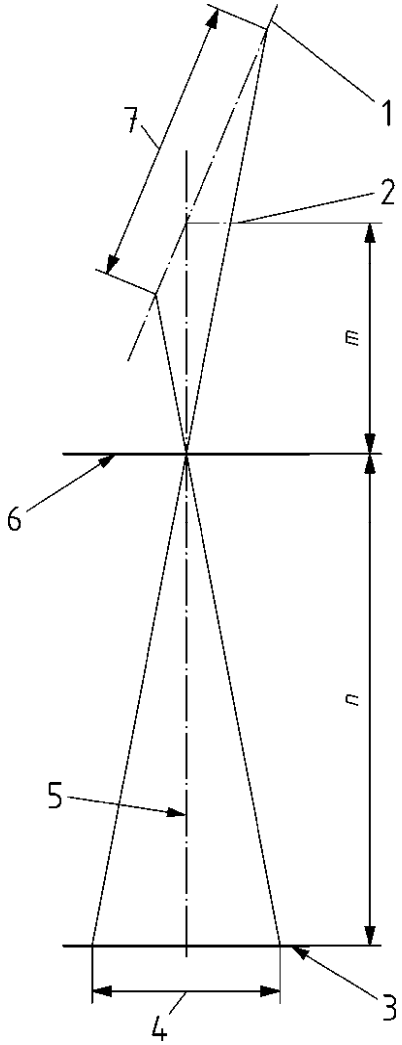
1 focal spot
2 beam direction
3 maximum deviation of the axis of the pinhole

Figure 2 — Alignment of the pinhole camera

The incident face of the pinhole diaphragm shall be placed at a distance *m* from the focal spot so that the variation of the magnification over the extension of the actual focal spot does not exceed ± 5 % in the beam direction. In no case shall this distance be less than 100 mm.

4.3 Position of the radiographic image detector

The radiographic image detector shall be placed normal to the beam direction at a distance *n* from the incident face of the pinhole diaphragm determined from the applicable magnification according to Figure 3 and Table 2.



Key

1 plane of anode
2 reference plane
3 radiographic image detector
4 magnified length of the effective focal spot
5 beam direction
6 incident face of the diaphragm
7 physical length of the actual focal spot

Figure 3 — Beam direction dimensions and planes

Table 2 — Magnification for focal spot pinhole radiographs

Focal spot size d mm	**Minimum magnification** n/m
0,2 to 2,0	3: 1
> 2,0	1: 1

4.4 Requirements on the radiographic image detector

Radiographic films or digital radiographic detectors can be used, provided sensitivity, dynamic range and detector unsharpness allow capturing of the full spatial size of the focal spot image without detector saturation. The maximum allowed detector unsharpness is given by the geometrical unsharpness u_G of the pin hole and is calculated according to:

$$u_G = P(1 + n/m) \quad (1)$$

The detector unsharpness shall be determined with the duplex wire IQI according to EN 462-5. For correct quantitative measurements the minimum projected length and width of the focal spot image should be covered always by at least 20 detector pixels. The signal-to-noise ratio of the focal spot image (ratio of the maximum intensity value inside the focal spot and the standard deviation of the background signal outside) should be at least 50. The maximum intensity inside the focal spot should be above 50 %, but lower than 100 % of the maximum linear detector output value to achieve an image with good contrast.

Imaging plates systems (Computed Radiography, CR) or digital detector arrays (e.g. based on CCD-, a-Si- or CMOS-detectors coupled to an X-ray fluorescent screen, direct converting detectors or image intensifiers with CCD cameras) may be used as digital image detectors.

If radiographic film is used as image detector, it shall meet the requirements of the film system class C 6 or better according to EN 584-1 and shall be used without screens. The film shall be exposed to give a maximum optical density between 1,5 and 2,5. For reference measurements, the film can be digitised with a maximum pixel size, which fulfils the requirements of the above unsharpness conditions, and evaluated according to 5.1.

4.5 Loading factors

The X-ray tube voltage shall be 75 % of the nominal tube voltage, but not more than 200 kV for visual film evaluation. For digital evaluation the maximum voltage is limited by the need that the background intensity is lower than half of the maximum intensity inside the focal spot. The X-ray tube current shall be the maximum applicable tube current at the selected voltage.

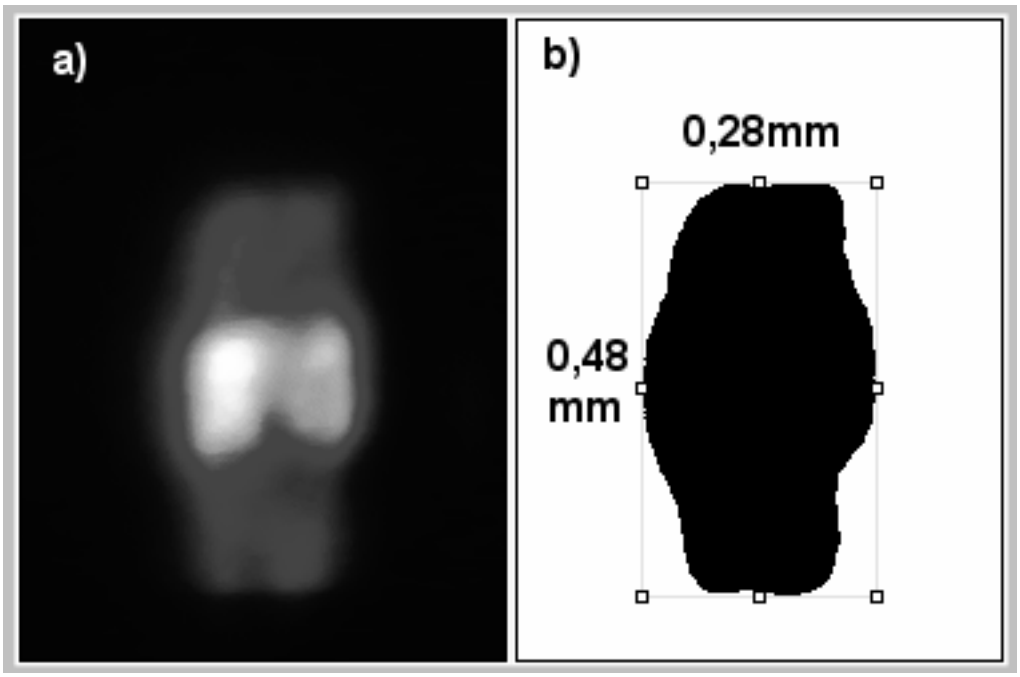
5 Measurement and determination of the focal spot size

5.1 Measurement

The grey scale image of the radiation detector shall be proportional to the X-ray dose. It shall be evaluated to measure the dimensions of the focal spot. The area of all pixels of the focal spot image with grey values higher than 10% of the maximum value (of a 3x3 pixel median filtered image to suppress outliers) above background intensity are used to represent the area of the focal spot (see Figure 4). An isodose contour plot at 10% of the maximum intensity (see Figure 6 in EN 12543-1:1999) may also be used to indicate the area of the focal spot. The focal spot size is determined by the extent of the focal spot area in x- and y-direction divided by the magnification factor (n/m) of the pinhole camera.

If radiographic film is used as an image detector, it is evaluated visually using an illuminator with a uniform luminance of 2000 cd/m² to 3000 cd/m². The visual evaluation shall be carried out using an X5 or X10

magnifying glass, with a built-in reticle, with divisions of 0,1 mm. The resulting focal spot is defined by the visible extent of the blackened area, divided by the selected magnification factor.



Key

a) grey scale image, which is proportional to the X-ray dose, from a radiographic image detector (e.g. CR)
b) evaluation result (binary image) based on a 10 % threshold between background intensity and maximum intensity of the focal spot image

Figure 4 — Evaluation of focal spot images

5.2 Determination of focal spot size

Each focal spot size is described by its size l (length) in the direction of the tube axis and its size w (width) across the X-ray tube. The operating parameters of the X-ray tube shall be recorded.

If the tube axis is not defined, then the direction of the electron trajectory is used instead.

The larger of these sizes (l or w) shall be used as the "focal spot size *d*".

A specification of the focal spot sizes d on the X-ray tube shall refer to this European Standard.

If the focal spot size will be certified, the measurement result has to meet the values of EN 12543-1 within an uncertainty of ± 10 %. This is fulfilled if the focal spot image is acquired digitally considering the requirements of 4.4, 4.5 and 5.1.

NOTE ASTM E 1165 describes a different test method for determination of focal spot sizes of X-ray tubes by the pin hole method. The user of this CEN standard should note that the ASTM standard provides smaller values due to a different measurement procedure.

Annex A
(informative)

Preferred values of d for the characterization of X-ray tube types

Table A.1 — Preferred values of *d* in millimetres

0,1	0,15	0,2	0,3	0,4	0,5
0,6	0,8	1,0	1,4	1,8	2,2
2,6	3,0	3,5	4,0	4,5	5,0
5,5	6,0	7,0	8,0	9,0	10,0

Additionally to d, the dimensions of l and w can be indicated in the same steps.

Bibliography

[1] ASTM E 1165, *Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging*

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