BS ISO 4993:2015

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Steel and iron castings — Radiographic testing

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National foreword

This British Standard is the UK implementation of ISO 4993:2015. It supersedes BS ISO 4993:2009 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/111, Steel Castings and Forgings.

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

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INTERNATIONAL STANDARD

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Third edition
2015-09-15

Steel and iron castings — Radiographic testing

Pièces moulées en acier ou en fonte — Contrôle radiographique

Reference number
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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.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

This third edition cancels and replaces the second edition (ISO 4993:2009), which has been technically revised with the following changes:

— Clause 12 has been deleted;

— B.3, B.4, B.5: ISO 5579 has been added;

— C.3, "light alloys and copper", has been deleted.

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Introduction

Radiography can be used to detect internal discontinuities in castings. The discontinuities can have higher or lower densities than the parent metal.

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INTERNATIONAL STANDARD **ISO 4993:2015(E)**

Steel and iron castings — Radiographic testing

1 Scope

This International Standard specifies the general requirements for the radiography of steel and iron castings by means of X-rays or gamma-rays, in accordance with procedures given in ISO 5579 and ISO 19232.

2 Normative references

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

ISO 5579, *Non-destructive testing — Radiographic testing of metallic materials using film and X- or gamma rays — Basic rules*

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

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

ISO 19232-3, *Non-destructive testing — Image quality of radiographs — Part 3: Image quality classes*

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

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

ASTM E186, *Standard Reference Radiographs for Heavy-Walled (2 to 4 1/2 in. [50.8 to 114 mm]) Steel Castings*

ASTM E192, *Standard Reference Radiographs for Investment Steel Castings for Aerospace Applications*

ASTM E280, *Standard Reference Radiographs for Heavy-Walled (4 1/2 to 12 in. [114 to 305 mm]) Steel Castings*

ASTM E446, *Standard Reference Radiographs for Steel Castings up to 2 in. (50.8 mm) in Thickness*

ASTM E689, *Standard Reference Radiographs for Ductile Iron Castings*

ASTM E802, *Standard Reference Radiographs for Gray Iron Castings up to 4 1/2 in. (114 mm) in Thickness*

ASTM E2660, *Standard Digital Reference Images for Investment Steel Castings for Aerospace Applications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5579 apply.

4 Basis of purchase

The request for radiographic testing and all pertinent information relating thereto, such as sensitivity, coverage, and acceptance criteria, shall be indicated in the enquiry and order.

Unless otherwise specified in the enquiry and order, the radiographic coverage may be of two types, i.e. pilot or regular production inspection. For both types, the manufacturing plan shall show the area

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to be examined and the frequency of testing and shall be subject to agreement between the supplier and purchaser.

If requirements are imposed for which there is not an accepted International Standard or other standard available, a detailed specification of such requirements shall be provided.

Castings with a complex geometry might include areas which cannot be radiographically inspected or can only be partly inspected. Such areas shall be identified before starting the radiographic examination. Areas which cannot be radiographically inspected shall be noted by all contracting parties and be marked on the film position plan.

5 General

5.1 Protection against ionizing radiation

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

WARNING — Exposure of any part of the human body to X-rays or gamma-rays can be highly harmful to health.

5.2 General requirements

This International Standard shall be used in combination with ISO 5579.

6 Testing parameters

Unless otherwise requested in the enquiry and order, the radiographic testing may be performed at any point in the manufacturing cycle, before or after the final heat-treatment.

The surface shall be conditioned, if necessary, so that surface irregularities cannot mask or be confused with discontinuities.

Any type of penetrameter or image quality indicator may be used, provided that the sensitivity level indicated by the purchaser is achieved.

The following items shall be agreed upon between contracting parties:

a) manufacturing stage;

b) extent of examination;

c) examination areas;

d) surface condition;

e) test class according to ISO 5579 (it is recommended that the examination be performed in accordance with ISO 5579);

f) information about the film position plan;

g) marking of examination areas on the casting;

h) image quality value, in accordance with ISO 19232;

i) marking of the films;

j) acceptance criteria.

Any additional items shall be agreed upon between the contracting parties.

Radiographs shall be evaluated by comparison to reference radiographs.

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7 Personnel qualifications

Operations shall be carried out by qualified personnel. The system of qualification shall be agreed upon between the purchaser and manufacturer and shall form a part of the technical specification or be stated in the enquiry.

8 Testing arrangements

The testing arrangements shall be in accordance with Annex A.

9 Film position plan

9.1 Film position plan for pilot radiography

When requested in the order or enquiry, preliminary shooting sketches shall be prepared by the supplier for submission with the radiographs of the pilot casting for approval by the customer. These sketches shall show the area of the part to be examined and shall include the following information for each exposure:

a) gamma source or kilovoltage used;

b) location of radiation source in relation to the area covered and the film;

c) physical size of the source;

d) area covered by the film;

e) placement of the film and location markers;

f) film-to-source distance;

g) placement of the image quality indicators or penetrameters and the image quality value;

h) section thickness;

i) number and types of films used;

j) film identification;

k) thickness and type of intensifying screens;

l) value of density required;

m) geometrical unsharpness;

n) conditions of development of films.

9.2 Film position plan for production radiography

The preliminary film position plan may, by agreement between the supplier and the purchaser, be adjusted at the time of the examination of the first casting sample. Subsequent production castings shall be examined in accordance with the finalized shooting sketches, which shall include the information listed in 9.1. Any new criteria established for the radiography of the production castings, such as changes in the percentage of coverage for the part or changes in the acceptance standards, shall be stated.

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10 Rejection/acceptance criteria

The rejection/acceptance criteria shall be specified in the purchase order and shall be based on ASTM E446, ASTM E186, ASTM E280, ASTM E192, ASTM E689, ASTM E802, and ASTM E2660, wherever applicable.

11 Foundry responsibility

Unless otherwise specified at the time of the enquiry or order, the responsibility of the manufacturer is limited to the attainment of the criteria specified in the order, in all castings, or portions of castings specifically calling for radiographic examination. Castings or portions of castings not required to be radiographically examined by the foundry shall not be subject to rejection based upon the results of any subsequent radiographic examination. Also, castings shall not be subject to rejection based upon radiographic re-examination subsequent to their acceptance on the basic of the original radiography if such examination is carried out by techniques other than those agreed upon at the time of the enquiry and order and/or in a manner different from that described in the finalized shooting sketch (see 9.2).

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Annex A
(normative)

Examination arrangements

A.1 General

The examination arrangements to be used could be in accordance with the following:

— Figures A.1, A.2, A.3, A.4, A5 and A.6 for test areas of simple section;

— Figure A.7 for double-wall radiography;

— Figures A.8, A.9, A.10, A.11 and A.12 for test areas of complex section.

If these arrangements are not applicable, other arrangements may be used.

A.2 Single-wall radiography of plane areas

The examination arrangement for single-wall radiography of plane areas shall be in accordance with Figure A.1.

A.3 Single-wall radiography of curved areas

The test arrangement for single-wall radiography of curved areas shall be in accordance with Figure A.2, Figure A.3, or Figure A.4.

If possible, the source of radiation should be placed in accordance with the arrangements shown in Figure A.3 and Figure A.4 to achieve a more suitable direction of examination. The reduction in minimum source-to-object distance should not be greater than 40 % provided that the image quality requirements are met. ISO 5579 should be taken into account.

When the source is located centrally inside the object and the film outside (technique shown in Figure A.4) and provided that the image quality indicator (IQI) requirements are met, this percentage can be increased. However, it is recommended that the reduction in minimum source-to-object distance be not greater than 50 %. Rigid cassettes can be used if the corresponding increase in distance, b, is considered for the calculation of the distance f between the source and source side of the test object.

A.4 Double-wall radiography of plane and curved areas

A.4.1 General

The examination arrangement for double-wall radiography of plane and curved areas shall be in accordance with Figure A.5, Figure A.6, or Figure A.7.

Double-wall radiography shall be used as an overview technique in accordance with Figure A.7 if the geometrical conditions make other examination arrangements difficult to apply or if there is a better sensitivity for detecting discontinuities by using this technique. It shall be ensured that unacceptable discontinuities are detected with sufficient certainty. The required image quality shall be met.

In the case of examination arrangements according to Figure A.6 and Figure A.7, the discontinuities shall be classified with reference to the single-wall thickness. In the case of different wall thicknesses, the reference shall be the smaller one.

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In the case of examination arrangements according to Figure A.5, the distance from the source to the surface of the area under examination shall be minimized, provided that the requirements of IQI are met.

A.4.2 Choice of examination arrangements for complex geometries

Unless otherwise agreed upon, the examination arrangements for complex geometry areas shall be in accordance with Figures A.8, A.9, A.10, A.11 and A.12 (as appropriate).

A.4.3 Acceptable examination area dimensions

In addition to the requirements given in ISO 5579, the angle of incident radiation shall not exceed 30°.

NOTE This value can be larger if special orientations of discontinuities can be detected in this way or if it is the only way to test areas otherwise impossible to test.

A.4.4 Explanation of symbols used in Figures A.1 to A.12

In Figure A.1, the following symbols apply:

Q is the source of radiation;

t is the nominal thickness of the material in the region under examination;

b is the distance between the source side of the test object side and the film surface measured along the central axis of the radiation beam;

B is the radiographic film;

f is the distance between the source of radiation and the source side of the test object measured along the central axis of the radiation beam;

w is the thickness of material in the direction of the radiation beam, calculated on the basis of the nominal thickness. If the actual thickness of the material deviates from the nominal one by more than 10 %, the actual material thickness shall be used.

In Figure A.2 to Figure A.12, the symbols given in Figure A.1 apply where appropriate.

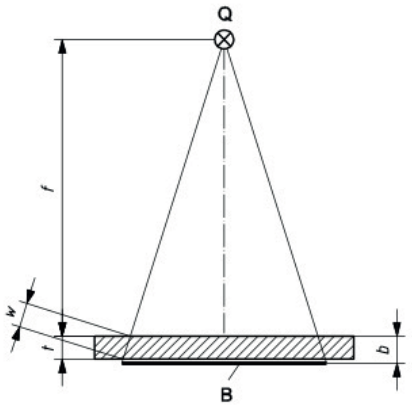

Figure A.1 — Examination arrangement for single-wall radiography of plane areas

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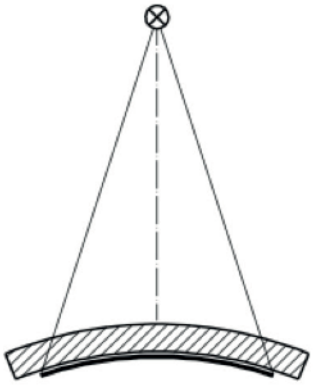

Figure A.2 — Examination arrangement for single-wall radiography of curved areas with the source on the convex side and the film on the concave side of the area under examination

Figure A.3 — Examination arrangement for single-wall radiography of curved areas with eccentric positioning of the source on the concave side and the film on the convex side of the area under examination

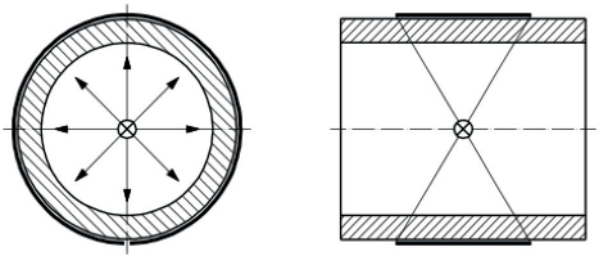

Figure A.4 — Examination arrangement for single-wall radiography of curved areas with central positioning of the source on the concave side and the film on the convex side of the area under examination

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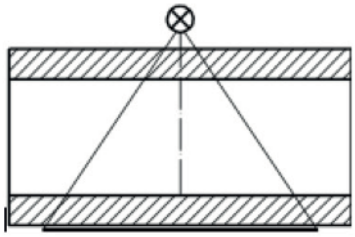

Figure A.5 — Examination arrangement for double-wall radiography of plane or curved areas under examination; source and film outside the test area, only the film-side wall imaged for interpretation

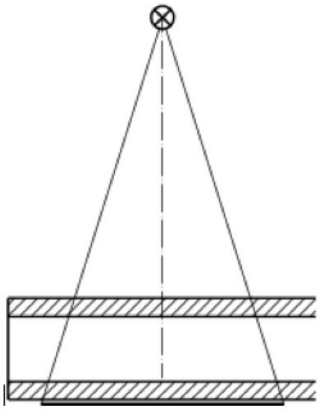

Figure A.6 — Examination arrangement for double-wall radiography of plane or curved areas under examination; several exposures; source and film outside of the test area; both walls imaged for interpretation

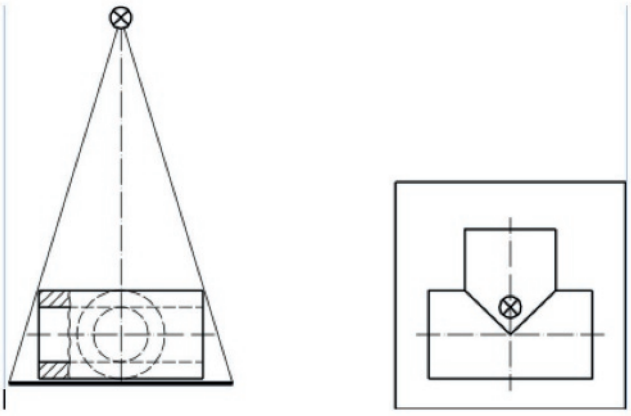

Figure A.7 — Examination arrangement for double-wall radiography of plane or curved areas under examination; overview exposure; source and film outside of the test area; both walls imaged for interpretation

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a) Preferred arrangement **b) Arrangement should only be used if a) is not possible**

Figure A.8 — Examination arrangement for edges and flanges

a) Preferred arrangement **b) Arrangement should only be used if a) is not possible**

Figure A.9 — Examination arrangement for ribs

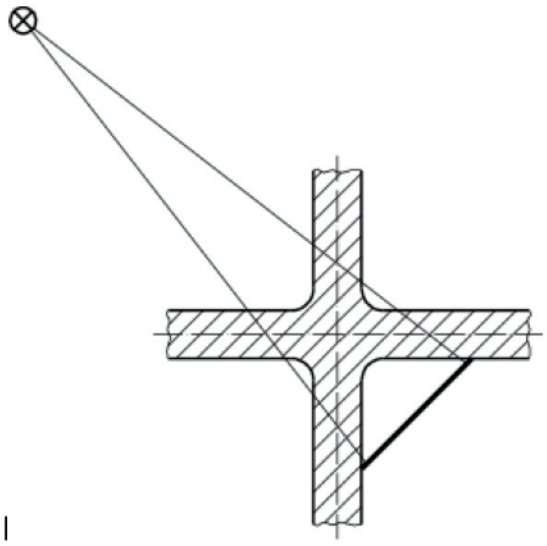

Figure A.10 — Examination arrangement for crosslike geometries

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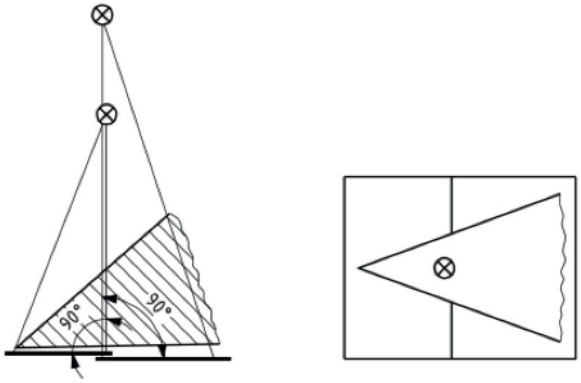
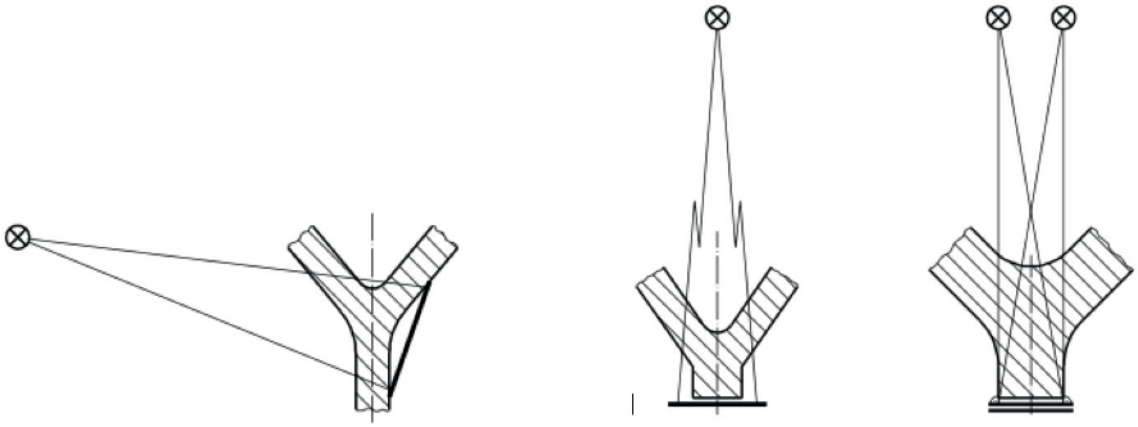


Figure A.11 — Examination arrangement for wedge geometries



a) **b)**

Figure A.12 — Examination arrangement for ribs and supports

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Annex B
(informative)

Techniques for increasing the covered thickness range

B.1 General

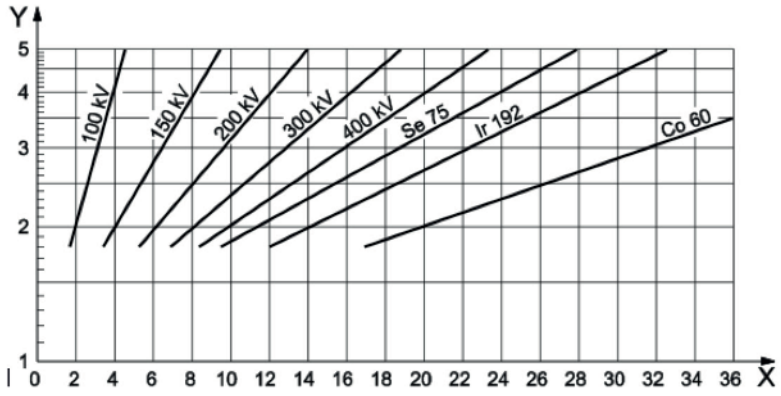
In many applications, it is useful to image a larger thickness range, within the given limits of the optical density, with one exposure. This can be done using one of the following techniques:

— multiple-film technique;

— decreasing contrast by using higher radiation energy or beam hardening;

— thickness equalization.

The possible covered thickness range within a certain range of density can be estimated in accordance with Figure B.1 for different X-ray tube voltages and gamma sources.



Key

X thickness range, mm

Y optimal density ratio D_{max}/D_{min}

Figure B.1 — Estimation of possible covered thickness range for different radiation energy levels for steel

B.2 Multiple-film technique

In the multiple-film technique, two or more films are exposed at the same time (see Figure B.2) and viewed singly or together.

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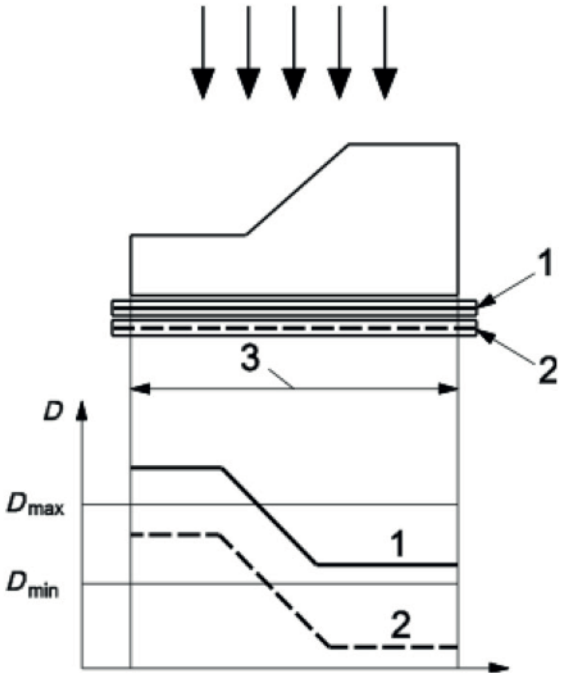

Key

D density
1 film system with higher sensitivity
2 film system with lower sensitivity
3 lateral dimension

Figure B.2 — Film arrangement for multiple-film technique

There shall be at least one screen between each of the films. When paper-backed lead screens are used, two screens shall be inserted with the metal layer to the film side. Films, front-screens, and back-screens shall be chosen in accordance with ISO 5579.

The film areas with low density shall be masked to avoid dazzle while viewing.

Viewing identification marks (at least two) shall be imaged to ensure the exact positioning of multiple films on top of each other. The geometrical features of the casting and of their images on the films shall correspond.

The density of a single film shall not be less than 1,3 if double-film viewing is used.

B.3 Contrast decrease using higher radiation energy

A contrast decrease using higher radiation energy is only permissible in test class A (ISO 5579).

For X-ray sources up to 500 keV, the maximum permissible tube voltage given in ISO 5579 may be exceeded by max. 30 %. To increase the covered thickness range, X-ray sources may be replaced by gamma-ray sources or linear accelerators.

The image quality requirement(s) given in ISO 19232-2 or ISO 19232-3 shall be met.

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B.4 Beam hardening

Beam hardening for contrast decreasing is only permissible for class A (ISO 5579) .

The image quality requirement(s) given in ISO 19232-3 or ISO 19232-4 shall be met.

B.5 Thickness equalization

In class A (ISO 5579), imaging different wall thicknesses with one exposure on one film is possible by covering the area of thinner wall thickness with material which equalizes the differences in wall thickness so that the requirements of density in accordance with Clause 9 are met for the whole thickness range.

The equalizing material shall be free from discontinuities and from coarse structure and shall not cause image disturbance that could harm a good analysis of the examined area.

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Annex C
(informative)

Choice of radiation source

C.1 General

The choice of the radiation source is a function of the penetrated thickness, *w*, of the test object (see ISO 5579), the test class, the examination arrangement, and the material. For non-perpendicular incident radiation, *w* is the penetrated thickness in the direction of the central beam. For double-wall radiography, *w* is the sum of the penetrated thicknesses of the test object. If there are different thicknesses imaged with one exposure, an averaged value of these thicknesses can be used.

Instead of using ISO 5579:2013, Table 1, the thickness range for cobalt 60 (^{60}Co) in test class A is limited to $40\ \text{mm} < w \leq 170\ \text{mm}$.

NOTE By agreement between the contracting parties, the minimum wall thickness of steel castings for ^{75}Se can be reduced to 5 mm.

C.2 Specific film system classes

When using a selenium source for the radiography of steel for class A, at least film system class C5 should be used and for test class B, at least film system class C4 should be used. Front-lead screens and back-lead screens with a thickness of 0,1 mm to 0,2 mm should be used.

C.3 Influence of crystalline structure

Diffraction and absorption in crystalline structures can result in diffraction mottle in a radiograph. Diffraction mottle can be confirmed by changing the exposure technique, e.g. by choosing higher radiation energy or by increasing the distance between the surface of the test object on the source side and the film (see Figure A.1).

When diffraction mottle makes film interpretation impossible, parameters other than those given in this International Standard may be used by agreement between the contracting parties.

NOTE Diffraction mottle can occur in austenitic steels.

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