INTERNATIONAL STANDARD

ISO 4993

Second edition
2009-03-15

Steel and iron castings — Radiographic inspection

Pièces moulées en acier ou en fonte — Contrôle radiographique

Reference number
ISO 4993:2009(E)

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

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.

ISO 4993 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 11, *Steel castings*.

This second edition cancels and replaces the first edition (ISO 4993:1987), which has been technically revised.

Introduction

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

Steel and iron castings — Radiographic inspection

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 (all parts).

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.

ISO 5579, *Non-destructive testing — Radiographic examination of metallic materials by X- and gamma-rays — Basic rules*

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

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

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

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: Image quality indicators (duplex wire type) — Determination of image unsharpness value*

ASTM E186, *Standard reference radiographs for heavy-walled (2 to 4 1/2 in. [51 to 114 mm]) steel castings*

ASTM E192, *Standard reference radiographs for investment steel castings of 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. (51 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*

3 Basis of purchase

The request for radiographic examination 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 to be examined and the frequency of examination, and shall be subject to agreement between the supplier and purchaser.

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

Castings with a complex geometry can 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.

4 Terms and definitions

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

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 injurious to health.

5.2 General requirements

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

6 Examination parameters

Unless otherwise requested in the enquiry and order, the radiographic examination 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 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 (all parts);

i) marking of the films;

j) acceptance criteria.

Any additional items shall be agreed between the contracting parties.

Radiographs shall be evaluated by comparison to reference radiographs.

7 Personnel qualifications

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

8 Examination arrangements

The examination 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 mutual 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.

10 Rejection/Acceptance criteria

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

11 Foundry responsibility

Unless otherwise specified at the time of the enquiry or order, the responsibility of the supplier (foundry) 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 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 (9.2).

12 Records

Unless otherwise agreed upon between the supplier and purchaser, records of radiographic inspection shall be kept by the supplier for a period of at least 5 years.

Annex A
(normative)

Examination arrangements

A.1 General

The examination arrangements to be used shall be in accordance with:

— Figures A.1 to A.6 for test areas of simple section;

— Figure A.7 for double-wall radiography;

— Figures A.8 to 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 either 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 Figures A.3 and 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 either Figure A.5, A.6 or 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 assured that unacceptable discontinuities are detected with sufficient certainty. The required image quality shall be met.

In the case of examination arrangements according to Figures A.6 and 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.

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, the examination arrangements for complex geometry areas shall be in accordance with Figures A.8 to 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 Figures A.2 to A.12, the symbols given in Figure A.1 apply where appropriate.

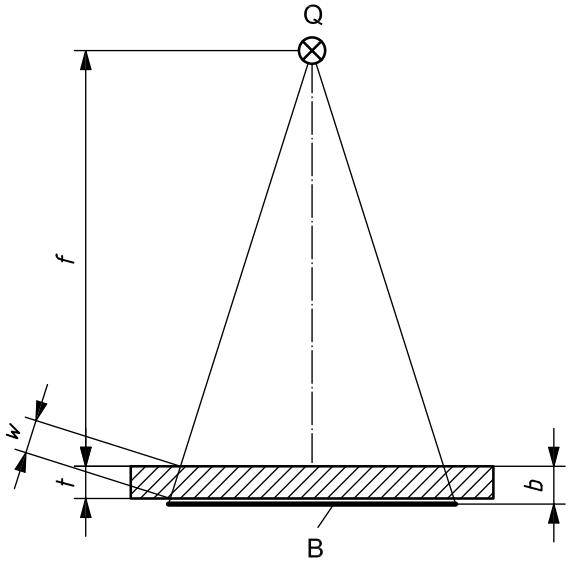


Figure A.1 — Examination arrangement for single-wall radiography of plane areas

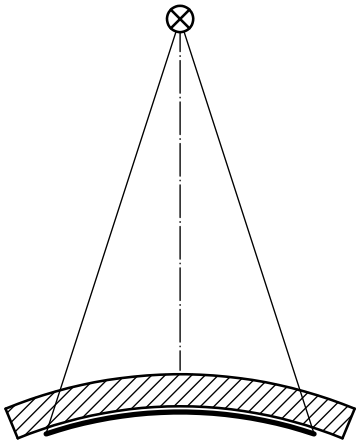


Figure A.2 — Examination arrangement for single-wall radiography of curved areas with the source on the convex side and the film on the concave side of the area under examination

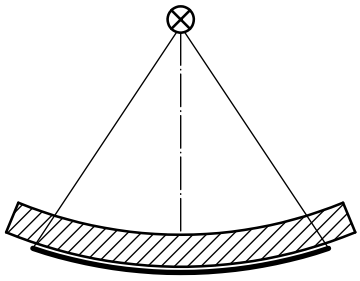


Figure A.3 — Examination arrangement for single-wall radiography of curved areas with eccentric positioning of the source on the concave side and the film on the convex side of the area under examination

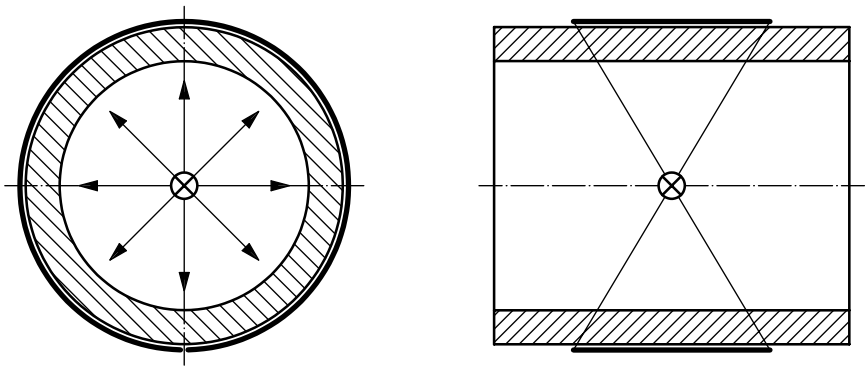


Figure A.4 — Examination arrangement for single-wall radiography of curved areas with central positioning of the source on the concave side and the film on the convex side of the area under examination

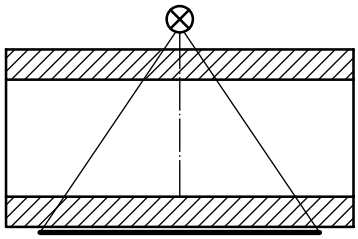


Figure A.5 — Examination arrangement for double-wall radiography of plane or curved areas under examination; source and film outside the test area, only the film-side wall imaged for interpretation

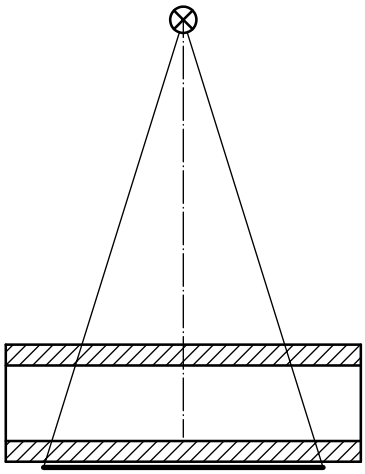


Figure A.6 — Examination arrangement for double-wall radiography of plane or curved areas under examination; several exposures; source and film outside of the test area; both walls imaged for interpretation

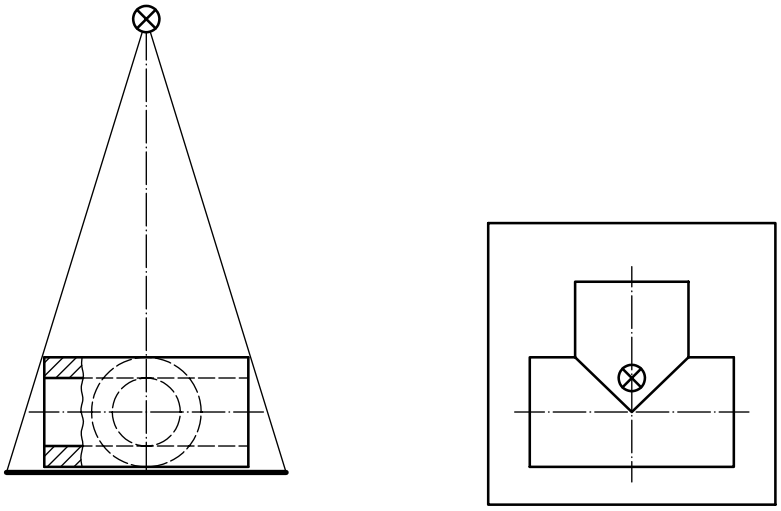
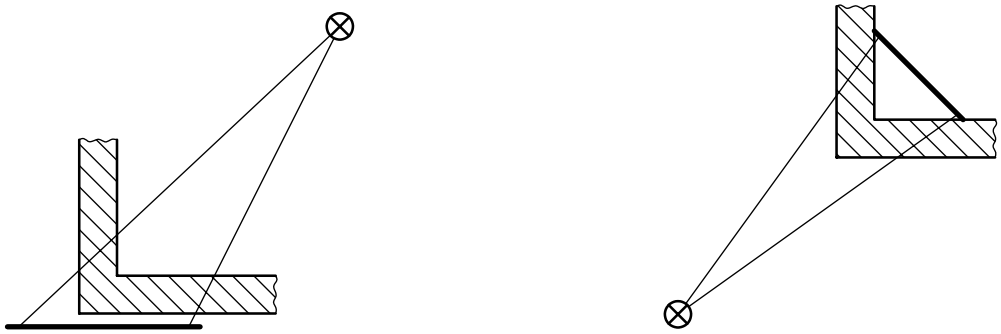


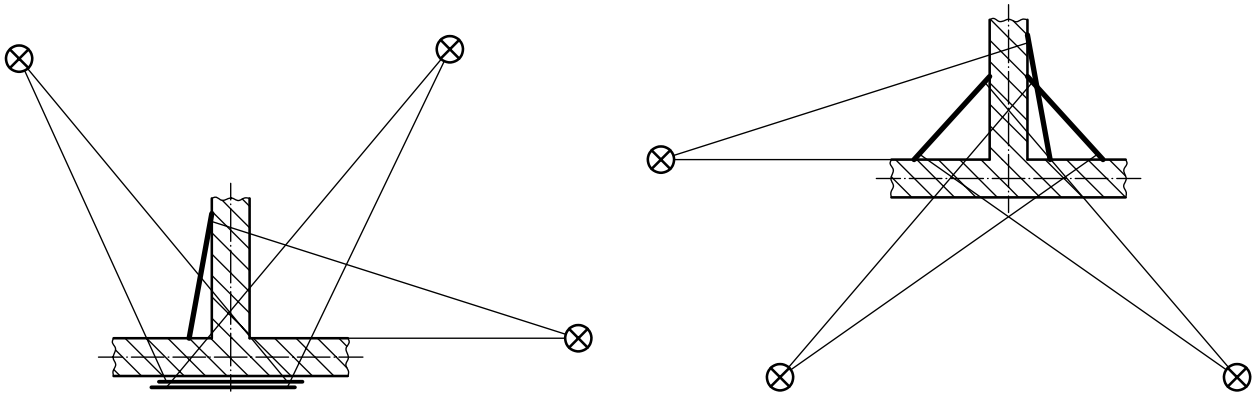
Figure A.7 — Examination arrangement for double-wall radiography of plane or curved areas under examination; overview exposure; source and film outside of the test area; both walls imaged for interpretation



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

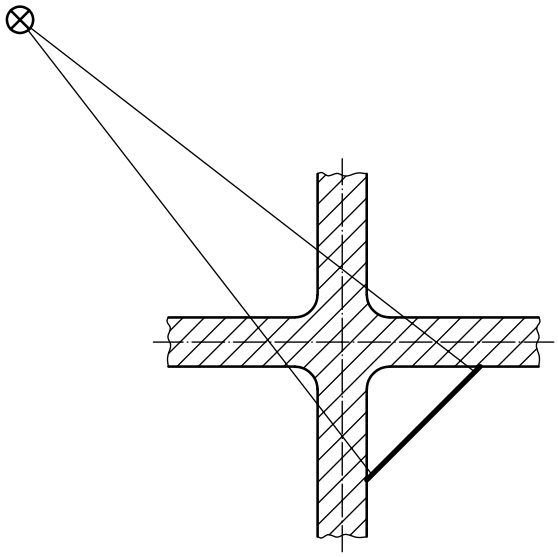


Figure A.10 — Examination arrangement for crosslike geometries

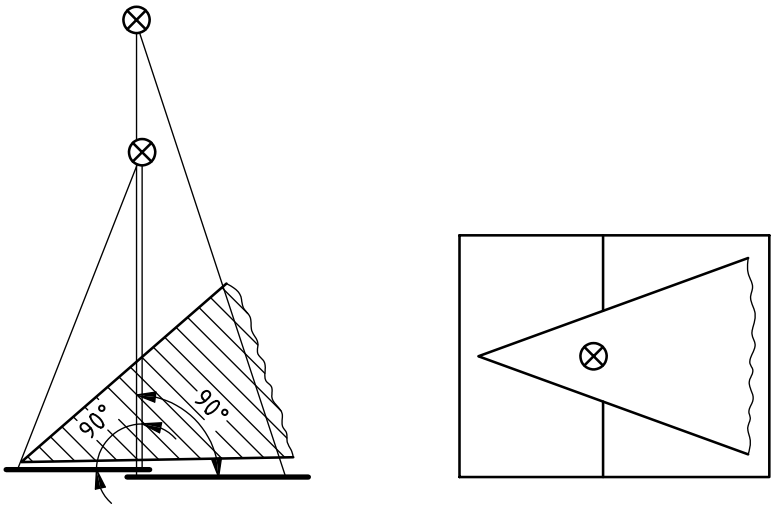
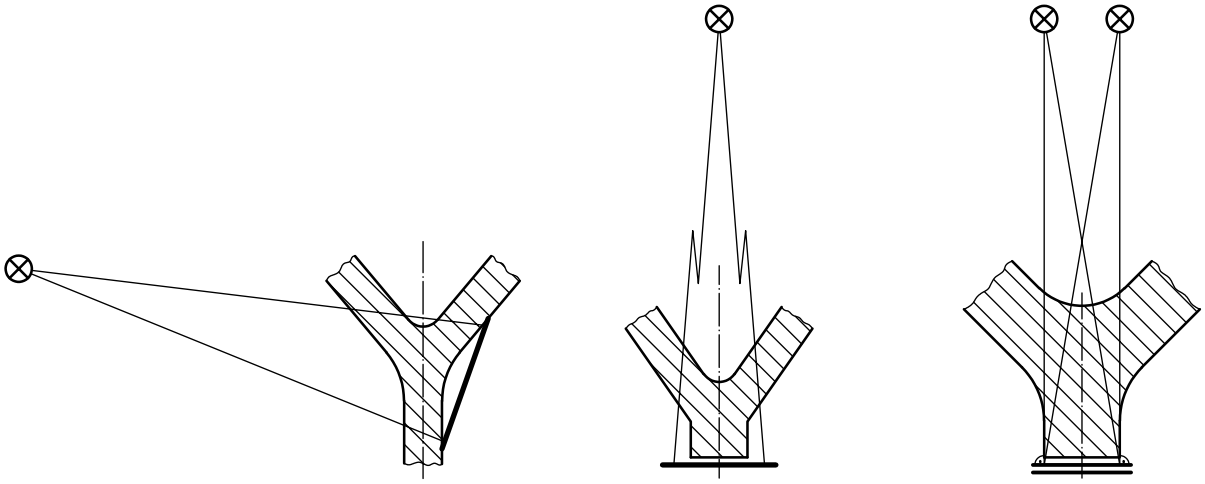


Figure A.11 — Examination arrangement for wedge geometries



a) b)

Figure A.12 — Examination arrangement for ribs and supports

Annex B
(informative)

Techniques for increasing the covered thickness range

B.1 General

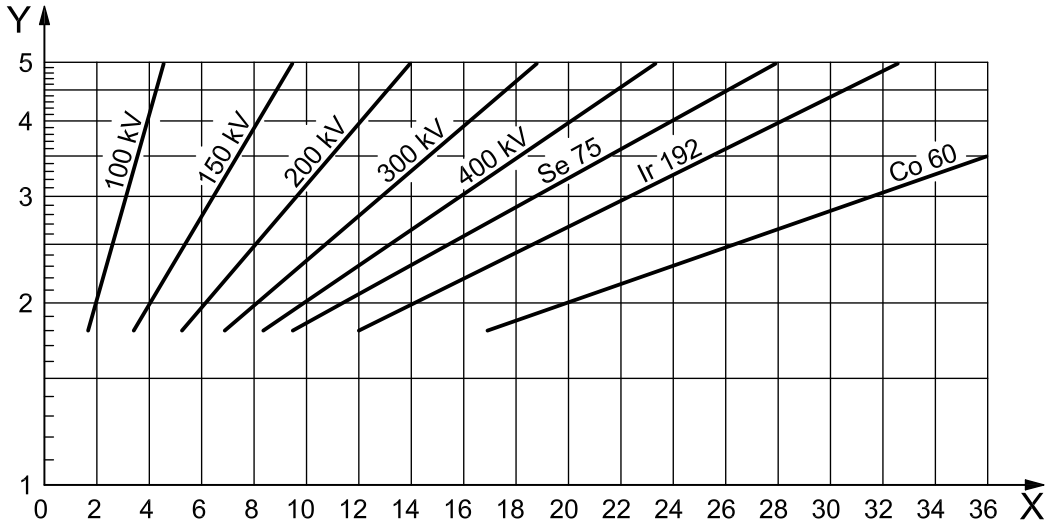
In many applications it is useful to image a larger thickness range, within the given limits of the optical density, with one exposure. This can be done using one of the following techniques:

— 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

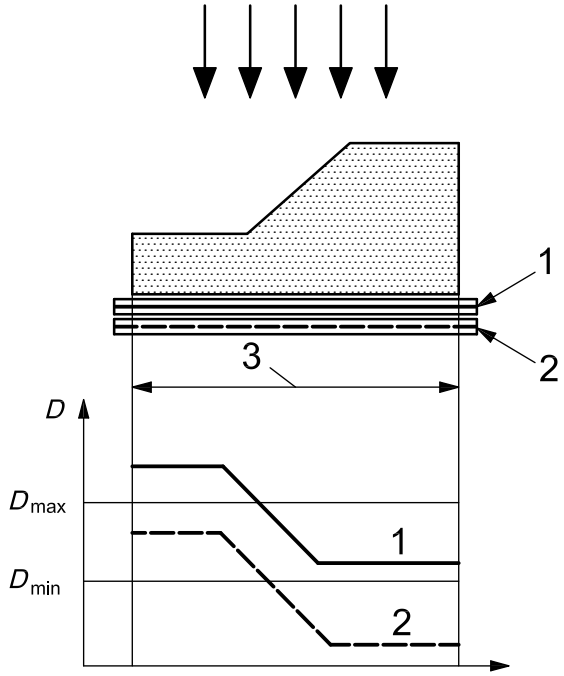
X thickness range, mm

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.



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 and front- and back-screens shall be chosen in accordance with ISO 5579.

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

Viewing identification marks (at least 2) 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.

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.

B.4 Beam hardening

Beam hardening for contrast decreasing is only permissible for class A.

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

B.5 Thickness equalization

In class A, 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.

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 (Table 1), the thickness range for cobalt 60 (^{60}Co) in test class A is limited to:

— Test class A, ^{60}Co: 40 mm $< w \leqslant$ 170 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 and of nickel and nickel alloys for class A, at least film system class C5, and for test class B at least film system class C4, should be used. Front- 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 a 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 can be used by agreement between the contracting parties.

NOTE Diffraction mottle can occur in some light alloys, copper alloys, cobalt and nickel alloys and austenitic steels.

ICS 77.040.20; 77.140.80

Price based on 15 pages