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Steel and iron castings — Radiographic testing

Pièces moulées en acier ou en fonte — Contrôle radiographique

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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 4993:2015), which has been technically revised.

The main changes are as follows:

— Annex A was rewritten to include a table for the various testing arrangements;

— term “examination” being replaced with testing.

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.

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 testing

1 Scope

This document specifies the general requirements for the radiography of steel and iron castings by means of X-rays or gamma-rays.

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

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

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 and basic spatial resolution 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*

ASTM E8268, *Standard Digital Reference Images for Steel Castings up to 2in. (50.8 mm) in Thickness*

ASTM E3030, *Standard Digital Reference Images for Heavy-Walled (2 to 412 In. (50.8 to 114 mm)) Steel Castings*

3 Terms and definitions

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

4 Basis of purchase

The request for radiographic testing and all requirements, see Clause 6, should be indicated in the enquiry and order.

Unless otherwise specified in the enquiry and order, the radiographic coverage can 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 testing. The acceptance criteria, see Clause 10, shall be subject to agreement between the manufacturer and purchaser.

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

5 General

Relevant 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.

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 should be conditioned so that surface irregularities cannot mask or be confused with discontinuities.

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

The following items shall be agreed upon between the purchaser and manufacturer:

a) manufacturing stage;

b) extent of testing;

c) testing areas;

d) surface condition;

e) test class in accordance with ISO 5579;

f) information about the film position plan;

g) marking of testing areas on the casting;

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

i) traceability of the films or digital images;

j) acceptance criteria.

Any additional items shall be agreed upon between the purchaser and manufacturer.

Radiographs shall be evaluated by comparison to reference radiographs.

7 Personnel qualifications

Operations shall be carried out by qualified personnel according to ISO 9712. The system of qualification shall be agreed upon between the purchaser and manufacturer.

8 Testing arrangements

Testing arrangements shall be agreed upon between the purchaser and the manufacturer. Some possible arrangements are in 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 manufacturer 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) name, address of test facility performing the testing;

b) part number and description;

c) instruction identification number, issue No. and date of issue;

d) material including requirements for surface preparation;

e) gamma source or kV used, tube current, exposure time, see Annex C for additional information about the choice of source used;

f) physical size of the source;

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

h) angle of beam to film;

i) object-to-film distance;

j) film-to-source distance;

k) section thickness, Annex B lists various techniques to increase the covered thickness range;

l) areas of the item to be examined (support by diagrams when required);

m) placement of the film and location markers;

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

o) filters, masks, diaphragms used including the letter B for monitoring the back scatter radiation;

p) film type, size, quantity, pattern, and identification;

q) thickness and type of intensifying screens;

r) value of density;

s) geometrical unsharpness;

t) conditions of development of films;

u) number of sheets that make up the instruction;

v) associated documents;

w) prepared by, approved by, associated signatures and qualifications and date.

9.2 Film position plan for production radiography

The preliminary film position plan can, by agreement between the supplier and the purchaser, be adjusted at the time of the testing 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 the applicable standard: ASTM E446, ASTM E186, ASTM E280, ASTM E192, ASTM E689, ASTM E802, ASTM E2660, E8268, or E3030.

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 testing. 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 testing. Also, castings shall not be subject to rejection based upon radiographic re-testing subsequent to their acceptance on the basic of the original radiography if such testing 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).

Annex A
(informative)

Testing arrangements

A.1 General

The testing arrangements for simple sections (single-wall of plane and curved surfaces), double-wall radiography and complex section can be in accordance with Table A.1.

A.2 Single-wall radiography of curved areas

Where possible, the standard arrangements should be used to achieve a more suitable direction of testing. The reduction in minimum source-to-object distance should not be greater than 40 % provided that the image quality requirements are met.

This percentage can be increased when the source is located centrally inside the object and the film outside, provided that the image quality indicator (IQI) requirements are met. However, the reduction in minimum source-to-object distance should 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.3 Double-wall radiography of plane and curved areas

A.3.1 General

Double-wall radiography should be used as an overview technique in accordance with line 7 of Table A.1 if the geometrical conditions make other testing arrangements difficult to apply or if there is a better sensitivity for detecting discontinuities by using this technique. It should be ensured that unacceptable discontinuities are detected with sufficient certainty. The required image quality should be met.

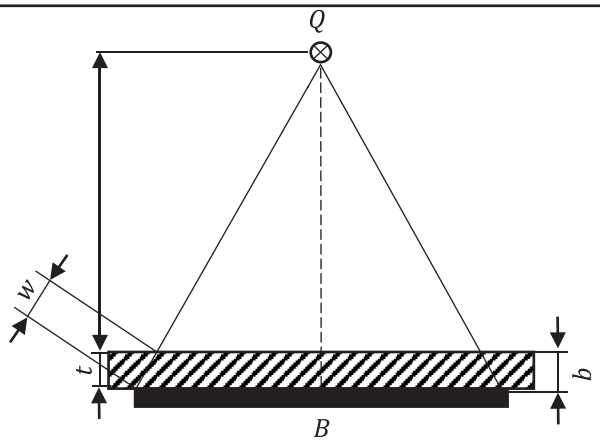
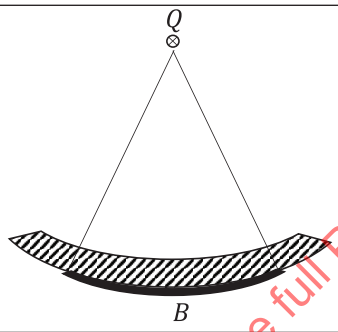
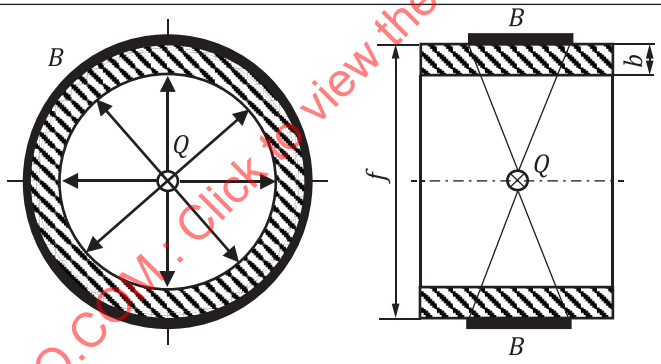
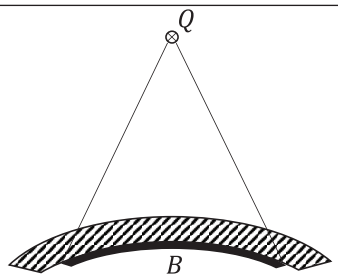
In the case of testing arrangements with several exposures or an overview exposure lines 6 and 7 of Table A.1, the discontinuities should be classified with reference to the single-wall thickness. In the case of different wall thicknesses, the reference should be the smaller one.

A.3.2 Acceptable testing 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.

Table A.1 — Testing arrangements for radiography

Description	Schematic	Comments
Line 1 Standard testing arrangement for single-wall radiography of plane areas		
Line 2 Standard testing arrangement for single-wall radiography of curved areas		
Line 3 Standard testing arrangement for single-wall radiography of curved areas with source centrally located		
Line 4 Alternate testing arrangement for single-wall radiography of curved areas		

Key

Q source of radiation

t nominal thickness of the material in the region under testing

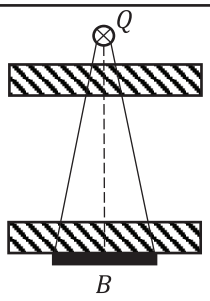
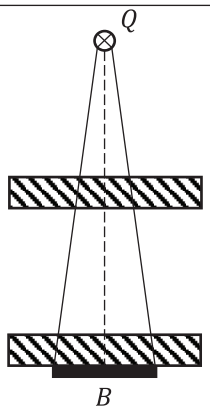
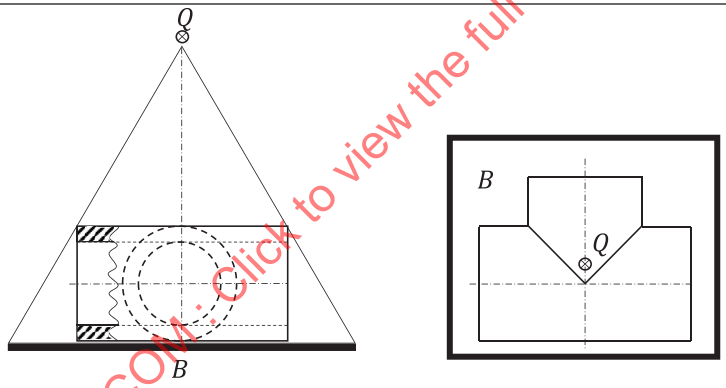
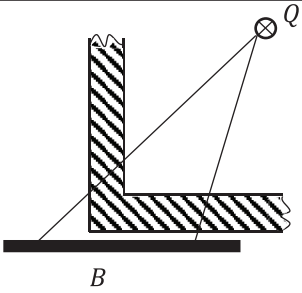
b distance between the source side of the test object side and the film surface measured along the central axis of the radiation beam

B radiographic film

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

w 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 should be used.

Table A.1 *(continued)*

Description	Schematic	Comments
Line 5 Testing arrangement for double-wall radiography of plane and curved areas with only film-side wall imaged		The distance from the source to the surface area should be minimized, provided the requirements of IQI are met.
Line 6 Testing arrangement for double-wall radiography of plane and curved areas using several exposures		Source and film are outside of the testing area and both walls are imaged for interpretation.
Line 7 Testing arrangement for double-wall radiography of plane and curved areas using an overview exposure		Source and film are outside of the testing area and both walls are imaged for interpretation.
Line 8 Standard testing arrangement for edges and flanges		

Key

Q source of radiation

t nominal thickness of the material in the region under testing

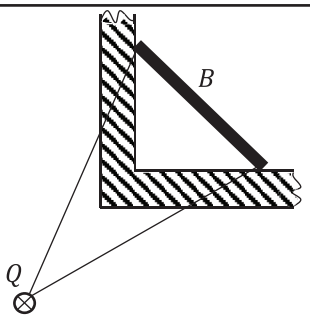
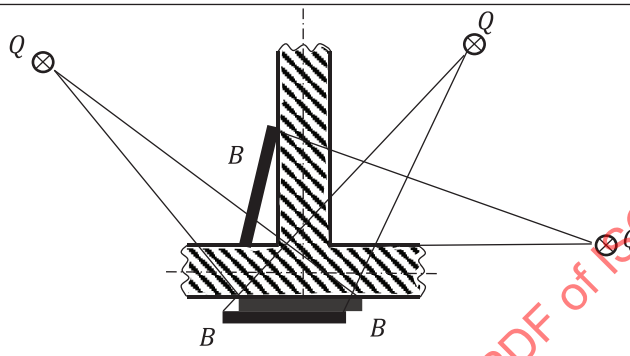
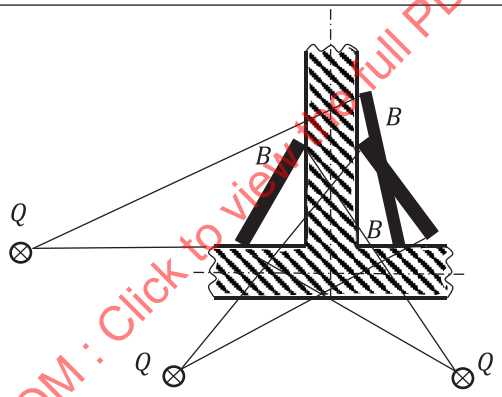
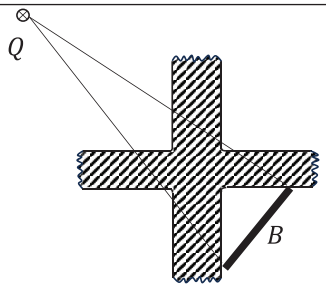
b distance between the source side of the test object side and the film surface measured along the central axis of the radiation beam

B radiographic film

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

w 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 should be used.

Table A.1 *(continued)*

Description	Schematic	Comments
Line 9 Alternate testing arrangement for edges and flanges		
Line 10 Standard testing arrangement for ribs		
Line 11 Alternate testing arrangement for ribs		
Line 12 Testing arrangement for cross like geometries		

Key

Q source of radiation

t nominal thickness of the material in the region under testing

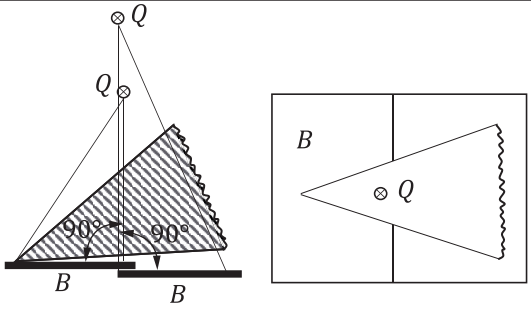
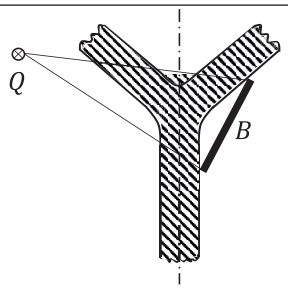
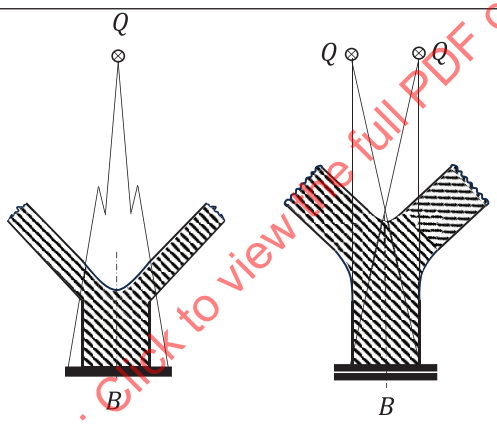
b distance between the source side of the test object side and the film surface measured along the central axis of the radiation beam

B radiographic film

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

w 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 should be used.

Table A.1 *(continued)*

Description	Schematic	Comments
Line 13 Testing arrangement for wedge geometries		
Line 14 Testing arrangements for ribs and supports		
		

Key

Q source of radiation

t nominal thickness of the material in the region under testing

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

B radiographic film

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

w 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 should be used.

Annex B
(informative)

Techniques for increasing the covered thickness range

B.1 General

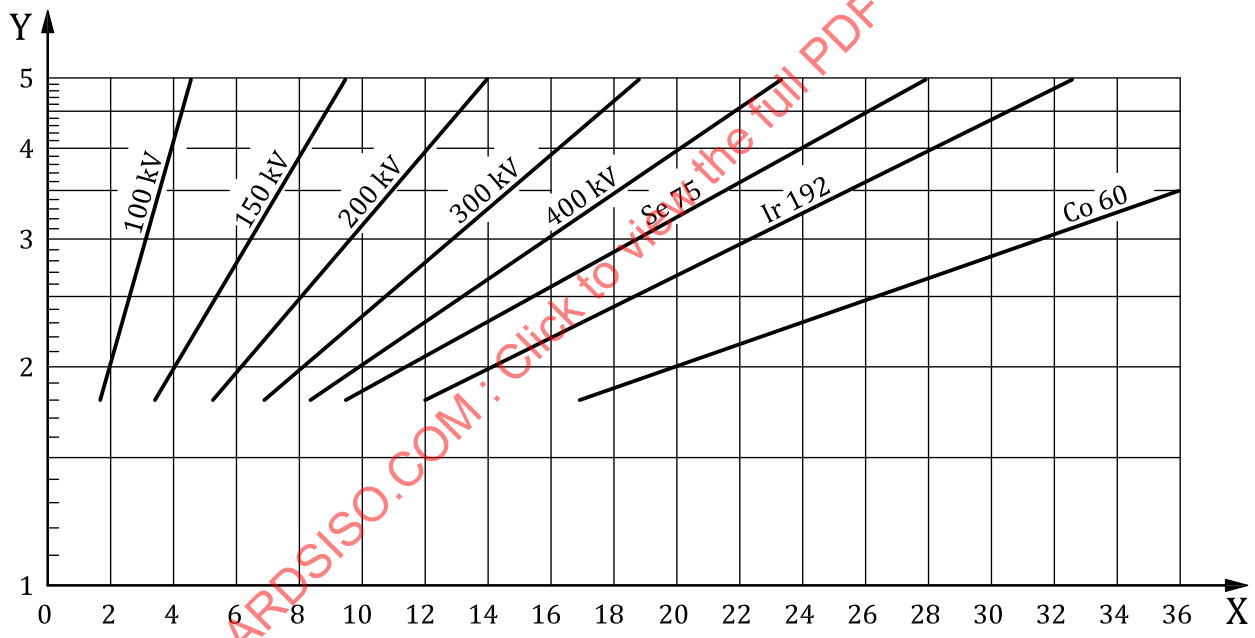
In many applications, it is useful to create a representation of a larger thickness range, within the given limits of the optical density, with one exposure. This can be done using one of the following techniques:

— 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 individually or together.