BS EN 12681-1:2017

BSI Standards Publication

Founding - Radiographic testing

Part 1: Film techniques

bsi.

National foreword

This British Standard is the UK implementation of EN 12681-1:2017. Together with BS EN 12681-2:2017, it supersedes BS EN 12681:2003, which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Fonderie - Contrôle par radiographie - Partie 1 : Techniques à l'aide de films

Gießereiwesen - Durchstrahlungsprüfung - Teil 1: Filmtechniken

This European Standard was approved by CEN on 16 July 2017.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 12681-1:2017) has been prepared by Technical Committee CEN/TC 190 “Foundry technology”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by May 2018, and conflicting national standards shall be withdrawn at the latest by May 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12681:2003.

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 10 “Testing for inner discontinuities”:

— to revise EN 12681:2003 into EN 12681-1, *Founding — Radiographic testing — Part 1: Film techniques*;

— and to prepare a further standard EN 12681-2, *Founding — Radiographic testing — Part 2: Techniques with digital detectors*

Annex G covers the significant technical changes between this European Standard and EN 12681:2003.

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

Introduction

Radiography can be used to detect internal discontinuities in a casting. The discontinuities can be gas holes, non-metallic inclusions, shrinkage, cracks, inserts or chills or inclusions that have lower or higher densities than the parent metal. This European Standard gives acceptance criteria through severity levels.

1 Scope

This European Standard gives specific procedures for industrial X-ray and gamma radiography for discontinuity detection purposes, using NDT (Non-destructive testing) film techniques. This part of EN 12681 specifies the requirements for film radiographic testing of castings.

Films after exposure and processing become radiographs with different area of optical density. Radiographs are viewed and evaluated using industrial radiographic illuminators.

This part of EN 12681 specifies the recommended procedure for the choice of operating conditions and radiographic practice.

These procedures are applicable to castings produced by any casting process, especially for steel, cast iron, aluminium, cobalt, copper, magnesium, nickel, titanium, zinc and any alloys of them.

NOTE This European Standard considers EN ISO 5579.

This part of this European Standard does not apply to:

— radiographic testing of castings for aerospace applications (see prEN 2002-21);

— radiographic testing of welded joints (see EN ISO 17636-1);

— radiography with digital detectors (see EN 12681-2);

— radioscopic testing (see EN 13068, all parts).

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.

EN 12543, *Non-destructive testing — Characteristics of focal spots in industrial X-ray systems for use in non-destructive testing (all parts)*

EN 12679, *Non-destructive testing - Determination of the size of industrial radiographic sources - Radiographic method*

EN 25580, *Non-destructive testing - Industrial radiographic illuminators - Minimum requirements (ISO 5580:1985)*

EN ISO 5579:2013, *Non-destructive testing - Radiographic testing of metallic materials using film and X- or gamma rays - Basic rules (ISO 5579:2013)*

EN ISO 9712, *Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712)*

EN ISO 11699-1, *Non-destructive testing - Industrial radiographic film - Part 1: Classification of film systems for industrial radiography (ISO 11699-1)*

EN ISO 11699-2, *Non-destructive testing - Industrial radiographic films - Part 2: Control of film processing by means of reference values (ISO 11699-2)*

EN 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 19232-1)*

EN 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 19232-2)*

ISO 5576, *Non-destructive testing — Industrial X-ray and gamma-ray radiology — Vocabulary*

ASTM E 1320:2010, *Reference Radiographs for Titanium Castings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5576, EN ISO 5579 and the following apply.

3.1
wall thickness
t
thickness as measured on the casting

3.2
nominal wall thickness
t_n
thickness as specified on the drawing

3.3
penetrated thickness
w
thickness of material in the direction of the radiation beam calculated on the basis of the real thicknesses of all penetrated walls

3.4
source size
d
size of the radiation source or focal spot size

[SOURCE: EN ISO 5579:2013, definition 3.4]

3.5
object-to-film distance
b
largest (maximum) distance between the source side of the radiographed part of the test object and the film surface measured along the central axis of the radiation beam

3.6
source-to-object distance
f
distance between the source of radiation and the source side of the test object, most distant from the film, measured along the central axis of the radiation beam

3.7
source-to-film distance
SFD
distance between the source of radiation and the film measured in the direction of the beam

Note 1 to entry: SFD = $f + b$

where

f source-to-object distance;

b object-to-film distance.

[SOURCE: EN ISO 5579:2013, definition 3.5, modified – description in words presented as formula]

4 Symbols and abbreviations

For the purposes of this document, the symbols and abbreviations given in Table 1 apply.

Table 1 — Symbols and abbreviations

Symbol or abbreviation	Term	Clause, Figure, Annex
b	object-to-film distance	3.5
d	source size	3.4
D	optical density of film	Clause 12 14.2 Figure 16 Figure 15
f	source-to-object distance	3.6
F	Film	Figure 1
IQI	image quality indicator	Clause 16 Annex A
S	source of radiation	Figure 1
SFD	source-to film-distance	3.7
t	wall thickness	3.1 Figure 1
t_n	nominal wall thickness	3.2 Annexes B to F
w	penetrated thickness	3.3

5 Classification of radiographic techniques

The radiographic techniques are divided into two classes:

— Class A: basic techniques;

— Class B: improved techniques.

It is recommended to perform the testing according to class A, if not otherwise specified in the order. Class B techniques will be used when class A might be insufficiently sensitive.

If, for technical or industrial reasons, it is not possible to meet one of the conditions specified for class B, such as the type of radiation source or the source-to-object distance *f*, it may be agreed by contracting parties that the condition selected may be what is specified for class A. In film radiography the loss of sensitivity shall be compensated by an increase of minimum optical density to 3,0 or by selection of a two class better film system. The other conditions for class B remain unchanged, especially the image quality achieved. Because of the better sensitivity compared to class A, the test specimen may be regarded as being examined to class B. This does not apply if the special SFD reductions as specified in Clause 11 for test arrangements Figure 3 and Figure 4 are used.

6 General preparations and requirements

6.1 General preparations

6.1.1 Protection against ionizing radiation

Local, national or international safety precautions shall be strictly 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. Wherever X-ray equipment or radioactive sources are in use, appropriate legal requirements shall be applied.

6.1.2 Surface preparation and stage of manufacture

In general, surface preparation is not necessary, but where surface imperfections can cause difficulty in detecting discontinuities, the surface shall be ground smooth.

Unless otherwise specified radiography shall be carried out after the final stage of manufacture, e.g. after grinding or heat treatment.

NOTE For some aluminium and magnesium alloy castings, radiography can be carried out before heat treatment.

6.2 Agreements

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

The following items shall be agreed between the contracting parties by the time of acceptance of the order:

a) manufacturing stage at which castings are to be tested;

b) extent of radiographic testing;

c) test areas;

d) surface condition;

e) testing class;

f) information about the film position plan;

g) marking of test areas on the casting;

h) image quality;

i) marking of the radiographs;

j) acceptance criteria;

k) any additional items;

l) any special requirements.

6.3 Personnel qualification

Unless otherwise agreed, testing shall be performed by personnel qualified in accordance with EN ISO 9712 or equivalent to an appropriate level in the relevant industrial sector.

7 Test arrangements

7.1 General

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

— Figures 1 to 4: for single wall radiography;

— Figures 5 to 7: for double wall radiography;

— Figures 8 to 12: for test areas of complex section.

NOTE For an explanation of the symbols in the figures, see Table 1.

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

7.2 Single wall radiography of plane areas

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

7.3 Single wall radiography of curved areas

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

NOTE Rigid cassettes can be used if the corresponding increase of b is considered for the calculation of the distance f between the source and source side of the test object (see Clause 11).

7.4 Double wall radiography of plane and curved areas

The test arrangement for double wall radiography of plane and curved areas shall be in accordance with either Figures 5, 6 or 7.

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

In the case of test arrangements according to Figures 6 and 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.

Double wall radiography shall be used, as an overview technique according to Figure 7, if the geometrical conditions make other test 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.

7.5 Choice of test arrangements for complex geometries

Unless otherwise agreed, the test arrangements for complex geometry areas shall be in accordance with Figures 8 to 12 (as appropriate).

7.6 Acceptable test area dimensions

The test area to be captured with one radiographic film should be limited in a way that the required optical density according to Clause 12, Table 5 is met in the region of interest.

In addition to the requirements above, the angle of incident radiation in the entire region of interest 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.

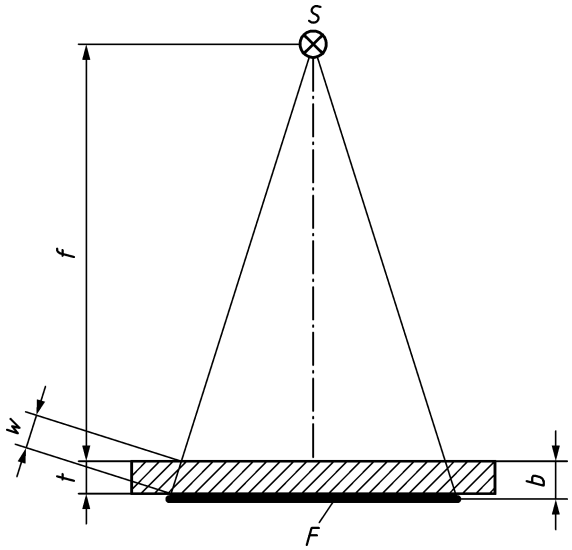
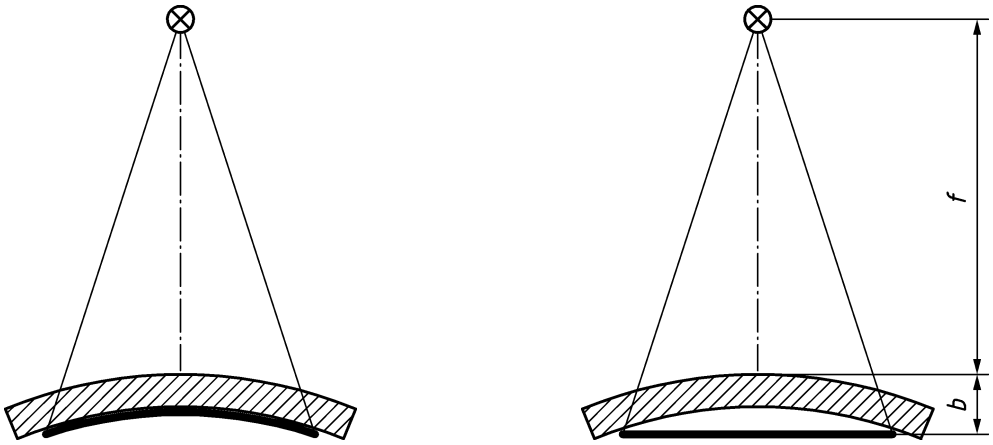
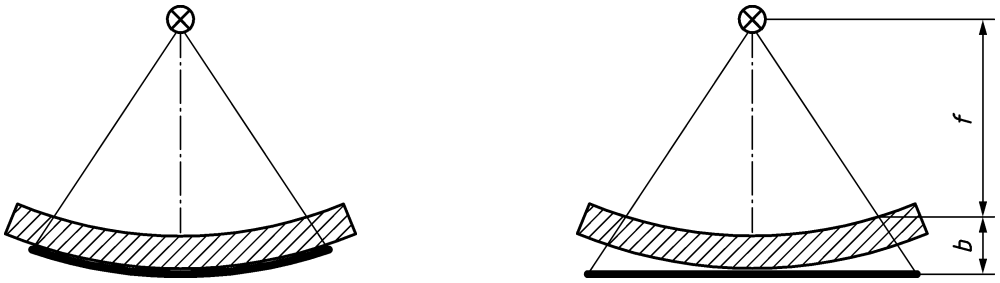


Figure 1 — Test arrangement for single wall radiography of plane areas



a) with flexible cassette b) with rigid cassette

Figure 2 — Test arrangement for single wall radiography of curved areas with the source on the convex side and the film on the concave side of the test area



a) with flexible cassette b) with rigid cassette

Figure 3 — Test 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 test area

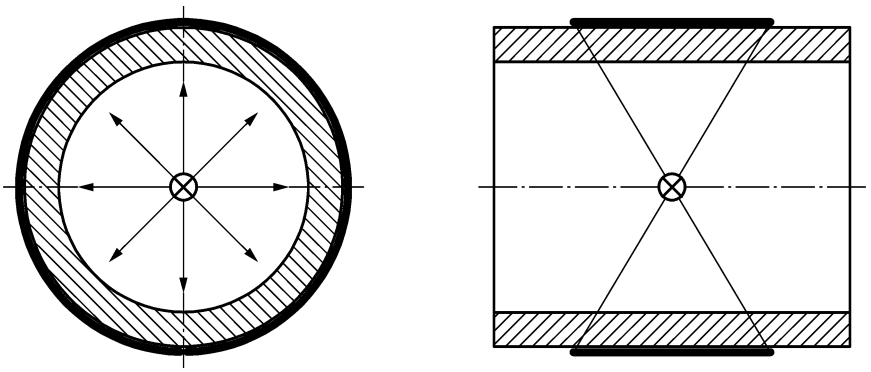


Figure 4 — Test arrangement for single wall radiography of curved areas with central positioning of the source on the concave side and film on the convex side of the test area

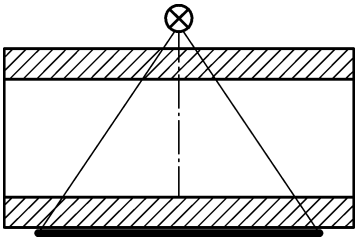


Figure 5 — Test arrangement for double wall radiography of plane or curved test areas; source and film outside the test area, only the film side wall imaged for interpretation

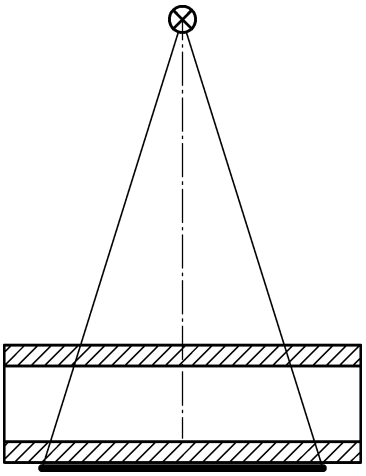


Figure 6 — Test arrangement for double wall radiography of plane or curved test areas; several exposures; source and film outside of the test area; both walls imaged for interpretation

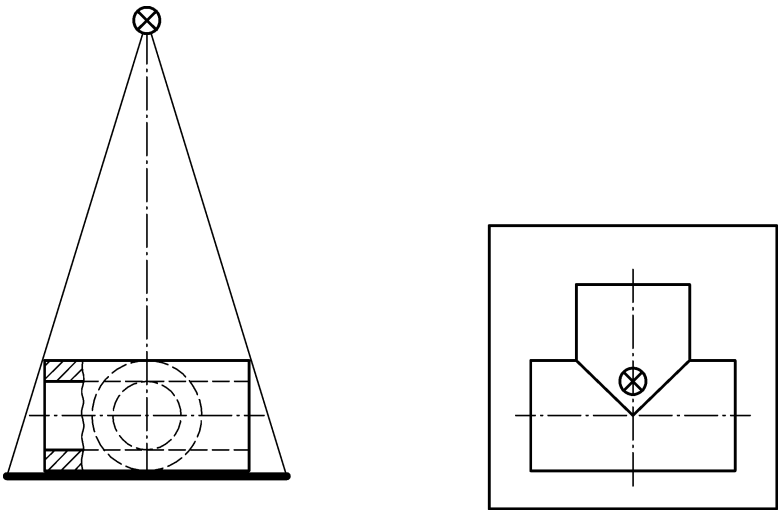
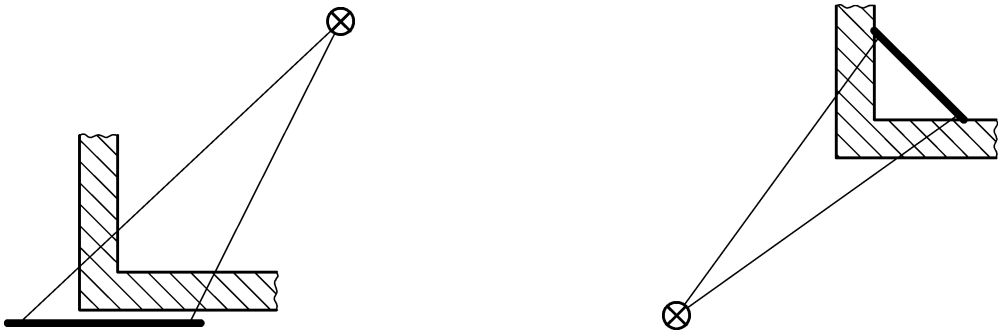
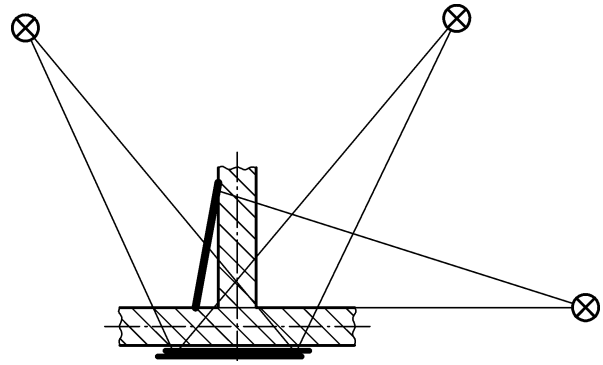


Figure 7 — Test arrangement for double wall radiography of plane or curved test areas; overview exposure; source and film outside of the test area; both walls imaged for interpretation

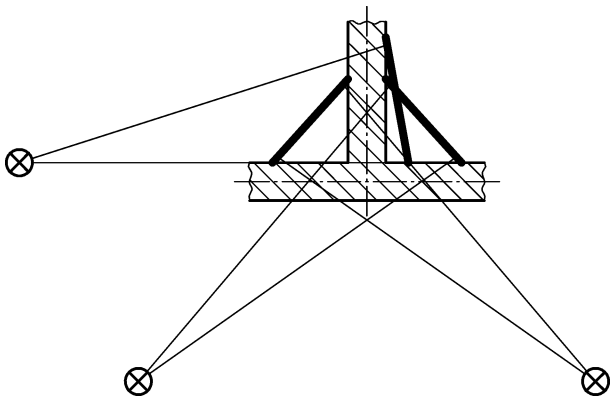


a) **b) should only be used, if a) is not possible.**

Figure 8 — Examples for edges and flanges



a)



b) should only be used, if a) is not possible.

Figure 9 — Examples for ribs

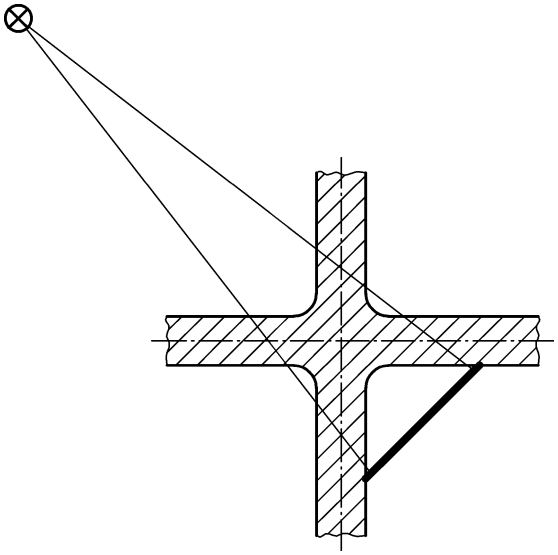


Figure 10 — Example for cross like geometries

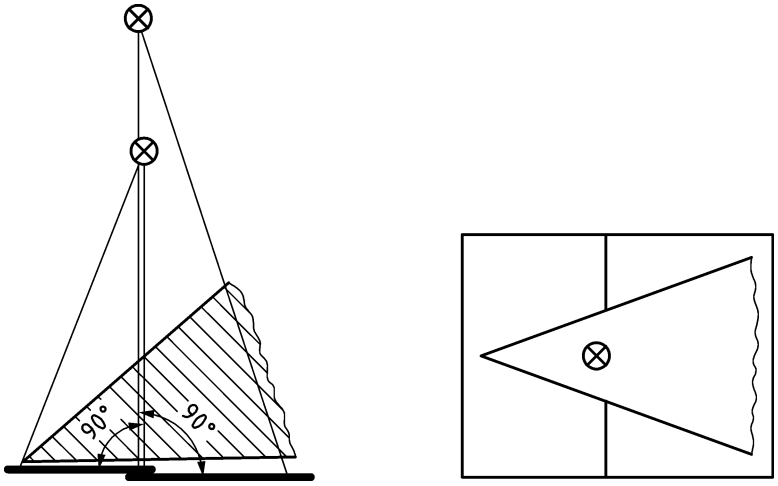
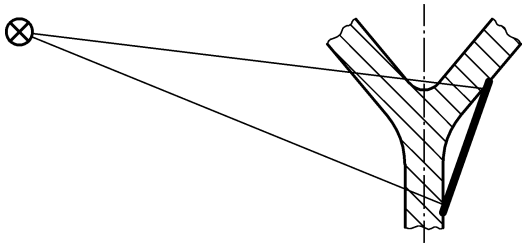
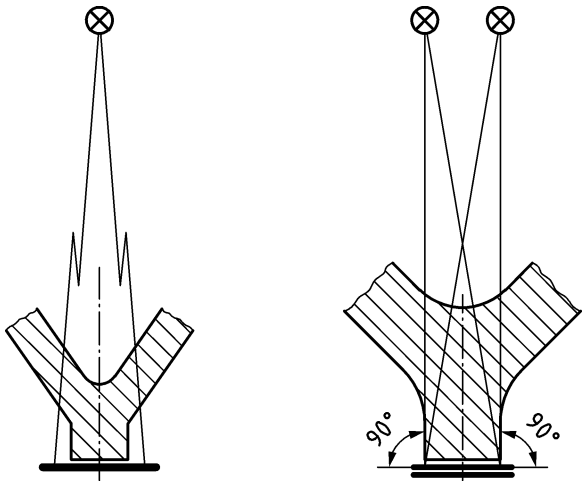


Figure 11 — Example for wedge geometries



a)



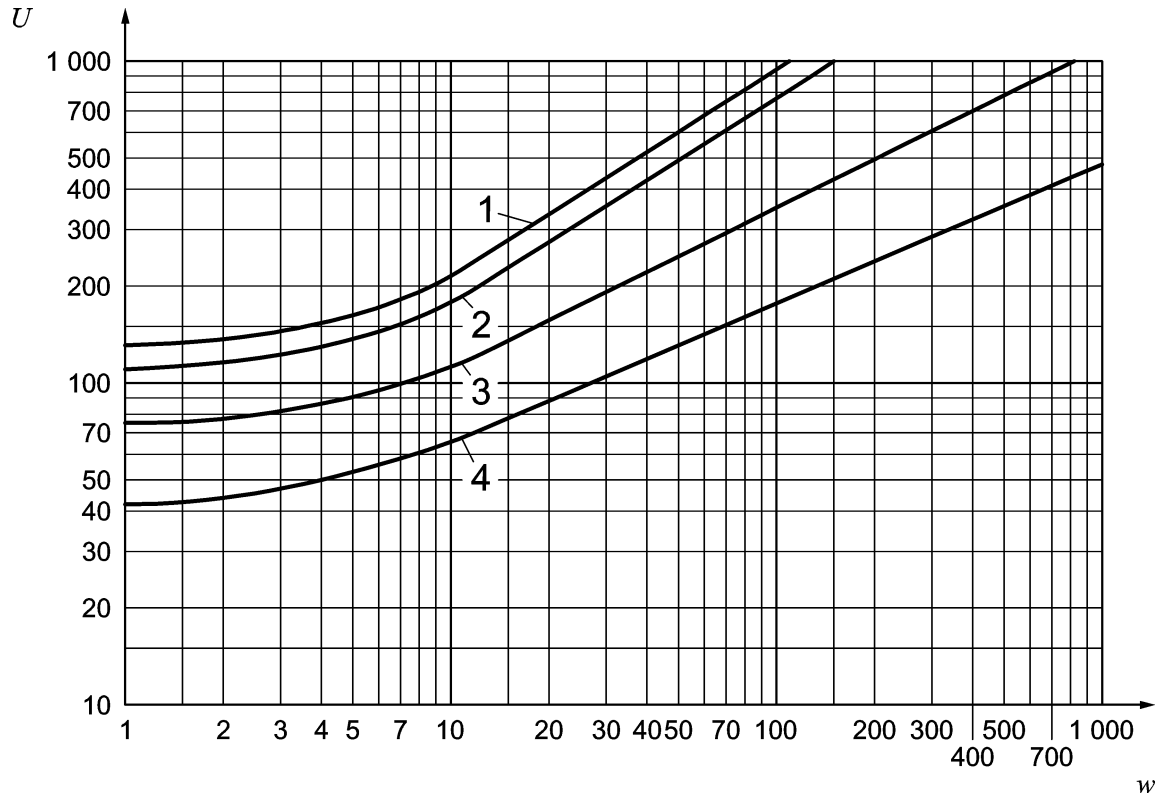
b)

Figure 12 — Example for ribs and supports

8 Choice of tube voltage and radiation source

8.1 X-ray devices up to 1 000 kV

To maintain good detection sensitivity, the X-ray tube voltage should be as low as possible. The maximum values of X-ray tube voltage versus thickness are given in Figure 13.



Key

1	copper/nickel and alloys	4	aluminium and alloys
2	steel and cast irons	*w*	penetrated thickness in mm
3	titanium and alloys	*U*	X-ray voltage in kV

Figure 13 — Maximum X-ray voltage *U* for X-ray devices up to 1 000 kV as a function of penetrated thickness *w* and material

For some casting applications where the thickness changes across the area of test object being radiographed, a modification of technique with a higher voltage may be used, but it should be noted that an excessively high tube voltage will lead to a loss of detection sensitivity. If there are different thicknesses imaged with one exposure, an averaged value of these thicknesses can be used.

8.2 Other radiation sources

The penetrated thickness ranges for gamma ray sources and X-ray equipment above 1 MeV are given in Table 2 for steels, cast irons, cobalt, copper and nickel based alloys.

For aluminium, magnesium, titanium and zinc testing using Se 75, the penetrated material thickness is 35 mm ≤ *w* ≤ 120 mm for class A.

Gamma rays from Se 75, Ir 192 and Co 60 sources will not produce radiographs having as good detection sensitivity as X-rays used with appropriate technique parameters. However because of the advantages of gamma ray sources in handling and accessibility, Table 2 gives a range of thicknesses for which each of these gamma ray sources may be used when the use of X-ray tubes is difficult.

By agreement between the contracting parties, the penetrated material thickness for Ir 192 may be further reduced to 10 mm and reduced to 5 mm for Se 75.

For certain applications wider material thickness ranges may be permitted, if sufficient image quality can be achieved.

For gamma rays, the total travel-time to and from the source position shall not exceed 10 % of the total exposure time.

Table 2 — Penetrated thickness range for gamma ray sources and X-ray equipment with energy above 1 MeV for steels, cast irons, cobalt, copper and nickel base alloys

Radiation source	Penetrated thickness w[a] mm	
	Class A	Class B
Se 75	$10 \leq w \leq 40$	$14 \leq w \leq 40$
Ir 192	$10 \leq w \leq 100$	$20 \leq w \leq 90$
Co 60	$40 \leq w \leq 200$	$60 \leq w \leq 150$
X-ray equipment with energy from 1 MeV to 4 MeV	$30 \leq w \leq 300$	$50 \leq w \leq 180$
X-ray equipment with energy from 4 MeV to 12 MeV	$w \geq 50$[b]	$w \geq 70$[b]
X-ray equipment with energy above 12 MeV	$w \geq 80$[b]	$w \geq 100$[b]

[a] If there are different thicknesses imaged with one exposure, an averaged value of these thicknesses can be used.

[b] The minimum penetrated wall thickness may be reduced by 10 mm in class A and by 20 mm in class B, if film system class C1 according to EN ISO 11699-1 is used, provided the IQI requirements are met.

9 Film systems and metal screens

For radiographic testing film system classes shall be used in accordance with EN ISO 11699-1.

For different radiation sources the minimum film system classes are given in Tables 3 and 4.

When using metal screens good contact between films and screens are required. This may be achieved either by using vacuum-packed films or by applying pressure.

Other screen thicknesses may be also agreed between the contracting parties provided the required image quality is achieved.

Table 3 — Film system classes and metal screens for the radiography of steels, cast irons, cobalt, copper and nickel base alloys

<table>
<tr><th rowspan="2">Radiation source</th><th rowspan="2">Penetrated thickness
w</th><th colspan="2">Film system class[a]</th><th colspan="2">Type and thickness of metal screens</th></tr>
<tr><th>Class A</th><th>Class B</th><th>Class A</th><th>Class B</th></tr>
<tr><td>X-ray potentials ≤ 100 kV</td><td rowspan="3">all w</td><td rowspan="3">C 5</td><td rowspan="2">C 3</td><td colspan="2">none or up to 0,03 mm front and back screens of lead</td></tr>
<tr><td>X-ray potentials > 100 kV to 150 kV</td><td colspan="2">up to 0,15 mm front and back screens of lead</td></tr>
<tr><td>X-ray potentials > 150 kV to 250 kV</td><td>C 4</td><td colspan="2">0,02 mm to 0,15 mm front and back screens of lead</td></tr>
<tr><td rowspan="2">X-ray potentials > 250 kV to 500 kV</td><td>w ≤ 50 mm</td><td rowspan="2">C 5</td><td>C 4</td><td colspan="2">0,02 mm to 0,2 mm front and back screens of lead</td></tr>
<tr><td>w > 50 mm</td><td>C 5</td><td colspan="2">0,1 mm to 0,2 mm front screens of lead[b]
0,02 mm to 0,2 mm back screens of lead</td></tr>
<tr><td rowspan="2">X-ray potentials > 500 kV to 1000 kV</td><td>w ≤ 75 mm</td><td>C 5</td><td>C 4</td><td colspan="2" rowspan="2">0,25 mm to 0,7 mm front and back screens of steel or copper[c]</td></tr>
<tr><td>w > 75 mm</td><td>C 5</td><td>C 5</td></tr>
<tr><td>Se 75</td><td>all w</td><td>C 5</td><td>C 4</td><td colspan="2">0,02 mm to 0,2 mm front and back screens of lead</td></tr>
<tr><td rowspan="2">Ir 192</td><td rowspan="2">all w</td><td rowspan="2">C 5</td><td rowspan="2">C 4</td><td>0,02 mm to 0,2 mm front screens of lead</td><td>0,1 mm to 0,2 mm front screens of lead[b]</td></tr>
<tr><td colspan="2">0,02 mm to 0,2 mm back screens of lead</td></tr>
<tr><td rowspan="2">Co 60</td><td>w ≤ 100 mm</td><td rowspan="2">C 5</td><td>C 4</td><td colspan="2" rowspan="2">0,25 mm to 0,7 mm front and back screens of steel or copper[c]</td></tr>
<tr><td>w > 100 mm</td><td>C 5</td></tr>
<tr><td rowspan="2">X-ray equipment with energy from 1 MeV to 4 MeV</td><td>w ≤ 100 mm</td><td rowspan="2">C 5</td><td>C 3</td><td colspan="2" rowspan="2">0,25 mm to 0,7 mm front and back screens of steel or copper[c]</td></tr>
<tr><td>w > 100 mm</td><td>C 5</td></tr>
<tr><td rowspan="3">X-ray equipment with energy from 4 MeV to 12 MeV</td><td>w ≤ 100 mm</td><td>C 4</td><td>C 4</td><td colspan="2" rowspan="3">up to 1 mm front screen of copper, steel or tantalum[d]
back screen of copper or steel up to 1 mm or tantalum up to 0,5 mm[d]</td></tr>
<tr><td>100 mm < w ≤ 300 mm</td><td rowspan="2">C 5</td><td>C 4</td></tr>
<tr><td>w > 300 mm</td><td>C 5</td></tr>
<tr><td rowspan="3">X-ray equipment with energy above 12 MeV</td><td>w ≤ 100 mm</td><td>C 4</td><td>C 1</td><td colspan="2" rowspan="2">up to 1 mm front screen of tantalum[e]
No back screen</td></tr>
<tr><td>100 mm < w ≤ 300 mm</td><td rowspan="2">C 5</td><td>C 4</td></tr>
<tr><td>w > 300 mm</td><td>C 5</td><td colspan="2">up to 1 mm front screen of tantalum[e] up to 0,5 mm back screen of tantalum</td></tr>
</table>

[a] Better film system classes may also be used, see EN ISO 11699-1.

[b] Ready packed films with a front screen up to 0,03 mm may be used if an additional lead screen of 0,1 mm is placed between the test object and the film.

[c] In class A also 0,5 mm to 2,0 mm screens of lead may be used.

[d] In class A lead screens 0,5 mm to 1 mm may be used by agreement between the contracting parties.

[e] Tungsten screens may be used by agreement.

Table 4 — Film system classes and metal screens for aluminium, magnesium, titanium and zinc

Radiation source	Film system class[a]		Type and thickness of intensifying screens
	Class A	Class B	
X-ray potentials ≤ 150 kV	C 5	C 3	none or up to 0,03 mm front and up to 0,15 mm back screens of lead
X-ray potentials > 150 kV to 250 kV			0,02 mm to 0,15 mm front and back screens of lead
X-ray potentials > 250 kV to 500 kV			0,1 mm to 0,2 mm front and back screens of lead
Se 75		not applicable	0,2 mm front[b] and 0,1 mm to 0,2 mm back screens of lead

[a] Better film system classes may also be used, see EN ISO 11699-1.

[b] Instead of one 0,2 mm lead screen, two 0,1 mm lead screens may be used.

10 Reduction of scattered radiation

10.1 Metal filters and collimators

In order to reduce the effect of scattered radiation, direct radiation shall be collimated as much as possible to the section under examination.

With Se 75, Ir 192 and Co 60 radiation sources or in case of edge scatter a sheet of lead can be used as a filter of low energy scattered radiation between the test object and the film. The thickness of this sheet is 0,5 mm to 2 mm in accordance with the penetrated thickness.

10.2 Interception of backscattered radiation

It shall be ensured that the effect of backscattered radiation is minimized.

If necessary, the film shall be shielded from backscattered radiation by an adequate thickness of lead at least 1 mm, or of tin at least 1,5 mm, placed behind the film-screen combination (or the cassette). The presence of backscattered radiation should be checked for each new test arrangement by a lead letter B (with a minimum height of 10 mm and a minimum thickness of 1,5 mm) placed immediately behind the cassette. If the image of this symbol records as a lighter image on the radiograph, it shall be rejected. If the symbol is darker or invisible the radiograph is acceptable and demonstrates good protection against scattered radiation.

11 Source-to-object distance

The minimum source-to-object distance $f_{\min}$ depends on the source size or focal spot size d and on the object-to-film distance b. The source size or focal spot size d shall be in accordance with EN 12543 or EN 12679.

When the source size or focal spot size is specified by two dimensions, the larger shall be used.

For exposure geometries, except for those in Figures 2 b) and 3 b), the distance *f* shall be chosen so that the ratio of this distance to the source size *d*, i.e. *f*/*d*, is not below the values given by Formulae (1) and (2):

For class A:

$$f / d \geq 7,5(b)^{2/3} \quad (1)$$

For class B:

$$f / d \geq 15(b)^{2/3} \quad (2)$$

where

b is given in millimetres (mm).

If the distance $b < 1,5\ t$ the dimension *b* in Formulae (1) and (2) and Figure 14 shall be replaced by the wall thickness *t*.

For determination of the source-to-object distance $f_{\min}$ the nomogram in Figure 14 may be used. The nomogram is based on Formulae (1) and (2).

For exposure geometries set on the basis of Figures 2 b) and 3 b), the distance *f* shall be chosen so that the ratio of this distance to the source size, *d*, i.e. *f*/*d*, is not below the values given by Formulae (3) and (4):

For class A:

$$\frac{f}{d} \geq 7,5 \frac{b}{\sqrt[3]{t}} \quad (3)$$

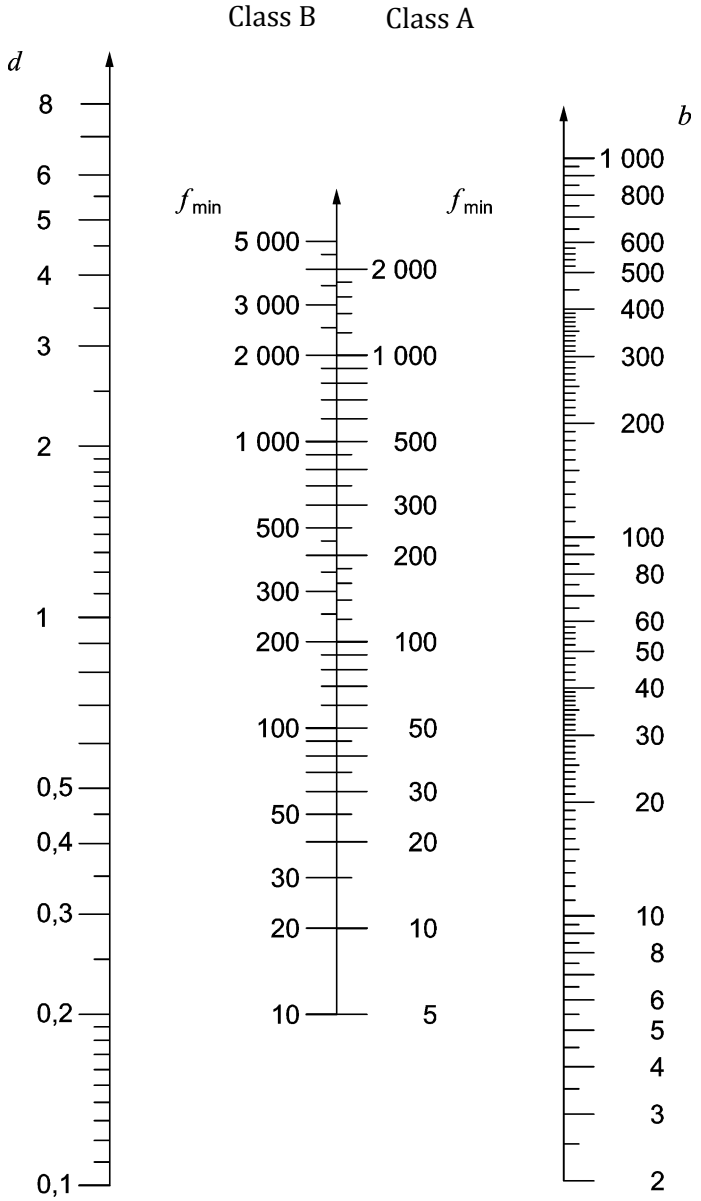
For class B:

$$\frac{f}{d} \geq 15 \frac{b}{\sqrt[3]{t}} \quad (4)$$

where

t is the wall thickness to test, in millimetres (mm);

b is the object-to-film distance, in millimetres (mm).



Key

b object-to-film distance in mm

d source size in mm

f_{min} minimum source-to-object distance in mm

NOTE This Nomogram does not apply for exposure geometries as shown in Figures 2 b) and 3 b).

Figure 14 — Nomogram for f_{min} in relation to *b* and *d*

If the radiation source could be placed inside the test object to be radiographed (techniques shown in Figures 3 and 4) to achieve a more suitable direction of exposition and when a double wall technique (see Figures 5 to 7) is avoided this method should be preferred. The reduction in minimum source-to-object distance should not be greater than 40 %.

When the source is located centrally inside the test object and film outside (technique shown in Figure 4) and provided that the IQI requirements are met, this percentage may be increased. However, the reduction in minimum source-to-object distance shall not be greater than 50 %.

12 Optical density *D* of radiograph

Exposure conditions should be such that the minimum optical density of the radiograph in the area examined is greater than or equal to those given in Table 5.

Table 5 — Optical density of the radiographs

Class	Optical density D[a,b]
A	≥ 2,0
B	≥ 2,3

[a] A measuring tolerance of ± 0,1 is permitted.

[b] For test areas with different wall thicknesses an optical density > 1,5 for class A and > 2,0 for class B is sufficient, if the image quality requirements given in Tables A.1 to A.3 are met.

High optical densities can be used with advantage where the viewing light is sufficiently bright in accordance with 13.2. The maximum readable optical density of the film depends on the film viewer used and its maximum luminance (see EN 25580). The maximum readable optical density shall be posted on the viewer.

In order to avoid unduly high fog densities arising from film ageing, development or temperature, the fog density shall be checked periodically on a non-exposed sample taken from the films being used, and handled and processed under the same conditions as the actual radiograph. The fog density shall not exceed 0,3. Fog density here is specified as the total optical density (emulsion and base) of a processed, unexposed film.

If double film viewing is requested the optical density of one single film shall not be lower than 1,3.

13 Film processing and viewing

13.1 Processing

Films are processed in accordance with the conditions recommended by the film and chemical manufacturer to obtain the selected film system class. Particular attention shall be paid to temperature, developing time and washing time. The film processing shall be controlled regularly in accordance with EN ISO 11699-2. The radiographs should be free from defects due to processing or other causes which would interfere with interpretation.

13.2 Film viewing conditions

The radiographs should be examined in a darkened room on an area of the viewing screen with an adjustable luminance in accordance with EN 25580. The viewing screen should be masked to the area of interest.

14 Techniques for increasing the covered thickness range

14.1 General

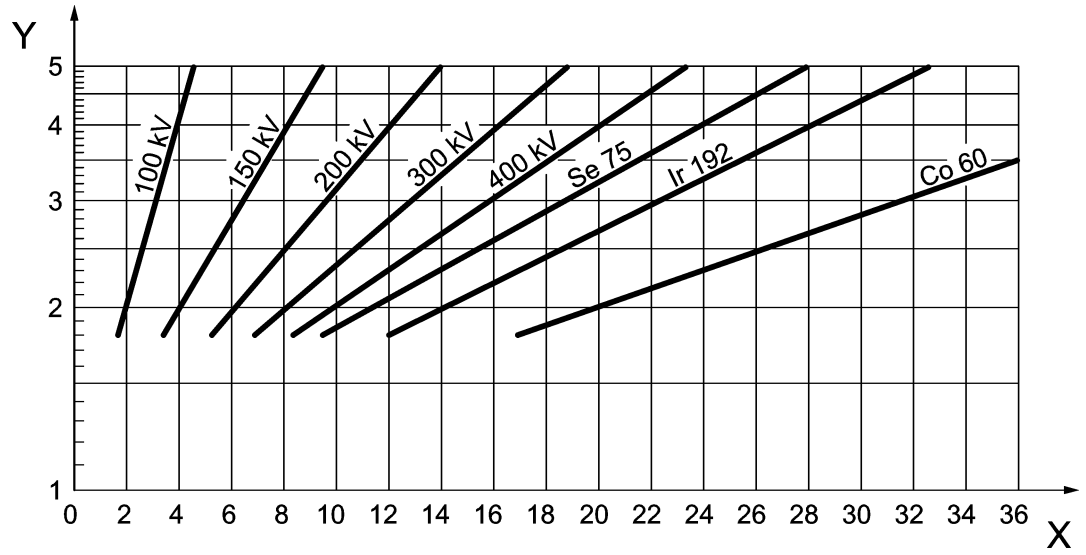
In many applications it is useful to image a larger thickness range within one film exposure. Figure 15 provides information on the expected thickness range (difference between maximum penetrated thickness and minimum penetrated thickness) for steels and cast irons depending on the optical density ratio in the radiograph. This can be done by one of the following techniques:

— multiple film technique;

— contrast decreasing by higher radiation energy;

— contrast decreasing by beam hardening;

— contrast decreasing by thickness equalization.



Key

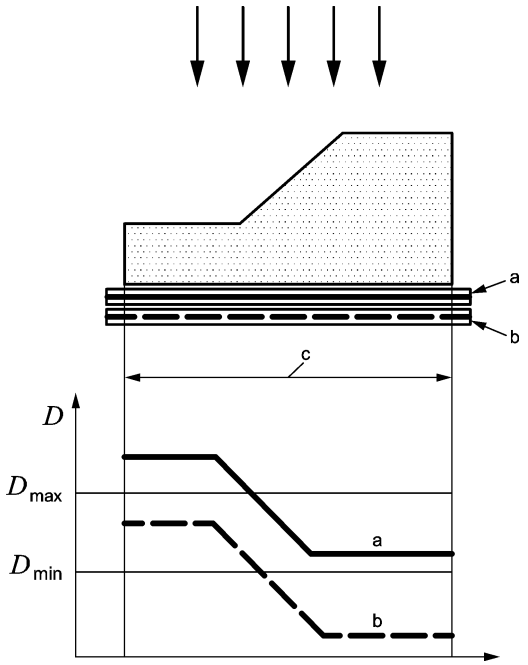
X Thickness range in millimetres (mm)

Y Quotient of optical density D_{max}/D_{min} for films

Figure 15 — Estimation of possible covered thickness range for different radiation energy levels for steels and cast irons

14.2 Multiple film technique

For multiple film technique two or more films with different sensitivities are exposed at the same time (see Figure 16) and viewed singly or together.



Key

D optical density of film

a film system with a higher film system class (higher ISO speed, see EN ISO 11699-1)

b film system with a lower film system class (lower ISO speed, see EN ISO 11699-1)

c lateral dimension

Figure 16 — Arrangement for multiple film technique

There shall be at least one screen between each of the films. When paper backed lead screens are used for film radiography 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 Tables 3 and 4.

Areas on the radiograph with high light intensities shall be masked to avoid dazzle while 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 radiographs shall correspond.

If double film viewing is used the optical density of a single film (see Clause 12) shall not be less than 1,3.

14.3 Contrast decreasing by higher radiation energy

For X-ray sources up to 800 kV, the maximum permissible tube voltage according to Figure 13 may be exceeded by max. 30 %. For increasing the covered thickness range, X-ray sources may be replaced by gamma ray sources or linear accelerators.

The image quality requirement(s) given in Tables A.1 to A.3 shall be met.

14.4 Contrast decreasing by beam hardening

Beam hardening for contrast decreasing is permissible, if the image quality requirement(s) given in Tables A.1 to A.3 are met.

14.5 Contrast decreasing by thickness equalization

In radiography imaging different wall thicknesses with one exposure on one radiograph is possible by covering the area of thinner wall thickness - which is imaged on the radiograph with higher optical density of the film - with material equalizing the differences in wall thickness, so that the requirements of optical density of the film according to Clause 12 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 test area.

15 Requirements on radiographs

15.1 Identification of radiograph, test area, film position plan

There shall be a clear identification of the test area and of the corresponding radiograph.

For castings which require a large number of radiographs a film position plan or photo documentation shall be prepared. The position of each film and the corresponding test areas shall have a clearly specified co-ordination.

In cases where the test arrangement figure according to this European Standard does not specify the position of the radiation source, either a special plan of the radiation sources shall be prepared or the radiation source shall be noted in the film position plan or a photo documentation.

15.2 Marking of the test areas

Permanent markings on the test object to be examined shall be made in order to accurately locate the position of each radiograph (e.g. zero point, direction, identification, measure).

Where the nature of the material and/or its service conditions does not permit permanent marking, the location may be recorded by means of accurate sketches or photographs.

15.3 Overlap of films

When radiographing an area with two or more separate films, the films shall overlap sufficiently to ensure that all the test area is radiographed. This shall be verified by high density markings placed on the surface of the test object which will appear on each film.

16 Verification of image quality

Unless otherwise agreed, the image quality shall be verified by the use of IQI in accordance with EN ISO 19232-1 or EN ISO 19232-2. The image quality requirement(s) given in Tables A.1 to A.3 shall be met. If the IQIs cannot be placed on the casting in accordance with these standards, the image quality shall be verified by one representative test object with an IQI on it on the same film. If a high number of radiographs have to be taken under the same conditions with one exposure, the image quality shall be verified by at least one IQI on at least one film. When an area with different wall thicknesses has to be radiographed, the IQI shall be positioned at the test area with the largest wall thickness.

The IQI shall be placed on the source side of the test object. If this is not possible it shall be placed on the film side and marked with “F” using high absorbing material.

For exposures of circular test objects with diameters of 200 mm and above with the source centrally located, at least three IQIs shall be placed equally spaced at the circumference.

The wall thickness in the area of the location of the IQI and the IQI type shall be recorded, in order to make a verification of the image quality.

17 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 radiation side and the film.

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

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

18 Acceptance criteria

18.1 General

Different acceptance criteria can be specified for different types of discontinuities and for different areas of the same casting (e.g. marked area and unmarked area or rim zone and core zone).

Acceptance criteria are specified by severity levels, see 18.2 and Annexes B to F.

The radiographs shall be evaluated by comparison to reference radiographs.

The casting shall be considered as conforming to this standard when the observed severity level is equal to or better than that specified in the order.

For nominal wall thicknesses outside the ranges given in the Annexes B to F the acceptance criteria shall be agreed between the manufacturer and the purchaser.

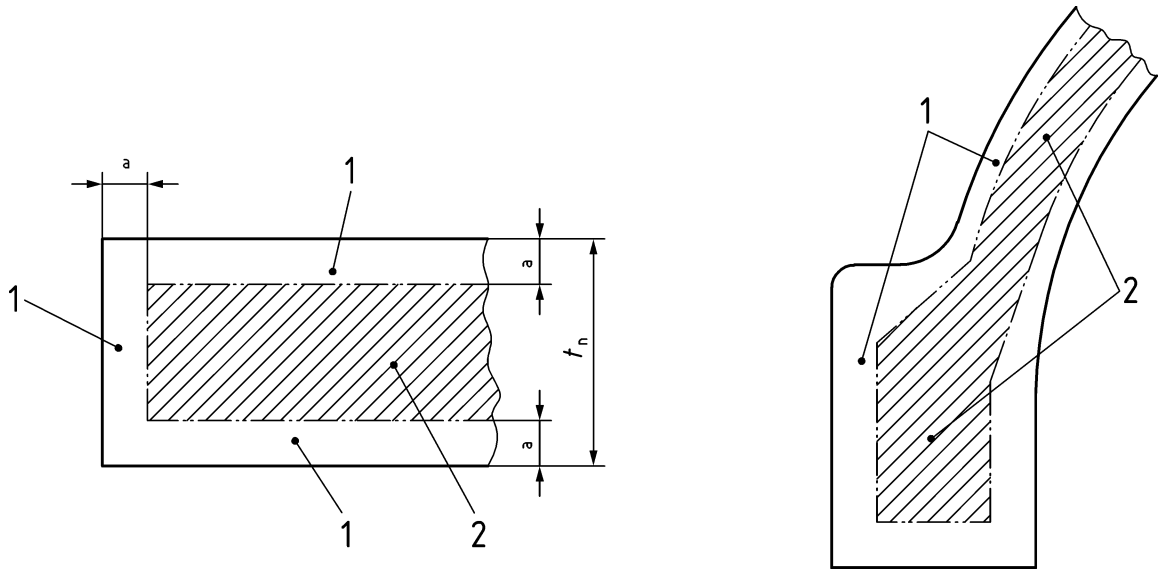
18.2 Severity levels

For castings produced in a material as listed in the scope of this European Standard, severity levels with the corresponding maximum discontinuity size and reference radiographs are given in the normative Annexes: Annex B (steel castings and investment steel castings), Annex C (cast iron castings), Annex D (aluminium alloy and magnesium alloy castings and die castings), Annex E (copper alloy castings) and Annex F (titanium and titanium alloy castings).

18.3 Wall section zones

The wall section shall be divided into zones as shown in Figure 17. For nominal wall thicknesses equal or less 10 mm the total wall thickness shall be considered as rim zone.

Unless otherwise agreed these wall sections shall relate to the dimensions of the casting in the “as delivered” condition.



Key

1 rim zone
2 core zone
t_n nominal wall thickness
a $t_n/5$ (min. 5 mm, max. 30 mm)

Figure 17 — Division of wall into zones

19 Test report

For each exposure or set of exposures a test report shall be prepared in accordance with EN ISO 5579.

The test report shall include at least the following information:

a) name of the inspection body which performs the test;

b) number of this European Standard (EN 12681-1);

c) casting designation;

d) casting identification;

e) material designation;

f) manufacturing stage, e.g. heat treatment;

g) material thickness;

h) acceptance criteria;

i) specification of testing;

j) radiographic technique and class, required IQI sensitivity in accordance with this European Standard;

k) test arrangement;

l) system of marking used;

m) film position plan or photo documentation;

n) radiation source, type and size of focal spot and identification of equipment used;

o) film type and system, screens and filters;

p) used tube voltage and current or source type and activity;

q) time of exposure and source-to-film distance;

r) film processing technique: manual/automatic, and development conditions;

s) type and position of image quality indicators;

t) single or double film viewing;

u) results of testing including data on the optical density of the film, IQI readings;

v) any deviation from this standard, by special agreement;

w) name, certification and signature of the responsible person(s);

x) date(s) of exposure and test report.

Annex A
(normative)

Minimum image quality values

The requirements on image quality in class A and B testing consider the good workmanship quality for general casting applications.

Table A.1 and Table A.2 provide minimum image quality requirements for the visibility of wire IQIs and step hole IQIs for class A or B. The IQIs shall be located on the source side of the objects to test. Only if this is not possible the IQIs may be located on the film side. If a single wall of a hollow part at film side is tested, the IQIs may be located inside the test object on the source side of the wall to test.

Table A.1 — Image Quality requirements for testing class A

Penetrated thickness		**Minimum wire IQI value**	**Maximum step hole IQI value**	**Minimum wire IQI value**	**Maximum step hole IQI value**
Lower thickness limit mm	**Upper thickness limit** mm	**IQI at source side**		**IQI at film side**[a]	
	1,2	W 18	H 2	W 18	H 2
> 1,2	2	W 17	H 3	W 17	H 3
> 2	3,5	W 16	H 4	W 16	H 4
> 3,5	5	W 15	H 5	W 15	H 5
> 5	7	W 14	H 6	W 14	H 6
> 7	10	W 13	H 7	W 13	H 7
> 10	15	W 12	H 8	W 12	H 8
> 15	25	W 11	H 9	W 11	H 9
> 25	32	W 10	H 10	W 11	H 9
> 32	40	W 9	H 11	W 10	H 10
> 40	55	W 8	H 12	W 9	H 11
> 55	85	W 7	H 13	W 8	H 12
> 85	150	W 6	H 14	W 7	H 13
> 150	200	W 5	H 15	W 7	H 13
> 200	250	W 4	H 15	W 7	H 13
> 250	380	W 3	H 16	W 7	H 13
> 380		W 2	H 17	W 6	H 14

[a] IQI may be located on film side only, if positioning on source side is not possible

Table A.2 — Image quality requirements for testing class B

Penetrated thickness		Minimum wire IQI value	Maximum step hole IQI value	Minimum wire IQI value	Maximum step hole IQI value
Lower thickness limit mm	Upper thickness limit mm	IQI at source side		IQI at film side[a]	
	2	W 18	H 2	W 18	H 2
> 2	3,5	W 17	H 3	W 17	H 3
> 3,5	5	W 16	H 4	W 16	H 4
> 5	7	W 15	H 5	W 15	H 5
> 7	10	W 14	H 6	W 14	H 6
> 10	15	W 13	H 7	W 13	H 7
> 15	25	W 12	H 8	W 12	H 8
> 25	32	W 11	H 9	W 11	H 9
> 32	40	W 10	H 10	W 11	H 9
> 40	55	W 9	H 11	W 10	H 10
> 55	85	W 8	H 12	W 9	H 11
> 85	150	W 7	H 13	W 8	H 12
> 150	200	W 6	H 14	W 7	H 13
> 200	250	W 5	H 15	W 7	H 13
> 250	380	W 4	H 15	W 7	H 13
> 380		W 3	H 16	W 7	H 13

[a] IQI may be located on film side only, if positioning on source side is not possible

Tables A.1 and A.2 show the minimum image quality values for metallic materials. If the image quality is disturbed by mottling effects the image quality values may be determined in accordance with EN ISO 19232-4 by agreement between the contracting parties.

In the case where Ir 192 or Se 75 sources are used, IQI values worse than the ones listed in Tables A.1 to A.2 may be accepted as shown in Table A.3.

Table A.3 — Image quality exceptions for gamma radiographic testing

	Lower thickness[a,b] limit mm	**Upper thickness[a,b] limit** mm	**Wires IQI value change in relation to Tables A.1 or A.2**	**Step holes IQI value change in relation to Tables A.1 or A.2**
Ir 192, class A	10	< 24	2 IQI values less	2 IQI values more
	24	≤ 30	1 IQI value less	1 IQI value more
Ir 192, class B	10	≤ 40	1 IQI value less	1 IQI value more
Se 75, class A	5	≤ 24	1 IQI value less	1 IQI value more
Se 75, class B	5	≤ 20	1 IQI value less	1 IQI value more

a Penetrated thickness

b For selection of thickness range for gamma radiography, see 8.2 and Table 2.

Annex B
(normative)

Severity levels for steel castings

Acceptance criteria for steel castings are given in Table B.1 and for investment steel castings in Table B.2.

Table B.1 — Severity levels for steel castings with corresponding maximum permissible discontinuity and reference radiograph

Discontinuity		Nominal wall thickness	Applicable ASTM standard	Severity level				
		t_n		1	2[b]	3[b]	4[b]	5
Type	Category[a]	mm		Maximum permissible discontinuity/Reference radiograph[a]				
Blowholes	A	$t_n \leq 51$	E 446:2014	A1	A3	A3	A4	A5
		$51 < t_n \leq 114$	E 186:2010	A1	A3	A3	A4	A5
		$114 < t_n \leq 305$	E 280:2010	[c]	A3	A3	A4	A5
Non-metallic inclusions	B	$t_n \leq 51$	E 446:2014	B1	B3	B3	B4	B5
		$51 < t_n \leq 114$	E 186:2010	B1	B3	B3	B4	B5
		$114 < t_n \leq 305$	E 280:2010	[c]	B3	B3	B4	B5
Shrinkage	C	$t_n \leq 51$	E 446:2014	Ca1, Cb1, Cc1, Cd1	Ca2, Cb2, Cc2, Cd2	Ca3, Cb3, Cc3, Cd3	Ca4, Cb4, Cc4, Cd4	Ca5, Cb5, Cc5, Cd5
		$51 < t_n \leq 114$	E 186:2010	C1–1, C2–1, C3–1	C1–3, C2–2, C3–2	C1–3, C2–3, C3–3	C1–4, C2–4, C3–4	C1–5, C2–5, C3–5
		$114 < t_n \leq 305$	E 280:2010	C1–1, C2–1, C3–1[c]	C1–2, C2–2, C3–2	C1–3, C2–3, C3–3	C1–4, C2–4, C3–4	C1–5, C2–5, C3–5
Cracks	D + E	$t_n \leq 51$	E 446:2014	n.p.[e]				D, E[f]
		$51 < t_n \leq 114$	E 186:2010					
		$114 < t_n \leq 305$	E 280:2010					
Inserts	F	$t_n \leq 51$	E 446:2014	n.p.[e]			F[d]	F
		$51 < t_n \leq 114$	E 186:2010				F	F
		$114 < t_n \leq 305$	E 280:2010				F	F

Discontinuity		Nominal wall thickness	Applicable ASTM standard	Severity level				
Type	Category[a]	t_n mm		1	2[b]	3[b]	4[b]	5
				Maximum permissible discontinuity/Reference radiograph[a]				

a See applicable ASTM Standard.

b If it can be shown (for example by ultrasonic testing) that the discontinuity is located in the core zone, the requirement for the next higher severity level value applies, unless otherwise specified in the material standard or order.

c The values to be adhered to should be agreed.

d Chaplets may be present, but they should be welded free from cracks at the surface.

e Not permitted.

f The permitted length of cracks should be agreed.

Table B.2 — Severity levels for investment steel castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 192:2013

Discontinuity			Plate thickness[a]	Nominal wall thickness	Severity level			
Type		Code[a]	mm	t_n mm	1	2	3	4
					Maximum permissible discontinuity/Reference radiograph[a]			
Gas holes		3.2.1.1	3,2	$t_n \leq 6,4$	2	3	5	6
			9,5	$6,4 < t_n \leq 12,7$	2	3	5	6
			19,1	$12,7 < t_n < 25,4$	2	3	4	5
Shrinkage	cavity	3.2.2.1	19,1	$t_n \leq 25,4$	none	1	2	3
	sponge	3.2.2.2	3,2	$t_n \leq 6,4$	1	3	5	6
			9,5	$6,4 < t_n \leq 12,7$	1	2	3	4
			19,1	$12,7 < t_n \leq 25,4$	1	2	4	5
	dendritic	3.2.2.3	3,2	$t_n \leq 6,4$	1	3	4	5
			9,5	$6,4 < t_n \leq 12,7$	1	3	4	5
			19,1	$12,7 < t_n \leq 25,4$	1	3	4	5
	filamentary	3.2.2.4	19,1	$t_n \leq 25,4$	none	1	2	3
Foreign materials	less dense	3.2.3.1	3,2	$t_n \leq 6,4$	2	4	5	6
			9,5	$6,4 < t_n \leq 12,7$	2	4	5	6
			19,1	$12,7 < t_n \leq 25,4$	2	4	5	6
	more dense[b]	3.2.3.2	9,5	$t_n \leq 25,4$	n.p.[c]			

Discontinuity			Plate thickness[a]	Nominal wall thickness	Severity level			
				t_n	1	2	3	4
Type		Code[a]	mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Discrete discontinuities	hot tear	3.2.4.1	9,5	$t_n \leq 25,4$	n.p.[c]			
	cold crack	3.2.4.2			n.p.[c]			
	cold shut	3.2.4.3			n.p.[c]			
	misrun	3.2.4.4			n.p.[c]			
	core shift	3.2.4.5			n.p.[c]			
Defective mould	mould buckle positive	3.2.5.1			Maximum allowable deviation shall be agreed between the manufacturer and the purchaser			
	mould buckle negative	3.2.5.2						
	mould ridge	—						
	excess metal in cracked core	—						
Diffraction pattern	columnar	3.2.6.1			n.p.[c]			
	mottled	3.2.6.2						

a See ASTM E 192.

b Single illustrations, not classified.

c Not permitted.

Annex C
(normative)

Severity levels for cast iron castings

Acceptance criteria for spheroidal graphite cast iron castings are given in Table C.1 or Table C.2 and for grey cast iron castings in Table C.3.

Acceptance criteria for spheroidal graphite cast iron castings and grey cast iron castings are also available in DGZFP Guideline D5.

Table C.1 — Severity levels for spheroidal graphite cast iron castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM Standards

Discontinuity		**Nominal wall thickness**	**Applicable ASTM standard**	**Severity level**				
		t_n		1	2	3	4	5
Type	**Category**[a]	mm		**Maximum permissible discontinuity/Reference radiograph**[a]				
Gas porosity	A	$t_n \leq 51$	E 689:2010, E 446:2014	A1	A3	A4	A5	A5
		$51 < t_n \leq 114$	E 689:2010, E 186:2010	A1	A3	A3	A4	A5
		$114 < t_n \leq 305$	E 689:2010 E 280:2010	b	A3	A3	A4	A5
Sand and slag inclusions	B	$t_n \leq 51$	E 689:2010, E 446:2014	B1	B1	B3	B4	B5
		$51 < t_n \leq 114$	E 689:2010, E 186:2010	B1	B3	B3	B4	B5
		$114 < t_n \leq 305$	E 689:2010 E 280:2010	b	B3	B3	B4	B5
Shrinkage	C	$t_n \leq 51$	E 689:2010, E 446:2014	Ca1, Cb1, Cc1, Cd1	Ca1, Cb1, Cc1, Cd1	Ca2, Cb2, Cc2, Cd2	Ca3, Cb3, Cc3, Cd2	Ca5, Cb4, Cc4, Cd3
		$51 < t_n \leq 114$	E 689:2010, E 186:2010	C1–1, C2–1, C3–1	C1–3, C2–2, C3–2	C1–3, C2–3, C3–3	C1–4, C2–4, C3–4	C1–5, C2–5, C3–5
		$114 < t_n \leq 305$	E 689:2010, E 280:2010	C1–1, C2–1, C3–1[c]	C1–2, C2–2, C3–2	C1–3, C2–3, C3–3	C1–4, C2–4, C3–4	C1–5, C2–5, C3–5
Crack	D	$t_n \leq 305$	E 689:2010, E 446:2014, E 186:2010,	n.p.[c]				
Hot tear	E	$t_n \leq 305$						

Discontinuity		Nominal wall thickness	Applicable ASTM standard	Severity level				
				1	2	3	4	5
Type	Category[a]	t_n mm		Maximum permissible discontinuity/Reference radiograph[a]				
Insert	F	$t_n \leq 305$	E 280:2010					
Mottling	G	$t_n \leq 305$						

a See applicable ASTM Standard.

b The values to be adhered to should be agreed between the manufacturer and the purchaser.

c Not permitted.

Table C.2 — Severity levels for spheroidal graphite cast iron castings with corresponding maximum permissible discontinuity and reference radiograph according VDG P 541:2001, Reference radiograph catalogue

Discontinuity		Nominal wall thickness	Severity level				
			1	2	3	4	5
Type	Category	t_n mm	Maximum permissible discontinuity/Reference radiograph				
Gas porosity	A	$50 < t_n \leq 100$	A1	A2	A3	A4	A5
		$100 < t_n \leq 250$	A1	A2	A3	A4	A5
		$250 < t_n \leq 400$	A1	A2	A3	A4	A5
Sand and slag inclusions	B	$50 < t_n \leq 100$	B1	B2	B3	B4	B5
		$100 < t_n \leq 250$	B1	B2	B3	B4	B5
		$250 < t_n \leq 400$	B1	B2	B3	B4	B5
Shrinkage	C	$50 < t_n \leq 100$	C1	C2	C4	C6	C7
		$100 < t_n \leq 250$	C2	C3	C5	C7	C8
		$250 < t_n \leq 400$	C3	C4	C6	C7	C8
Dross[a]	D	$50 < t_n \leq 400$	Maximum permissible discontinuity shall be agreed between the manufacturer and the purchaser.				

a Single illustrations, not classified.

Table C.3 — Severity levels for grey cast iron castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM Standards

Discontinuity		Nominal wall thickness	Applicable ASTM standard	Severity level				
Type	Category[a]	t_n mm		1	2	3	4	5
				Maximum permissible discontinuity/Reference radiograph[a]				
Gas porosity	A	$t_n \leq 51$	E 802:1995, E 446:2014	A1	A3	A4	A5	A5
		$51 < t_n \leq 114$	E 802:1995, E 186:2010	A1	A3	A3	A4	A5
Sand and slag inclusions	B	$t_n \leq 51$	E 802:1995, E 446:2014	B1	B1	B3	B4	B5
		$51 < t_n \leq 114$	E 802:1995, E 186:2010	B1	B3	B3	B4	B5
Shrinkage	C	$t_n \leq 51$	E 802:1995, E 446:2014	Ca1, Cb1, Cc1, Cd1	Ca1, Cb1, Cc1, Cd1	Ca2, Cb2, Cc2, Cd2	Ca3, Cb3, Cc3, Cd2	Ca5, Cb4, Cc4, Cd3
		$51 < t_n \leq 114$	E 802:1995, E 186:2010	C1–1, C2–1, C3–1	C1–3, C2–2, C3–2	C1–3, C2–3, C3–3	C1–4, C2–4, C3–4	C1–5, C2–5, C3–5
Centerline shrinkage		$t_n \leq 114$	E 802:1995	1	2	3	3	4
Crack	D	$t_n \leq 114$	E 802:1995, E 446:2014, E 186:2010	n.p.[b]				
Hot tear	E	$t_n \leq 114$						
Insert	F	$t_n \leq 114$						

a See applicable ASTM Standard.

b Not permitted.

Annex D
(normative)

Severity levels for aluminium alloy and magnesium alloy castings

Acceptance criteria for aluminium and magnesium alloy castings are given in Tables D.1 to D.5.

Table D.1 — Severity levels for aluminium alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 155:2010

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
Type	Description in subclause of ASTM E 155[a]		t_n	1	2	3	4
		mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Gas holes	3.2.3	6,4	$t_n \leq 12,7$	1	2	5	6
		19,1	$12,7 < t_n \leq 51$	1	2	5	6
Gas porosity, round	3.2.4	6,4	$t_n \leq 12,7$	1	2	5	7
		19,1	$12,7 < t_n \leq 51$	1	2	5	7
Gas porosity, elongated	3.2.4	6,4	$t_n \leq 12,7$	1	2	4	6
		19,1	$12.7 < t_n \leq 51$	1	2	3	6
Shrinkage, cavity	3.2.9	6,4	$t_n \leq 51$	n.p.[b]	1	2	4
Shrinkage, sponge	3.2.10	6,4	$t_n \leq 12,7$	1	2	4	5
		19,1	$12,7 < t_n \leq 51$	1	2	3	6
Foreign material, less dense	3.2.2	6,4	$t_n \leq 12,7$	1	2	4	6
		19,1	$12,7 < t_n \leq 51$	1	2	4	6
Foreign material, more dense	3.2.2	6,4	$t_n \leq 12,7$	1	2	4	6
		19,1	$12,7 < t_n \leq 51$	n.p.[b]	1	3	5

[a] See ASTM E 155, Volume 1.

[b] Not permitted.

Table D.2 — Severity levels for magnesium alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 155:2010

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
Type	Description in subclause of ASTM E 155 [a]	mm	t_n mm	1	2	3	4
				Maximum permissible discontinuity/Reference radiograph[a]			
Gas holes	3.2.3	6,4	$t_n \leq 12,7$	1	3	5	7
		19,1	$12,7 < t_n \leq 51$	1	3	4	6
Microshrinkage, feathery	3.2.5	6,4	$t_n \leq 12,7$	1	3	5	7
		19,1	$12,7 < t_n \leq 51$	1	2	3	5
Microshrinkage, sponge	3.2.6	6,4	$t_n \leq 12,7$	1	2	3	5
		19,1	$12,7 < t_n \leq 51$	1	2	3	5
Foreign material, less dense	3.2.2	6,4	$t_n \leq 12,7$	1	2	4	6
		19,1	$12,7 < t_n \leq 51$	1	3	4	6
Foreign material, more dense	3.2.2	6,4	$t_n \leq 12,7$	n.p.[b]	1	3	5
		19,1	$12,7 < t_n \leq 51$	n.p.[b]	1	2	4

[a] See ASTM E 155, Volume 1.

[b] Not permitted.

Table D.3 — Severity levels for magnesium alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 155:2010

Discontinuity			Plate thickness[a]	Nominal wall thickness	Severity level			
Type		Description in subclause of ASTM E 155[a]		t_n	1	2	3	4
			mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Reacted sand inclusions		3.2.7	6,4	$t_n \leq 51$	n.p.[b]	1	2	4
Gravity segregation		3.2.8.1	6,4	$t_n \leq 51$	1	2	3	5
Eutectic segregation	Micro-shrinkage type	3.2.8.2	6,4	$t_n \leq 51$	1	3	5	6
	Pipeshrink with eutectic segregation[c]		6,4	$t_n \leq 51$	n.p.[b]	Maximum permissible discontinuity shall be agreed between the manufacturer and the purchaser.		
	Hot tears with eutectic segregation[c]		6,4	$t_n \leq 51$				
	Flow line[c]		6,4	$t_n \leq 51$				
	Oxide inclusions in alloys containing Zr[c]		6,4	$t_n \leq 51$				

a See ASTM E 155, Volume 2.

b Not permitted.

c Single illustration, not classified.

Table D.4 — Severity levels for aluminium alloy die castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 505:2001

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
			t_n	1	2	3	4
Type	Category[a]	mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Porosity	A	3,2	$t_n \leq 9,5$	n.p.[b]	1	2	3
		15,9	$9,5 < t_n \leq 25,4$	1	2	3	3
Cold fill	B	3,2	$t_n \leq 9,5$	n.p.[b]	1	2	3
Shrinkage	C	15,9	$9,5 < t_n \leq 25,4$	n.p.[b]	1	2	3
Foreign material[c]	D	5,1	$t_n \leq 25,4$	Maximum permissible discontinuity shall be agreed between the manufacturer and the purchaser.			

a See ASTM standard E 505.

b Not permitted.

c Single illustration, not classified.

Table D.5 — Severity levels for magnesium alloy die castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 505:2001

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
			t_n	1	2	3	4
Type	Category[a]	mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Porosity	A	3,2	$t_n \leq 9,5$	n.p.[b]	1	2	3
		15,9	$9,5 < t_n \leq 25,4$	1	2	3	3
Cold fill	B	3,2	$t_n \leq 9,5$	n.p.[b]	1	2	3
Shrinkage	C	15,9	$9,5 < t_n \leq 25,4$	n.p.[b]	1	2	3
Foreign material[c]	D	3,2	$t_n \leq 25,4$	Maximum permissible discontinuity shall be agreed between the manufacturer and the purchaser.			

a See ASTM standard E 505.

b Not permitted.

c Single illustration, not classified.

Annex E
(normative)

Severity levels for copper alloy castings

Acceptance criteria for copper alloy castings are given in Tables E.1 and E.2.

Table E.1 — Severity levels for high strength copper base and nickel copper alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 272:2010

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
Type	Category		t_n	1	2	3	4
		mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Gas porosity	A	25,4	$t_n \leq 51$	1	2	3	4
		76	$51 < t_n \leq 152$	1	2	3	4
Sand inclusions	Ba	25,4	$t_n \leq 51$	n.p.[b]	1	2	4
		76	$51 < t_n \leq 152$	n.p.[b]	1	2	3
Dross inclusions	Bb	25,4	$t_n \leq 51$	n.p.[b]	1	2	4
		76	$51 < t_n \leq 152$	n.p.[b]	1	2	4
Shrinkage, linear	Ca	76	$51 < t_n \leq 152$	n.p.[b]	1	2	3
Shrinkage, feathery	Cb	25,4	$t_n \leq 51$	n.p.[b]	2	3	4
Shrinkage, spongy	Cc	76	$51 < t_n \leq 152$	n.p.[b]	1	2	3

a See ASTM E 272.

b Not permitted.

Table E.2 — Severity levels for copper tin alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 310:2010

Discontinuity		Nominal wall thickness	Severity level			
Type	Category[a]	t_n mm	1	2	3	4
			Maximum permissible discontinuity/Reference radiograph[a]			
Gas porosity	A	$t_n \leq 51$	1	2	3	4
Sand and slag inclusion	B	$t_n \leq 51$	n.p.[b]	1	2	4
Shrinkage, linear	Ca	$t_n \leq 51$	n.p.[b]	1	2	4
Shrinkage, spongy and feathery	Cd	$t_n \leq 51$	n.p.[b]	1	2	3
Hot tear[b]	Da	$t_n \leq 51$	n.p.[b]			
Insert, chaplet[c]	Eb	$t_n \leq 51$	n.p.[b]			

a See ASTM E 310.

b Not permitted.

c Single illustration, not classified.

Annex F
(normative)

Severity levels for titanium and titanium alloy castings

Acceptance criteria for titanium and titanium alloy castings with a nominal wall thickness up to and including 25,4 mm are given in Table F.1.

For castings with a nominal wall thickness between 25,4 mm and up to and including 51 mm, the acceptance criteria shall be agreed between the manufacturer and the purchaser in accordance with ASTM E 1320 Volume 2.

Table F.1 — Severity levels for titanium and titanium alloy castings with corresponding maximum permissible discontinuity and reference radiograph according ASTM E 1320:2010

Discontinuity		Plate thickness[a]	Nominal wall thickness	Severity level			
			t_n	1	2	3	4
Type	Description in subclause of ASTM E 1320[a]	mm	mm	Maximum permissible discontinuity/Reference radiograph[a]			
Gas holes	5.1.1.1	N/A	$t_n \leq 25,4$	n.p.[b]	4[c]	6[d]	7[e]
Clustered gas holes	5.1.1.2	6,4	$t_n \leq 9,5$	n.p.[b]	5	6	7
		12,7	$9,5 < t_n \leq 15,9$	n.p.[b]	3	4	5
		19,1	$15,9 < t_n \leq 25,4$	n.p.[b]	3	4	6
Scattered gas holes	5.1.1.3	6,4	$t_n \leq 9,5$	n.p.[b]	3	4	5
		12,7	$9,5 < t_n \leq 15,9$	n.p.[b]	2	3	5
		19,1	$15,9 < t_n \leq 25,4$	n.p.[b]	2	3	5
Scattered shrinkage cavity	5.1.2.1	6,4	$t_n \leq 9,5$	n.p.[b]	3	5	6
		12,7	$9,5 < t_n \leq 15,9$	n.p.[b]	3	4	5
		19,1	$15,9 < t_n \leq 25,4$	n.p.[b]	2	3	4
Centerline shrinkage	5.1.2.2	6,4	$t_n \leq 9,5$	n.p.[b]	2	3	4
		12,7	$9,5 < t_n \leq 15,9$	n.p.[b]	2	3	5
		19,1	$15,9 < t_n \leq 25,4$	n.p.[b]	3	4	5
Shrinkage cavity	5.1.2.3	12,7	$6,4 < t_n \leq 15,9$	n.p.[b]	1	2	3
		19,1	$15,9 < t_n \leq 25,4$	n.p.[b]	1	3	4
Inclusions less dense	5.1.3	N/A	$t_n \leq 9,5$	2[c]	4[d]	5[d]	6[e]
			$9,5 < t_n \leq 15,9$	3[c]	4[d]	5[d]	6[e]

Discontinuity		**Plate thickness**[a]	**Nominal wall thickness**	**Severity level**			
			t_n	1	2	3	4
Type	**Description in subclause of ASTM E 1320**[a]	mm	mm	**Maximum permissible discontinuity/Reference radiograph**[a]			
			$15{,}9 < t_n \leq 25{,}4$	4[c]	5[d]	6[d]	7[e]
Inclusions more dense	5.1.4	N/A	$t_n \leq 9{,}5$	2[c]	3[d]	5[d]	6[e]
			$9{,}5 < t_n \leq 15{,}9$	3[c]	4[d]	6[d]	7[e]
			$15{,}9 < t_n \leq 25{,}4$	4[c]	5[d]	7[d]	7[e]

a See ASTM E 1320, Volume 1.

b Not permitted.

c A maximum of two individual discontinuities per field of the reference radiograph shall be permitted.

d A maximum of three individual discontinuities per field of the reference radiograph shall be permitted.

e A maximum of five individual discontinuities per field of the reference radiograph shall be permitted.

Annex G
(informative)

Significant technical changes between this European Standard and the previous edition

Table G.1 — Significant technical changes between this European Standard and the previous edition

Clause/paragraph/table/figure/annex	Change
Clause 3 “Terms and definitions”	Revised, concepts taken from EN ISO 5579
Clause 4 “General”	revised, now Clause 6 “Requirements”
Clause 5 “Examination arrangements”	revised, now Clause 7 “Test arrangements”
Clause 6 “Choice of radiation source”	revised, now Clause 8 “Choice of tube voltage and radiation source”
Clause 7 “Specific film classes”	revised, now Clause 9 “Film systems and metal screens”; Tables 3 and 4 added
Clause 8 “Techniques for increasing the covered thickness range”	revised, now Clause 14 “Techniques for increasing the covered thickness range”
Clause 9 “Radiographs”	revised, now Clause 15 “Requirements on radiographs”
Clause 10 “Verification of image quality”	revised, now Clause 16 “Verification of image quality”
Clause 11 “Radiograph density requirements”	revised, now Clause 12 “Optical density D of radiograph”
Clause 12 “Influence of crystalline structure”	revised, now Clause 17 “Influence of crystalline structure”
Annex A “Possible discontinuities in castings — Reference radiographs and designation”	revised, new Annex A “Minimum quality image values”
—	New: Clauses 5, 10, 11, 13, 18 and 19; Annexes B, C, D, E, F and G
NOTE The technical changes referred include the significant technical changes from the EN revised but is not an exhaustive list of all modifications from the previous version.	

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[4] ASTM E 192:2013, *Standard Reference Radiographs of Investment Steel Castings of Aerospace Applications*

[5] ASTM E 272:2010, *Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Alloy Castings*

[6] ASTM E 280:2010, *Reference Radiographs for Heavy-Walled (41/2 to 12-in.) (114 to 305-mm) Steel Castings*

[7] ASTM E 310:2010, *Reference Radiographs for Tin Bronze Castings*

[8] ASTM E 446:2014, *Standard Reference Radiographs for Steel Castings up to 2 in. (50.8 mm) in Thickness*

[9] ASTM E 505:2001, *Reference Radiographs for Inspection of Aluminium and Magnesium Die Castings*

[10] ASTM E 689:2010, *Standard Reference Radiographs for Ductile Iron Castings*

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