INTERNATIONAL STANDARD

ISO 5579

Second edition
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Non-destructive testing — Radiographic examination of metallic materials by X- and gamma-rays — Basic rules

Essais non destructifs — Examen radiographique des matériaux métalliques au moyen de rayons X et gamma — Règles de base

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Contents

Page

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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.

International Standard ISO 5579 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing,* Subcommittee SC 5, *Radiation methods.*

This second edition cancels and replaces the first edition (ISO 5579:1985) which has been technically revised.

Annex A of this International Standard is for information only.

Introduction

For an item submitted for radiographic inspection by means of X- or gamma rays, the detectability of flaws depends on the details of the radiographic technique. Since the quality of the radiograph cannot be completely ensured by the use of an image quality indicator (I.Q.I.), this International Standard explains the basic rules and technical procedure for obtaining good radiographic quality.

Standards relating to specific applications should conform to these basic rules.

NOTE — Throughout this International Standard the term "flaw" has no implication of either unacceptability or acceptability.

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

1 Scope

This International Standard specifies the basic rules for industrial X- and gamma radiography for flaw detection purposes, using film techniques, applicable to metallic products and materials.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1027:1983, *Radiographic image quality indicators for non-destructive testing — Principles and identification.*

ISO 2504:1973, *Radiography of welds and viewing conditions for film — Utilization of recommended patterns of image quality indicators (I.Q.I.).*

ISO 5580:1985, *Non-destructive testing — Industrial radiographic illuminators — Minimum requirements*.

ISO 11699-1:—[1)], *Non-destructive testing — Industrial radiographic films — Part 1: Classification of film systems for industrial radiography.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 nominal thickness, *t*: The nominal thickness of the material in the region under examination.

NOTE — Manufacturing tolerances need not be taken into account.

3.2 penetrated thickness, *w*: Thickness of material in the direction of the radiation beam calculated on the basis of the nominal thickness including for multiple wall techniques.

3.3 object-to-film distance, *b*: Distance between the radiation side of the test object and the film surface measured along the central axis of the radiation beam.

3.4 source size, *d*: Size of the source of radiation equal to the larger dimension of the radiation source.

1) To be published.

3.5 source-to-film distance (SFD): Distance between the source of radiation and the film measured in the direction of the beam.

3.6 source-to-object distance, *f*: Distance between the source of radiation and the source side of the test object measured along the central axis of the radiation beam.

4 Classification of radiographic techniques

Radiographic techniques are divided into two classes:

— class A: basic techniques;

— class B: improved techniques.

Class B techniques shall be used when class A may be insufficiently sensitive.

Better techniques compared with class B are possible and may be agreed between the contracting parties by specification of all appropriate test parameters.

The choice of radiographic technique shall be agreed between the parties concerned.

If, for technical 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 between the contracting parties that the condition selected may be that specified for class A. The loss of sensitivity shall be compensated by an increase of minimum density to 3,0 or by choice of a higher contrast film system. Because of the better sensitivity compared to class A, the test sections may be regarded as examined within class B.

5 General

5.1 Protection against 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. Local or national or international safety precautions when using ionizing radiation shall be strictly applied.

5.2 Test arrangement

The test arrangement consists of the radiation source, test object and the film or film-screen combination in cassette and depends on the size and shape of the object and the accessibility of the area to be tested. Generally, one of the arrangements illustrated in figures 1 to 7 should be used, figure 1 being the most usual case.

The beam of radiation shall be directed at the middle of the section under examination and shall be normal to the surface at that point, except when it is known that certain flaws are better revealed by a different alignment of the beam.

When radiographs are taken in a direction other than normal to the surface, this shall be indicated in the test report.

Double-wall techniques are acceptable only if single-wall techniques are not practical.

5.3 Surface preparation and stage of manufacture

In general, surface preparation is not necessary, but where surface imperfections or coatings might cause difficulty in detecting defects, the surface shall be ground smooth or the coatings shall be removed.

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

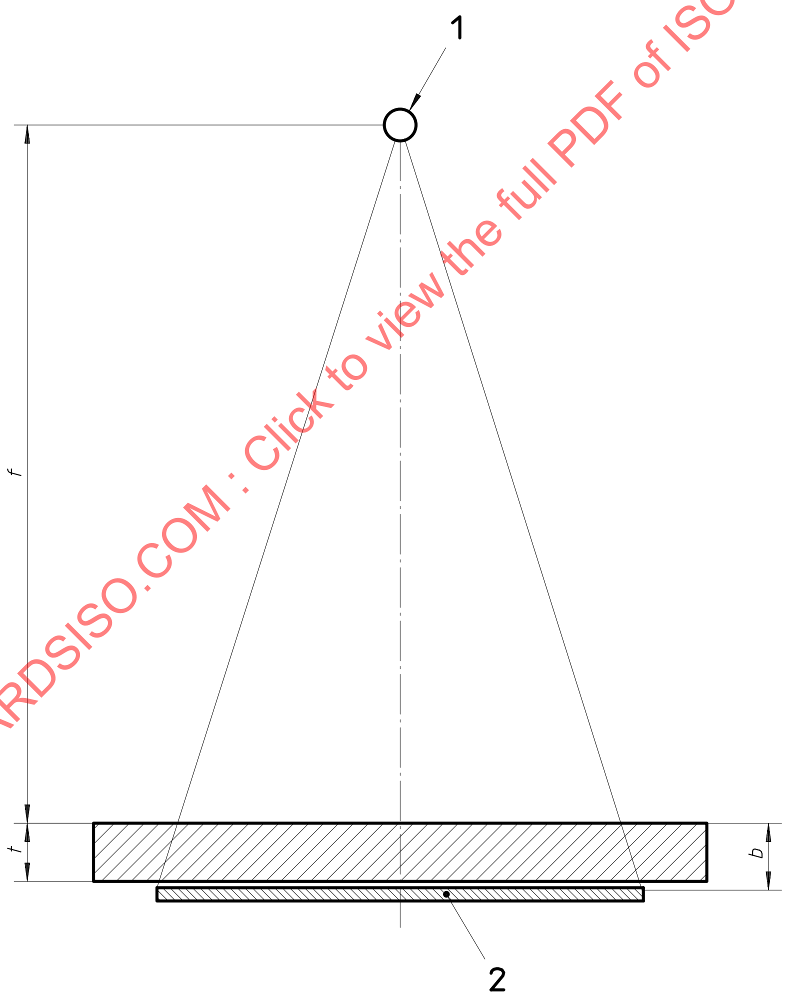
5.4 Identification of radiographs

Symbols shall be affixed to each section of the object being radiographed. The images of these symbols shall appear in the radiograph outside the region of interest where possible and shall ensure unequivocal identification of the section.

5.5 Marking

Permanent markings on the object to be examined shall be made in order to accurately locate the position of each radiograph.

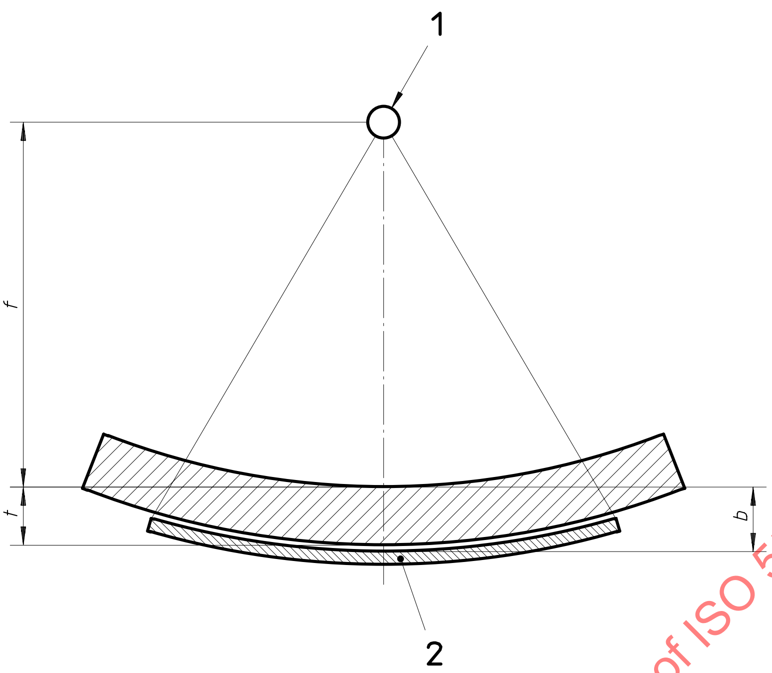
Where the nature of the material and/or its service conditions do not permit permanent marking, the location may be recorded by means of accurate sketches.



Key

1 radiation source with an effective optical focus size *d*
2 film
f source-to-object distance
t material thickness
b distance between the film and the surface of the object nearest the source

Figure 1 — Arrangement 1: Single-wall penetration — Objects with plane walls

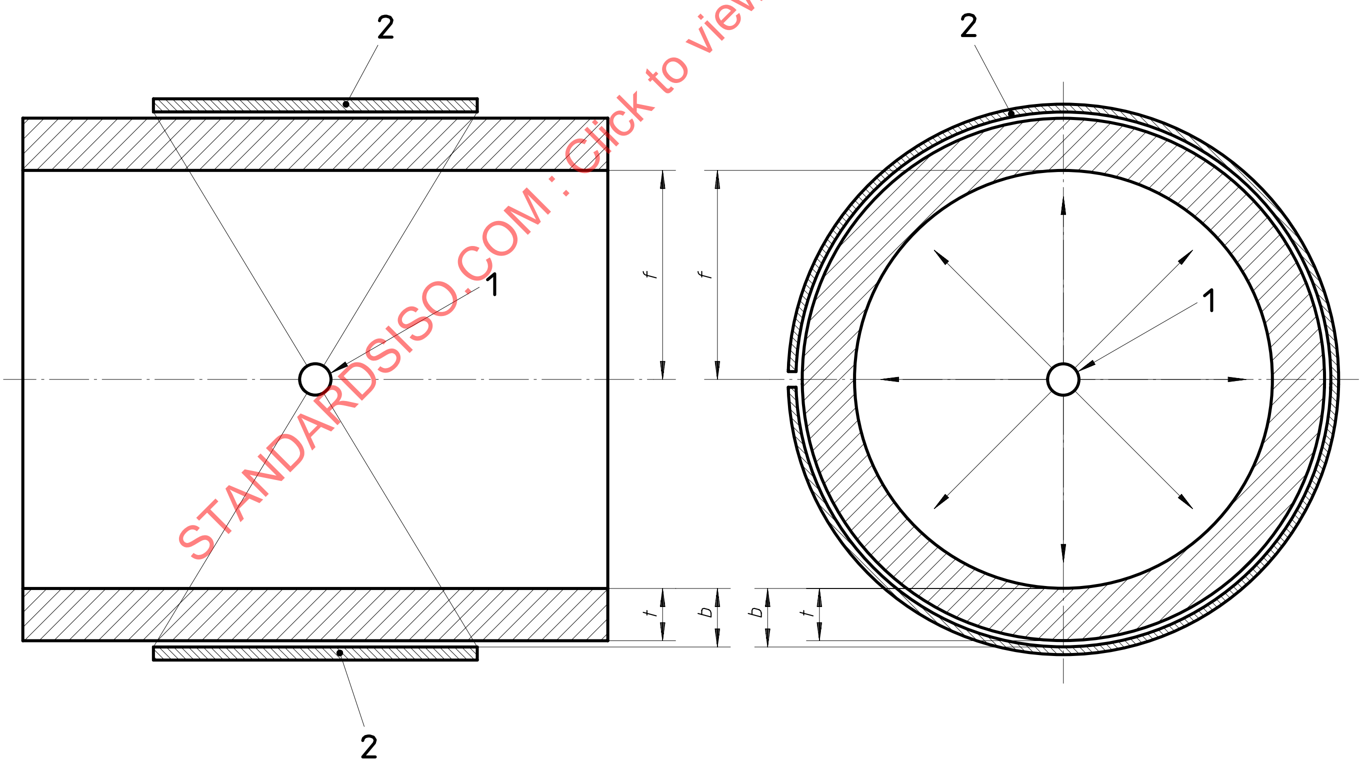


Key

See figure 1

NOTE — This arrangement is preferred to arrangement 4 (see figure 4).

Figure 2 — Arrangement 2: Single-wall penetration — Object with curved walls — Source off-centre on concave side — Film on convex side

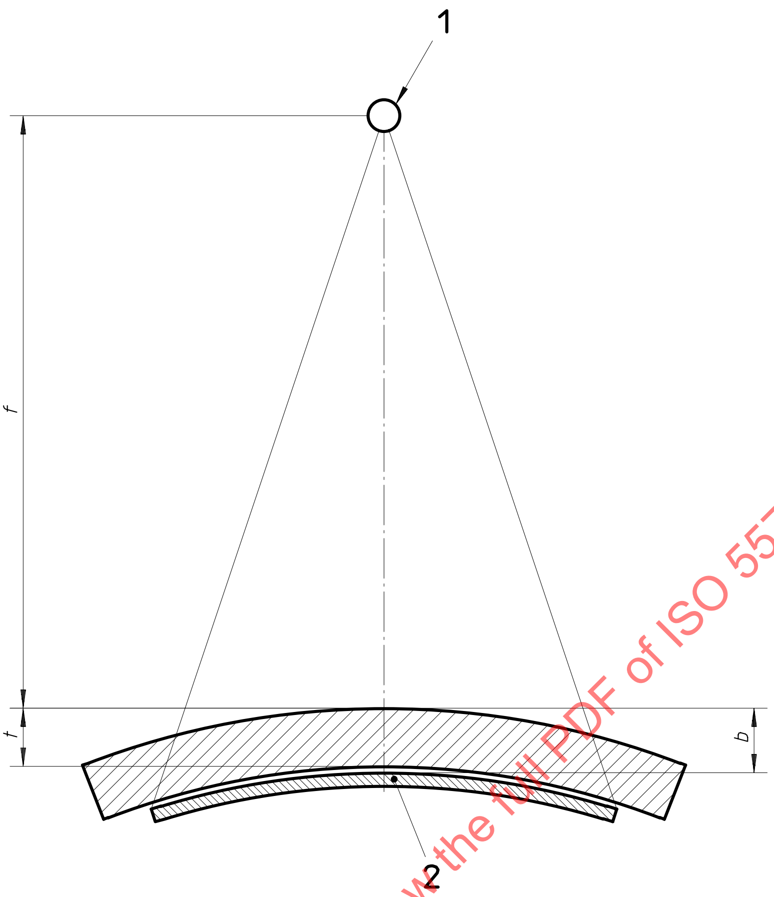


Key

See figure 1

NOTE — One advantage of this technique is that the whole circumference may be radiographed in one exposure. This arrangement is preferred to arrangements 2 (see figure 2), 4 (see figure 4) or 5 (see figure 5).

Figure 3 — Arrangement 3: Single-wall penetration — Object with curved walls — Source located centrally



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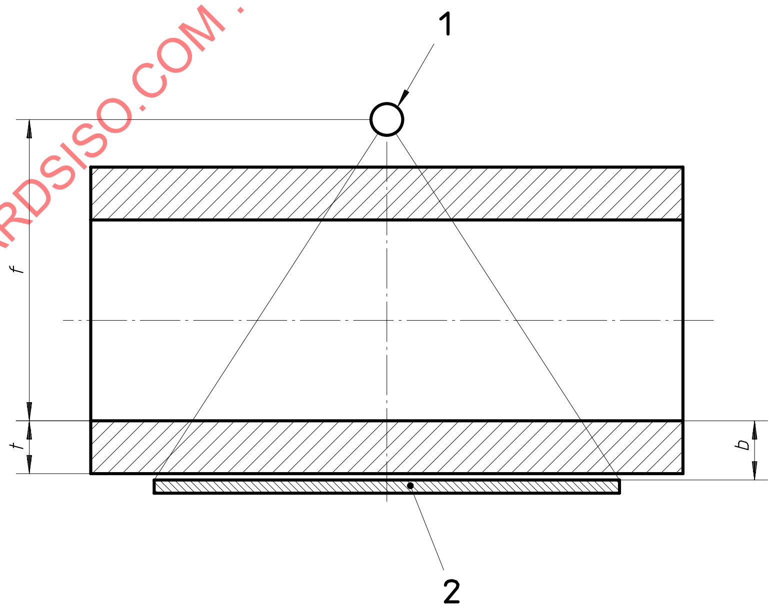
See figure 1

Figure 4 — Arrangement 4: Single-wall penetration — Object with curved walls — Source on convex side — Film on concave side



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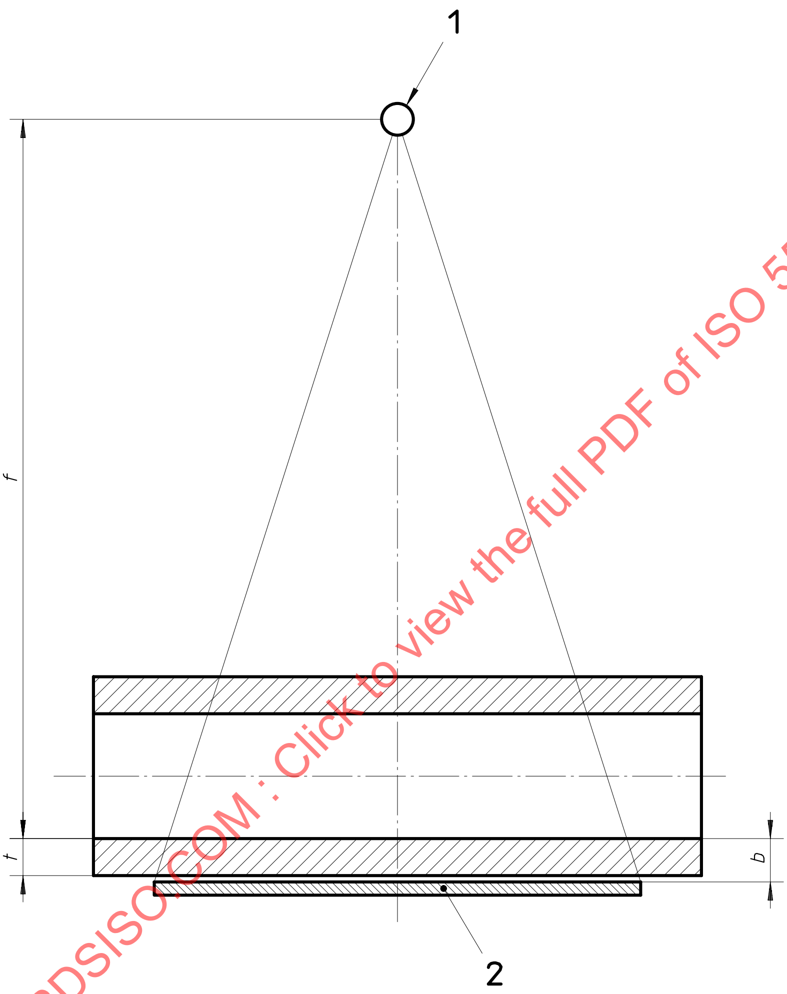
See figure 1

NOTE — Because the source is close to the upper wall, flaws should not be evaluated in this wall.

Figure 5 — Arrangement 5: Double-wall penetration — Single-wall evaluation — Source and film outside

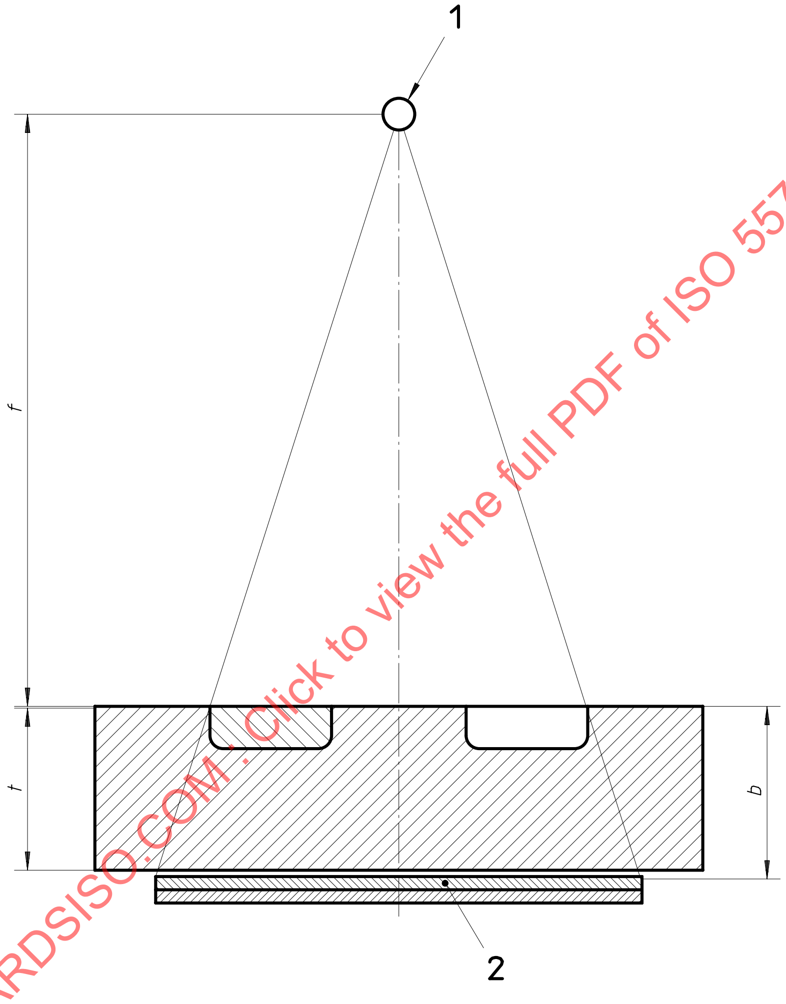


Key

See figure 1

NOTE — Flaws in the upper wall may be evaluated. For some applications the radiation beam might be used at a different angle (i. e. not perpendicular to the centre of the film).

Figure 6 — Arrangement 6: Double-wall penetration — Double-wall evaluation — Source and film outside



Key

See figure 1

Figure 7 — Arrangement 7: Single-wall penetration — Objects with plane or curved walls of different thicknesses or materials — Two films with the same or different speeds

5.6 Overlap of films

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

5.7 Image quality indicator (I.Q.I)

The quality of image shall be verified by use of an I.Q.I. in accordance with specific application standards, ISO 1027 and ISO 2504.

6 Recommended techniques for making radiographs

6.1 Choice of X-ray tube voltage and radiation source

6.1.1 X-ray equipment

To maintain good flaw sensitivity, the X-ray tube voltage shall be as low as possible. The maximum values of tube voltage versus thickness are given in figure 8.

6.1.2 Other radiation sources

The permitted penetrated thickness ranges for gamma ray sources and X-ray equipment above 1 MeV are given in table 1.

On thin steel specimens, gamma rays from ^{192}Ir and ^{60}Co will not produce radiographs having as good a defect detection sensitivity as X-rays used with appropriate technique parameters. However because of the advantages of gamma ray sources in handling and accessibility, table 1 gives a range of thicknesses for which each of these gamma ray sources may be used when the use of X-rays is difficult.

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

In cases where radiographs are produced using gamma rays, the travel-time required to position the source shall not exceed 10 % of the total exposure time.

6.2 Film systems and screens

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

For different radiation sources the minimum film system classes are given in tables 2 and 3.

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

For different radiation sources, tables 2 and 3 show the recommended screen materials and thicknesses.

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

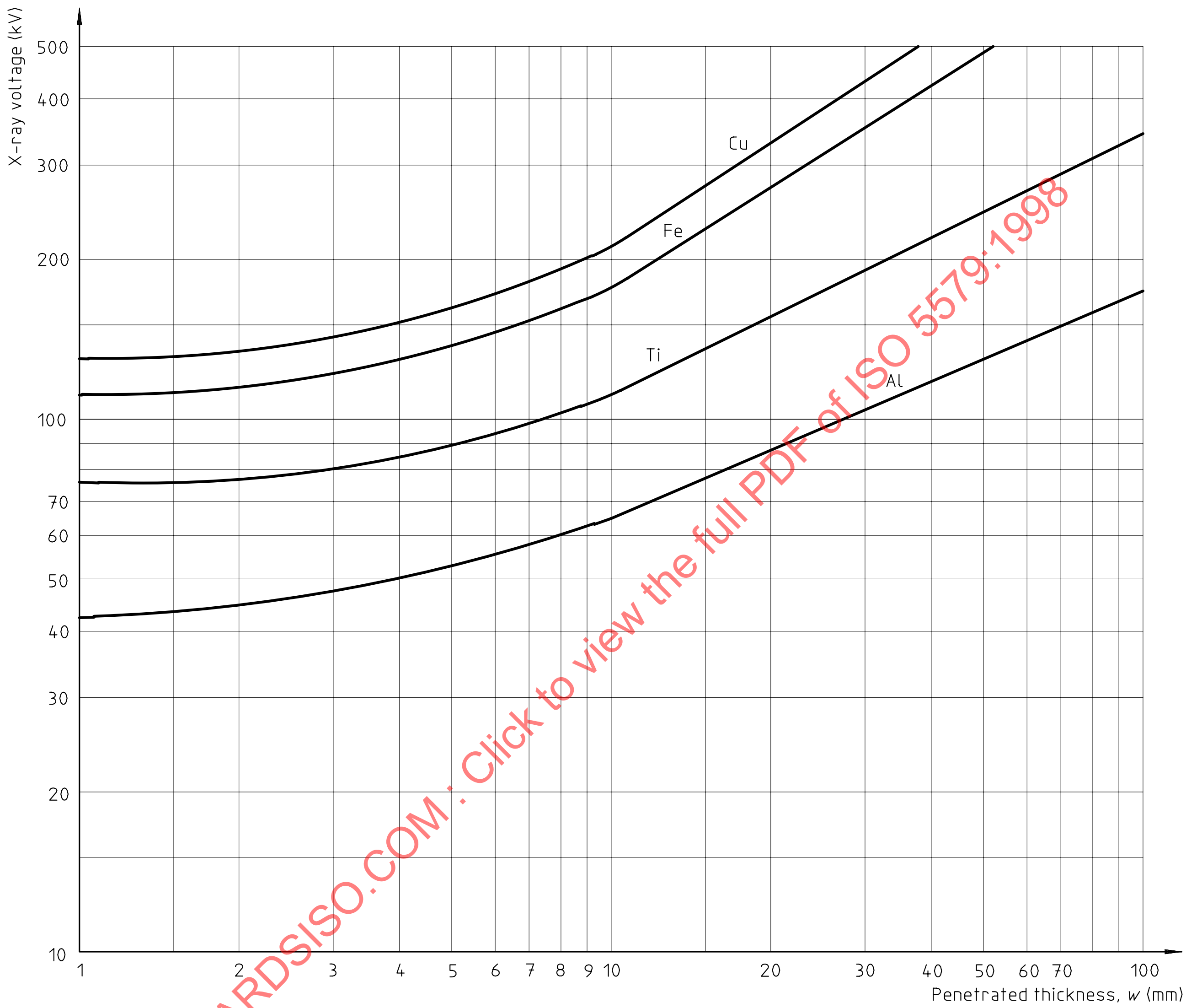


Figure 8 — Maximum X-ray voltage for X-ray devices up to 500 kV as a function of penetrated thickness and material

Table 1 — Penetrated thickness range for gamma ray sources and X-ray equipment with energy from 1 MeV and above for steel, copper and nickel-base alloys

Radiation source	Penetrated thickness, w mm	
	Test class A	Test class B
^{170}Tm	$w \leqslant 5$	$w \leqslant 5$
^{169}Yb 1)	$1 \leqslant w \leqslant 15$	$2 \leqslant w \leqslant 12$
^{75}Se 2)	$10 \leqslant w \leqslant 40$	$14 \leqslant w \leqslant 40$
^{192}Ir	$20 \leqslant w \leqslant 100$	$20 \leqslant w \leqslant 90$
^{60}Co	$40 \leqslant w \leqslant 200$	$60 \leqslant w \leqslant 150$
X-ray equipment with energy from 1 MeV to 4 MeV	$30 \leqslant w \leqslant 200$	$50 \leqslant w \leqslant 180$
X-ray equipment with energy above 4 MeV to 12 MeV	$w \geqslant 50$	$w \geqslant 80$
X-ray equipment with energy above 12 MeV	$w \geqslant 80$	$w \leqslant 100$

1) For aluminium and titanium the penetrated material thickness is 10 mm $< w <$ 70 mm for class A and 25 mm $< w <$ 55 mm for class B.
2) For aluminium and titanium the penetrated material thickness is 35 mm $\leqslant w \leqslant$ 120 mm for class A.

Table 2 — Film system classes and metal screens for the radiography of steel, Cu- and Ni-based alloys

Radiation source	Penetrated thickness, *w* mm	Film system class 1) Class A	Film system class 1) Class B	Type and thickness of metal screens Class A	Type and thickness of metal screens Class B
X-ray potentials ≤100 kV		T3	T2	None or up to 0,03 mm front and back screens of lead	
X-ray potentials > 100 kV to 150 kV				Up to 0,15 mm front and 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	
^{169}Yb	$w < 5$	T3	T2	None or up to 0,03 mm front and back screens of lead	
^{170}Tm	$w \geq 5$			0,02 mm to 0,15 mm front and back screens of lead	
X-ray potentials > 250 kV to 500 kV	$w \leq 50$	T3	T2	0,02 mm to 0,3 mm front and back screens of lead	
	$w > 50$		T3	0,1 mm to 0,3 mm front screen of lead 2) 0,02 mm to 0,3 mm back screen of lead	
^{75}Se		T3	T2	0,1 mm to 0,2 mm front and back screens of lead 2)	
^{192}Ir		T3	T2	0,02 mm to 0,2 mm front screen of lead 0,02 mm to 0,2 mm back screen of lead	0,1 mm to 0,2 mm front screen of lead 2)
^{60}Co	$w \leq 100$	T3	T3	0,25 mm to 0,7 mm front and back screens of steel or copper 3)	
	$w > 100$				
X-ray equipment with energy from 1 MeV to 4 MeV	$w \leq 100$	T3	T2	0,25 mm to 0,7 mm front and back screens of steel or copper 3)	
	$w > 100$				
X-ray equipment with energy above 4 MeV to 12 MeV	$w \leq 100$	T2	T2	Up to 1 mm front screen of copper, steel or tantalum 4) Back screen of copper or steel up to 1 mm and tantalum 4) up to 0,5 mm	
	$100 < w \leq 300$	T3	T2		
	$w > 300$		T3		
X-ray equipment with energy > 12 MeV	$w \leq 100$	T2	—	Up to 1 mm front screen of tantalum 5) No back screen	
	$100 < w \leq 300$	T3	T2		
	$w > 300$		T3	Up to 1 mm front screen of tantalum 5) Up to 0,5 mm back screen of tantalum	

1) Better film system classes may also be used.

2) 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 object and the film.

3) In class A also 0,5 mm to 2 mm screens of lead may be used.

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

5) Tungsten screens may be used by agreement.

Table 3 — Film system classes and metal screens for aluminium and titanium

Radiation source	Film system class 1)		Type and thickness of intensifying screens
	Class A	Class B	
X-ray potentials ⩽ 150 kV			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	T3	T2	0,1 mm to 0,2 mm front and back screens of lead
^{169}Yb			0,02 mm to 0,15 mm front and back screens of lead
^{75}Se			0,2 mm front screens 2) and 0,1 mm to 0,2 mm back screens of lead

1) Better film system classes may also be used.
2) Instead of 0,2 mm lead, a 0,1 mm screen with an additional filter of 0,1 mm may be used.

6.3 Alignment of beam

The beam of radiation shall be directed to the centre of the area being inspected and shall be normal to the object surface at that point, except when it can be demonstrated that certain inspections are best revealed by a different alignment of the beam. In this case, an appropriate alignment of the beam can be permitted.

Between the contracting parties other ways of radiographing may be agreed upon.

6.4 Reduction of scattered radiation

Scattered radiation reaching the film is an important cause of reduced image quality, particularly with X-rays between 150 kV and 400 kV. Scattered radiation can originate from both inside and outside the specimen. In order to minimize the effect of scattered radiation, the area of the field of radiation shall be masked, so that the beam is limited to the area of interest. This is normally done by masking the primary cone of the radiation beam, either with a physical cone or with a diaphragm on the tube head. The film shall also be shielded from radiation scattered from other parts of the specimen or from objects behind or beside the specimen. This can be done by using a back intensifying screen of extra thickness or by using a sheet of lead behind the film screen combination; this extra sheet may by used inside the cassette or placed immediately behind the cassette. Depending on the set-up, typical lead thicknesses are in the range of 1 mm to 4 mm.

If the upper edge of a thick specimen is within the radiation field, a method of reducing undercutting scatter is generally necessary. Figure 9 shows two typical methods.

With ^{192}Ir and ^{60}Co 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 object and the cassette. The thickness of this sheet is 0,5 mm to 2 mm dependent on the penetrated thickness.

With X-rays of 6 MV energy or more used without back intensifying screens, shielding against scattered radiation is not necessary, unless there is scattering material close behind the film.

In general, with X-rays between 150 kV and 400 kV and with gamma rays, if a beam restrictor cannot be used, such as when panoramic exposures are being made, the exposures shall be made in as large a room as possbile, so that extraneaous scatter is attenuated by distance; the specimens, whenever possible, shall be well above floor level and the floor near the specimen shall be covered with lead.

The effect on scattered radiation shall be checked for each arrangement by a lead letter B (with a height of minimum 10 mm and a thickness of minimum 1,5 mm) placed immediately behind each cassette. If the image of this symbol is lighter than the radiograph it shall be rejected. If the symbol is darker or invisible the radiograph is acceptable and sufficiently protected against scattered radiation.

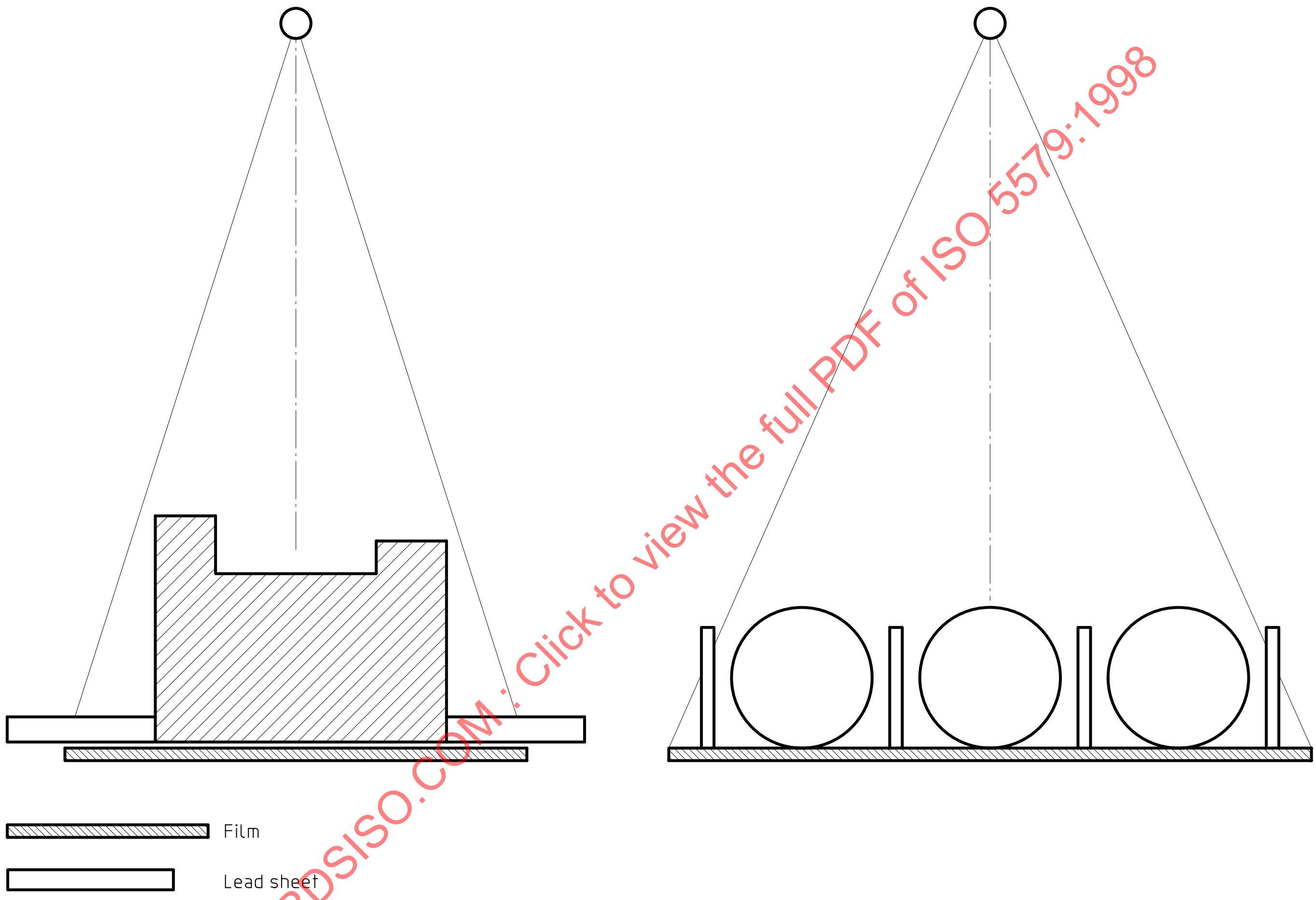


Figure 9 — Methods of reducing the effect of scattered radiation

6.5 Source-to-object distance

The minimum source-to-object distance, f_{min}, depends on the source size d and on the object-to-film distance b.

The distance f, shall, where practicable, 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 the following equations.

For class A

$$\frac{f}{d} \geqslant 7{,}5 \times b^{2/3} \qquad \text{... (1)}$$

For class B

$$\frac{f}{d} \geqslant 15 \times b^{2/3} \qquad \text{... (2)}$$

If distance $b < 1{,}2\ t$ the dimension b in equations (1) and (2) and figure 10 shall be replaced by the nominal thickness t.

For determination of the source-to-object distance, f_{min}, the nomogram in figure 10 may be used.

The nomogram is based on equations (1) and (2).

In class A, if planar imperfections have to be detected the minimum distance f_{min} shall be the same as for class B in order to reduce the geometric unsharpness by a factor of 2.

In critical technical applications of crack-sensitive materials more sensitive radiographic techniques than class B shall be used.

If the radiation source could be placed centrally inside the object to be radiographed (figure 3) to achieve a more suitable beam direction and to avoid a double wall technique (figures 5 and 6), this method shall be preferred. The reduction in minimum source-to-object distance should not be greater than 50 %.

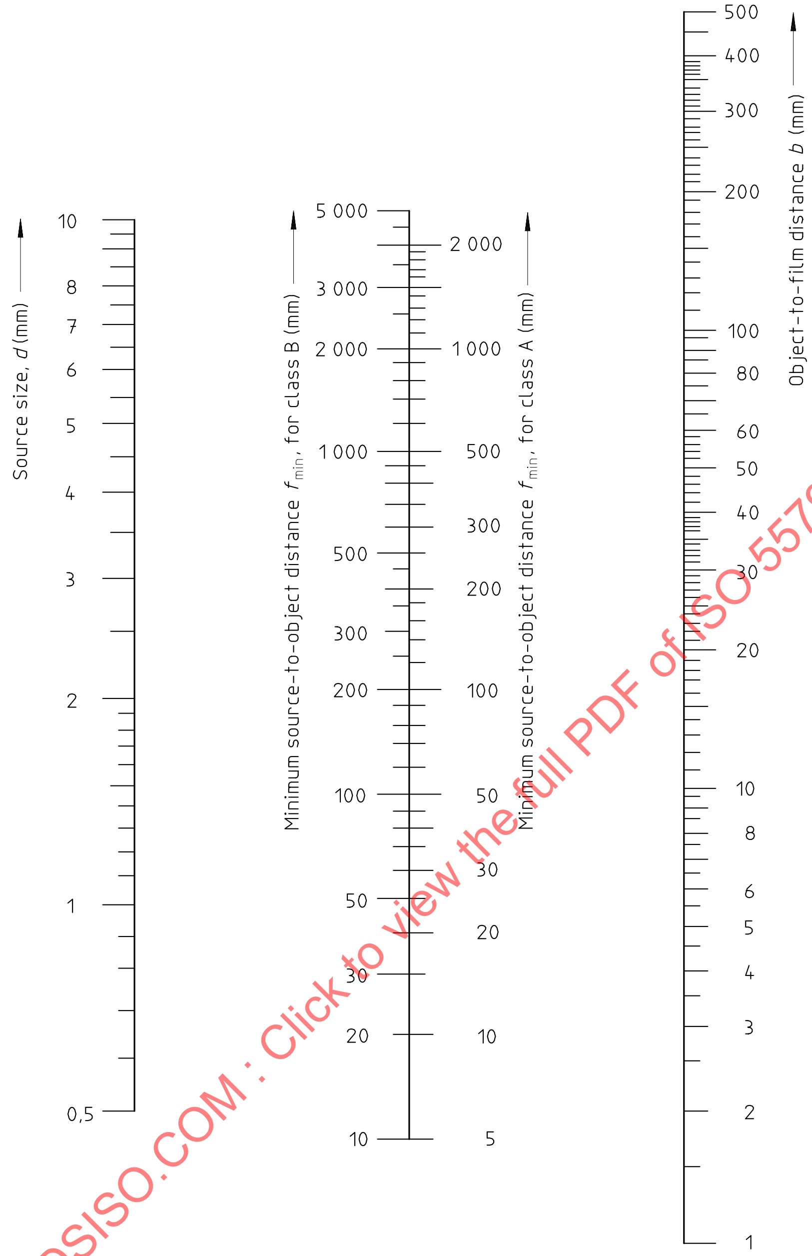


Figure 10 — Nomogram for determination of minimum source-to-object distance f_{min} in relation to of object-to-film distance and the source size