British Standard

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29 May 2003

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BRITISH STANDARD

BS EN 1435:1997
Incorporating Corrigendum No. 1 and Amendment No. 1

Non-destructive testing of welds — Radiographic testing of welded joints

The European Standard EN 1435:1997, with the incorporation of amendment A1:2002, has the status of a British Standard

ICS 25.160.40

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National foreword

This British Standard is the English language version of EN 1435:1997, including amendment A1:2002. It supersedes BS 2600:Part 1:1983, BS 2600:Part 2:1973, BS 2910:1986 and BS 7257:1989, which are withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A1⟩ ⟨A1]. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by [A1⟩ ⟨A1].

As agreed by CEN/TC 121/SC 5 resolution 134/2000 and in accordance with amendment A1:2002, the term "examination" has been replaced by "testing" throughout the document.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 32, an inside back cover and a back cover.

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Amd. No.	Date	Comments
10616 Corrigendum No. 1	August 1999	Correction to Table 2
13985	15 November 2002	See national foreword

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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1435

August 1997

+ A1

May 2002

ICS 25.160.40

Descriptors: Welded joints, fusion welding, butt welds, quality control, non-destructive tests, radiographic analysis, setting-up conditions

English version

Non-destructive testing of welds — Radiographic testing of welded joints

(includes amendment A1:2002)

Contrôle non destructif des assemblages soudés — Contrôle par radiographie des assemblages soudés (inclut l'amendement A1:2002)

Zerstörungsfreie Prüfung von Schweißverbindungen — Durchstrahlungsprüfung von Schmelzschweißverbindungen (enthält Änderung A1:2002)

This European Standard was approved by CEN on 1997-08-02. Amendment A1 was approved by CEN on 2002-05-05. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 121, Welding, the Secretariat of which is held by DS.

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 February 1998, and conflicting national standards shall be withdrawn at the latest by February 1998.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Foreword to amendment A1

This document EN 1435:1997/A1:2002 has been prepared by Technical Committee CEN/TC 121, Welding, the Secretariat of which is held by DS.

This amendment to the European Standard EN 1435:1997 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2002, and conflicting national standards shall be withdrawn at the latest by November 2002.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

Annex A and Annex B are normative.

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Contents

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1 Scope

This European Standard specifies fundamental techniques of radiography with the object of enabling satisfactory and repeatable results to be obtained economically. The techniques are based on generally recognized practice and fundamental theory of the subject.

This standard applies to the radiographic testing of fusion welded joints in metallic materials.

It applies to the joints of plates or pipes. Besides its conventional meaning, “pipe” as used in this standard should be understood to cover other cylindrical bodies such as tubes, penstocks, boiler drums and pressure vessels. This standard complies with EN 444.

This standard does not specify acceptance levels of the indications.

If lower test criteria [A1) are permitted by specification (A1], the quality achieved may be significantly lower than when this standard is strictly applied.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 444, *Non-destructive testing — General principles for the radiographic examination of metallic materials using X- and gamma-rays.*

EN 462-1, *Non-destructive testing — Image quality of radiographs — Part 1: Concepts, image quality indicators (wire type), determination of image quality value.*

EN 462-2, *Non-destructive testing — Image quality of radiographs — Part 2: Concepts, image quality indicators (step/hole type), determination of image quality value.*

EN 462-3, *Non-destructive testing — Image quality of radiographs — Part 3: Image quality classes for ferrous metals.*

EN 462-4, *Non-destructive testing — Image quality of radiographs — Part 4: Experimental evaluation of image quality values and image quality tables.*

EN 473, *Qualification and certification of non-destructive personnel — General principles.*

EN 584-1, *Non-destructive testing — Industrial radiographic film — Part 1: Classification of film systems for industrial radiography.*

EN 584-2, *Non-destructive testing — Industrial radiographic film — Part 2: Control of film processing by means of reference value.*

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

3 Definitions

For the purpose of this standard, the following definitions apply.

3.1
nominal thickness, *t*
the nominal thickness of the parent material only. Manufacturing tolerances do not have to be taken into account

3.2
penetrated thickness, *w*
the thickness of material in the direction of the radiation beam calculated on the basis of the nominal thickness

For multiple wall techniques the penetrated thickness is calculated from the nominal thickness.

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3.3
object-to-film distance, *b*
the 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*
the size of the radiation source

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

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

3.7
diameter, D_e
the nominal external diameter of the pipe

4 Classification of radiographic techniques

The radiographic techniques are divided into two classes:

— class A: basic techniques;

— class B: improved techniques.

Class B techniques will be used when class A might be insufficiently sensitive.

[A1] Better techniques compared to class B are possible and may be defined by specification of all appropriate test parameters. [A1]

The choice of radiographic technique shall be [A1] defined by specification. [A1]

If, for technical reasons, it is not possible to meet one of the conditions specified for class B, such as type of radiation source or the source-to-object distance, *f*, it may be [A1] defined by specification [A1] 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 the choice of a higher contrast film system. Because of the better sensitivity compared to class A, the test specimen may be regarded as tested within class B. This does not apply if the special SFD reductions as described in **6.6** for test arrangements **6.1.4** and **6.1.5** are used.

5 General

5.1 Protection against ionizing radiation

WARNING NOTICE. 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 must be applied.

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

5.2 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.

5.3 Location of the weld in the radiograph

Where the radiograph does not show the weld, high-density markers shall be placed on either side of the weld.

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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 unambiguous identification of the section.

5.5 Marking

Permanent markings on the object to be tested 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.

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 Types and positions of image quality indicators (IQI)

The quality of image shall be verified by use of IQI in accordance with EN 462-1 or EN 462-2.

The IQI used shall be placed preferably on the source side of the test object at the centre of the area of interest on the parent metal beside the weld. The IQI shall be in close contact with the surface of the object.

Its location shall be made in a section of uniform thickness characterized by a uniform optical density on the film.

According to the IQI type used, two cases shall be considered.

a) When using a wire IQI, the wires shall be directed perpendicular to the weld and its location shall ensure that at least 10 mm of the wire length will show in a section of uniform optical density, which is normally in the parent metal adjacent to the weld. At exposures in accordance with **6.1.6** and **6.1.7**, the IQI can be placed with the wires across to the pipe axis, and they should not be projected into the image of the weld.

b) When using a step/hole IQI, it shall be placed in such a way that the hole number required is placed close to the weld.

At exposures in accordance with **6.1.6** and **6.1.7**, the IQI type used can be placed either on the source or on the film side. If the IQIs cannot be placed in accordance with the above conditions, the IQIs will be placed on the film side and the image quality shall be determined at least once from comparison exposure with one IQI placed at the source side and one at the film side under the same conditions.

For double-wall exposures, when the IQI is placed on the film side, the above test is not necessary and in this case reference should be made to the tables of correspondence given in Annex B.

Where the IQIs are placed at the film side, the letter "F" shall be placed near the IQI and it shall be noted in the test report.

If steps have been taken to guarantee that radiographs or similar test objects and regions are produced with identical exposure and processing techniques, and no differences in the image quality value are likely, the image quality need not be verified for every radiograph, the extent of image quality verification being subject to [A1⟩ specification ⟨A1].

For exposures of pipes with diameter 200 mm and above with the source centrally located, at least three IQIs should be placed equally spaced at the circumference. The film(s) showing IQI images are then considered representative for the whole circumference.

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5.8 Evaluation of image quality

The films shall be viewed in accordance with EN 25580.

From the testing of the image of the IQI on the radiograph, the number of the smallest wire or hole which can be discerned is determined. The image of a wire is accepted if a continuous length of at least 10 mm is clearly visible in a section of uniform optical density. In the case of the step/hole type IQI, if there are two holes of the same diameter, both shall be discernible in order that the step be considered as visible.

The image quality obtained shall be indicated on the test report of the radiographic test. In each case, the type of indicator used shall be clearly stated, as shown on the IQI.

5.9 Minimum image quality values

Table B.1 to Table B.12 in Annex B show the minimum quality values for ferrous materials. For other materials these requirements or corresponding requirements may be [A1⟩ defined by specification ⟨A1]. The requirements shall be determined in accordance with EN 462-4.

5.10 Personnel qualification

Personnel performing non-destructive testing in accordance with this standard shall be qualified in accordance with EN 473, or equivalent, to an appropriate level in the relevant industrial sector.

6 Recommended techniques for making radiographs

6.1 Test arrangements

6.1.1 *General*

Normally, radiographic techniques in accordance with **6.1.2**, **6.1.3**, **6.1.4**, **6.1.5**, **6.1.6**, **6.1.7**, **6.1.8** and **6.1.9** shall be used.

The elliptical technique (double wall/double image) in accordance with Figure 11 should not be used for external diameter $D_e > 100$ mm, wall thickness $t > 8$ mm and weld width $> D_e/4$. Two 90° displaced images are sufficient if $t/D_e < 0,12$. The distance between the two weld images shall be about one weld width.

When it is difficult to carry out an elliptic test at $D_e \leqslant 100$ mm, the perpendicular technique in accordance with **6.1.7** may be used (see Figure 12). In this case, three exposures 120° or 60° apart are required.

For test arrangements in accordance with Figure 11, Figure 13 and Figure 14, the inclination of the beam shall be kept as small as possible and be such as to prevent superimposition of the two images. The source-to-object distance, *f*, shall be kept as small as possible, in accordance with **6.6**. The IQI shall be placed close to the film with a lead letter “F”.

Other radiographic techniques may be [A1⟩ specified, ⟨A1] e.g. for reasons like geometry of the [A1⟩ test object ⟨A1] or differences in material thickness. In **6.1.9** an example of such a case is presented. Multi-film techniques shall not be used to reduce exposure times on uniform sections.

NOTE In Annex A the minimum number of radiographs necessary is given in order to obtain an acceptable radiographic coverage of the total circumference of a butt weld in pipe.

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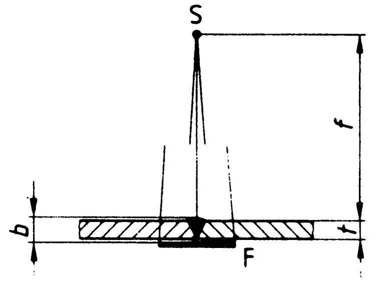
6.1.2 ***Radiation source located in front of the object and with the film at the opposite side***

See Figure 1.



S radiation source

F film

See clause **3** for *f*, *b*, *t*.

Figure 1 — Test arrangement for plane walls and single-wall penetration

6.1.3 ***Radiation source located outside the object and with the film inside***

See Figure 2, Figure 3 and Figure 4.

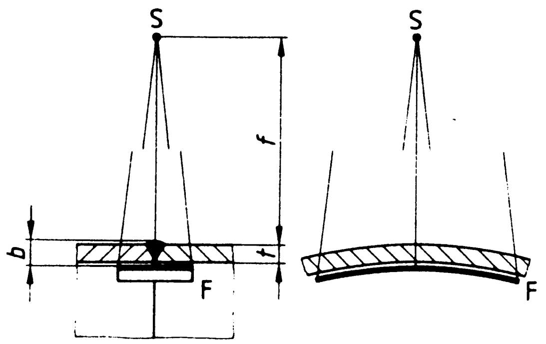


Figure 2 — Test arrangement for single-wall penetration of curved objects

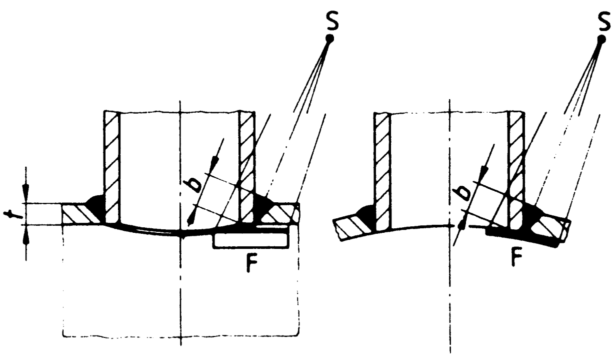


Figure 3 — Test arrangement for single-wall penetration of curved objects (set-in weld)

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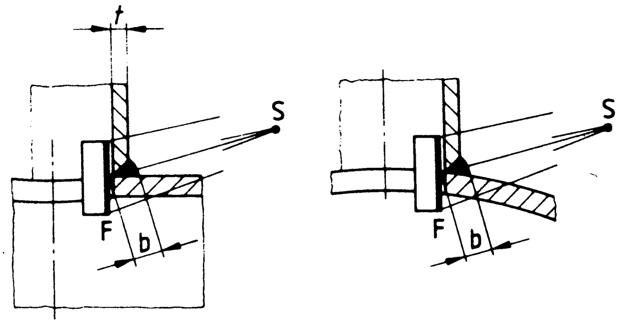

Figure 4 — Test arrangement for single-wall penetration of curved objects (set-on weld)

6.1.4 ***Radiation source centrally located inside the object and with the film outside***

See Figure 5, Figure 6 and Figure 7.

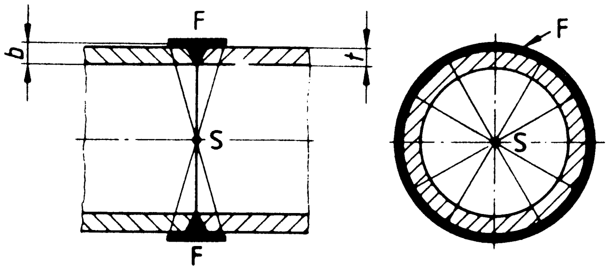

Figure 5 — Test arrangement for single-wall penetration of curved objects

[A1⟩

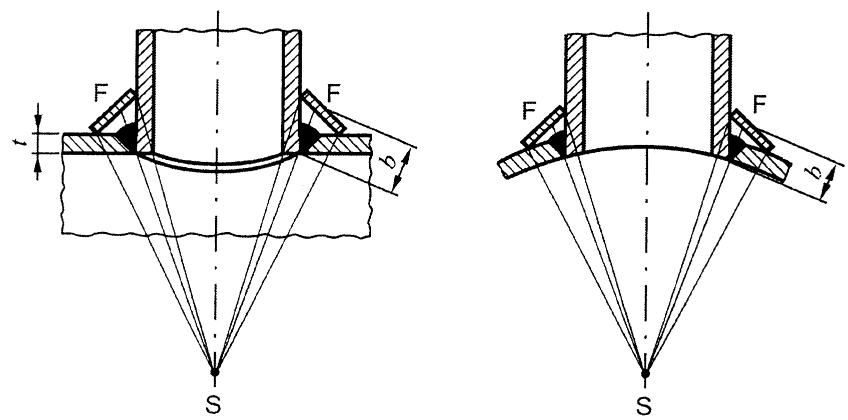

Figure 6 — Test arrangement for single-wall penetration of curved objects (set-in weld)

⟨A1]

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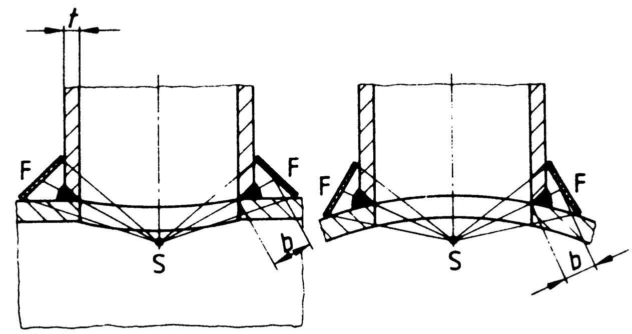

Figure 7 — Test arrangement for single-wall penetration of curved objects (set-on weld)

6.1.5 ***Radiation source located off-centre inside the object and with the film outside***

See Figure 8, Figure 9 and Figure 10.

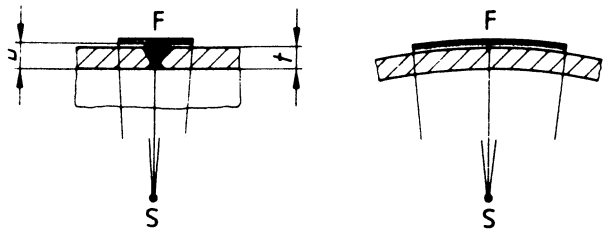

Figure 8 — Test arrangement for single-wall penetration of curved objects

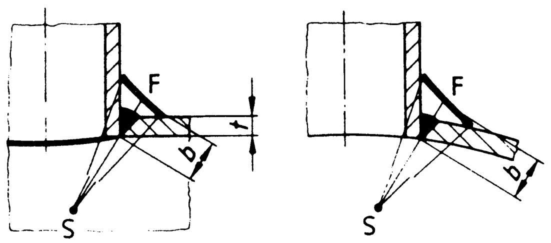

Figure 9 — Test arrangement for single-wall penetration of curved objects (set-in weld)

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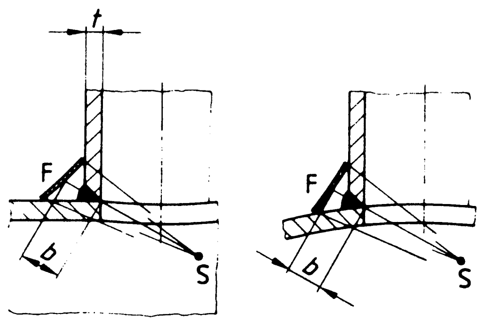

Figure 10 — Test arrangement for single-wall penetration of curved objects (set-on weld)

6.1.6 ***Elliptic technique***

See Figure 11.

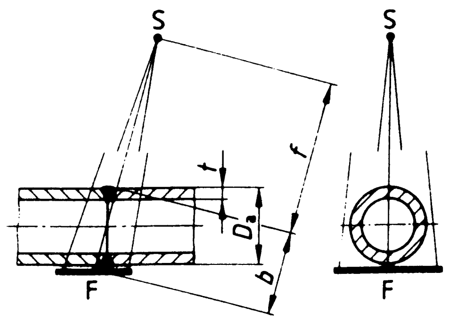

Figure 11 — Test arrangement for double-wall penetration double image of curved objects for evaluation of both walls (source and film outside the test object)

6.1.7 ***Perpendicular technique***

See Figure 12.

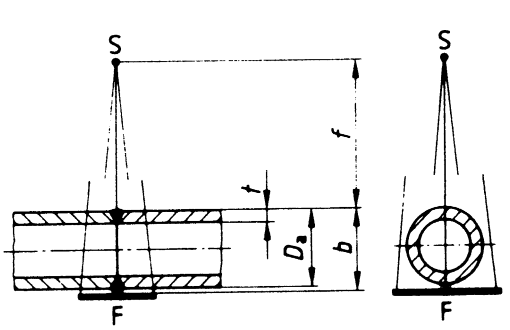

Figure 12 — Test arrangement for double-wall penetration double image of curved objects for evaluation of both walls (source and film outside the test object)

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6.1.8 ***Radiation source located outside the object and with the film on the other side***

See Figure 13, Figure 14, Figure 15, Figure 16, Figure 17 and Figure 18.

A1

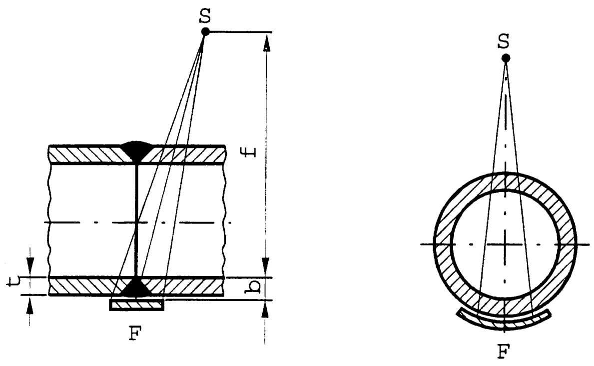

Figure 13 — Test arrangement for double-wall penetration single image of curved objects for evaluation of the wall next to the film, with the IQI placed close to the film

A1

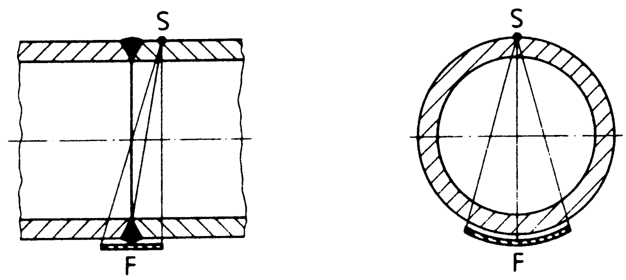

Figure 14 — Test arrangement for double-wall penetration single image

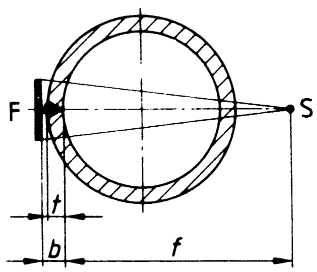

Figure 15 — Test arrangement for double-wall penetration single image of longitudinal welds

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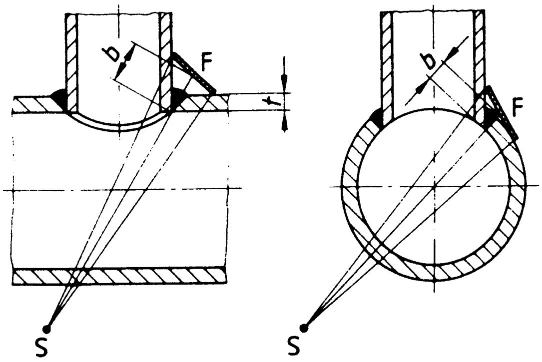

Figure 16 — Test arrangement for double-wall penetration single image of curved objects for evaluation of the wall next to the film

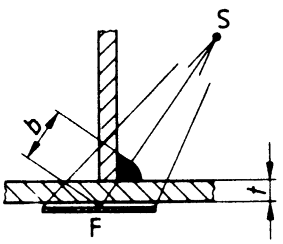

Figure 17 — Test arrangement for penetration of fillet welds

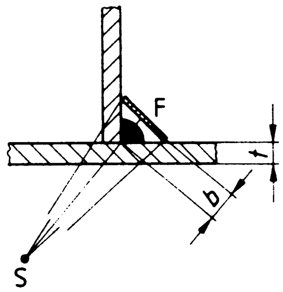

Figure 18 — Test arrangement for penetration of fillet welds

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6.1.9 ***Technique for different material thicknesses***

See Figure 19.

Radiation source

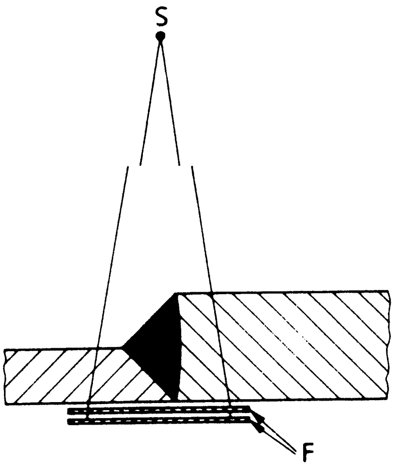

Figure 19 — Multi-film technique

6.2 Choice of tube voltage and radiation source

6.2.1 ***X-ray devices up to 500 kV***

To maintain a good flaw sensitivity, the X-ray tube voltage should be as low as possible. The maximum values of tube voltage versus thickness are given in Figure 20.

For some applications where there is a thickness change across the area of object being radiographed, a modification of technique with a slightly higher voltage may be used, but it should be noted that an excessively high tube voltage will lead to a loss of defect detection sensitivity. For steel, the increment shall be not more than 50 kV, for titanium not more than 40 kV, and for aluminium not more than 30 kV.

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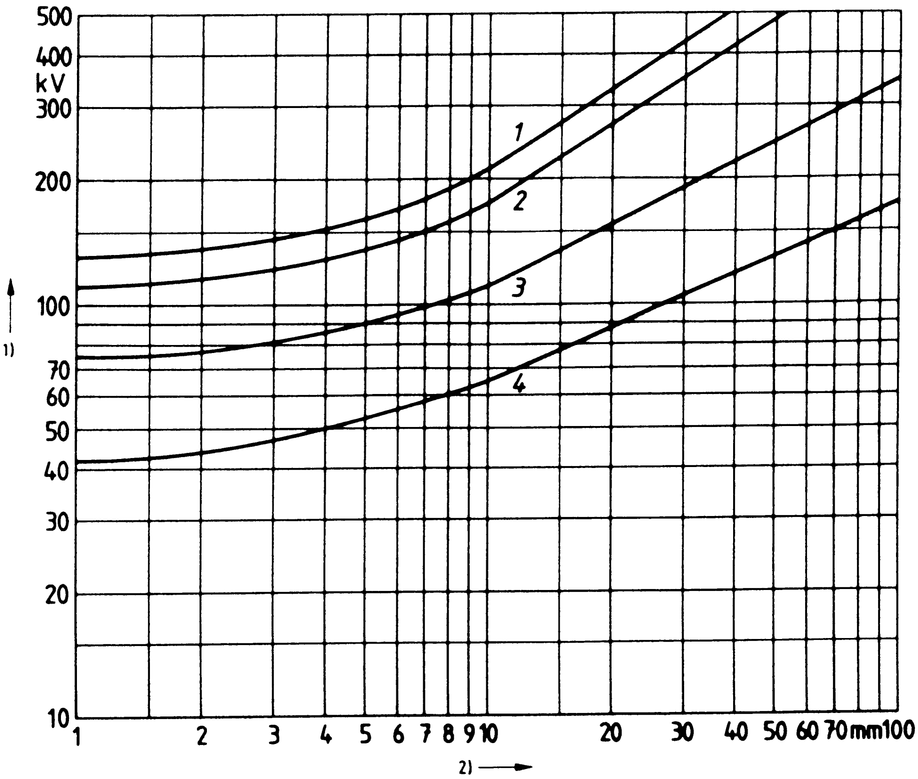

1 Copper/nickel and alloys
2 Steel
3 Titanium and alloys
4 Aluminium and alloys

1) X-ray voltage
2) Penetrated thickness *w*

Figure 20 — Maximum X-ray voltage for X-ray devices up to 500 kV as a function of penetrated thickness and material

6.2.2 *Other radiation sources*

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

[A1⟩ If permitted by specification ⟨A1], the value for Ir 192 may further be reduced to 10 mm and for Se 75 to 5 mm.

On thin steel specimens, gamma rays from Se 5, Ir 192 and Co 60 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 to position the source shall not exceed 10 % of the total exposure time.

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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-based alloys

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

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.

6.3 Film systems and screens

For radiographic testing, film system classes shall be used in accordance with EN 584-1.

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

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

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

Other screen thicknesses may be [A1) specified (A1], provided that the required image quality is achieved.

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Table 2 — Film system classes and metal screens for the radiography of steel, copper and nickel-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		C 5	C 3	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			C 4	0,02 mm to 0,15 mm front and back screens of lead	
Yb 169 Tm 170	w < 5	C 5	C 3	None or up to 0,03 mm front and back screens of lead	
	w ⩾ 5		C 4	0,02 mm to 0,15 mm front and back screens of lead	
X-ray potentials > 250 kV to 500 kV	w ⩽ 50	C 5	C 4	0,02 mm to 0,2 mm front and back screens of lead	
	w > 50		C 5	0,1 mm to 0,2 mm front screens of lead[2)] 0,02 mm to 0,2 mm back screens of lead	
Se 75		C 5	C 4	0,1 mm to 0,2 mm front and back screens of lead	
Ir 192		C 5	C 4	0,02 mm to 0,2 mm front screens of lead[2)]	0,1 mm to 0,2 mm front screens of lead[2)]
				0,02 mm to 0,2 mm back screens of lead	
Co 60	w ⩽ 100	C.5	C 4	0,25 mm to 0,7 mm front and back screens of steel or copper[3)]	
	w > 100		C 5		
X-ray equipment with energy from 1 MeV to 4 MeV	w ⩽ 100	C 5	C 3	0,25 mm to 0,7 mm front and back screens of steel or copper[3)]	
	w > 100		C 5		
X-ray equipment with energy from 4 MeV to 12 MeV	w ⩽ 100	C 4	C 4	Up to 1 mm front screen of copper, steel or tantalum[4)]	
	100 < w ⩽ 300	C 5	C 4	Back screen of copper or steel up to 1 mm and tantalum up to 0,5 mm[4)]	
	w > 300		C 5		
X-ray equipment with energy above 12 MeV	w ⩽ 100	C 4	—	Up to 1 mm front screen of tantalum[5)]	
	100 < w ⩽ 300	C 5	C 4	No back screen	
	w > 300		C 5	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, 0,5 mm to 2,0 mm screens of lead may also be used.
[4)] In class A, lead screens 0,5 mm to 1 mm may be used [A1⟩ if permitted by specification. ⟨A1]
[5)] Tungsten screens may be used by agreement.

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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	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
Yb 169			0,02 mm to 0,15 mm front and back screens of lead
Se 75			[A1⟩ 0,2 mm ⟨A1] front[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.

6.4 Alignment of beam

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

Other ways of radiographing may be [A1⟩ specified ⟨A1].

6.5 Reduction of scattered radiation

6.5.1 *Filters and collimators*

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

With Ir 192 and Co 60 radiation sources or in the 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, in accordance with the penetrated thickness.

6.5.2 *Interception of back scattered radiation*

If necessary, the film shall be shielded from back scattered 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.

The presence of back scattered radiation shall 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 each 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.

6.6 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.

$$\text{For class A: } \frac{f}{d} \geq 7,5\left(\frac{b}{\text{mm}}\right)^{2/3} \quad (1)$$

$$\text{For class B: } \frac{f}{d} \geq 15\left(\frac{b}{\text{mm}}\right)^{2/3} \quad (2)$$

b is given in millimetres (mm).

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If the distance $b < 1{,}2t$, the dimension b in equations (1) and (2) and Figure 21 shall be replaced by the nominal thickness t.

For determination of the source-to-object distance, f_{min}, the nomogram in Figure 21 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.

When using the elliptic technique described in **6.1.6** or the perpendicular technique described in **6.1.7**, b shall be replaced by the external diameter, D_e, of the pipe in equations (1) and (2) and in Figure 21.

When the source is outside the object and the film is on the other side (the technique described in **6.1.8** as double-wall penetration/single image), the source-to-object distance is determined only by the wall thickness.

If the radiation source can be placed inside the object to be radiographed (the techniques shown in **6.1.4** and **6.1.5**) to achieve a more suitable direction of test, and when a double-wall technique (see **6.1.6**, **6.1.7** and **6.1.8**) is avoided, this method should be preferred. The reduction in minimum source-to-object distance should not be greater than 20 %.

When the source is located centrally inside the object and the film is outside (the technique shown in **6.1.4**), 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 %.

6.7 Maximum area for a single exposure

The number of radiographs for a complete testing of flat welds (see Figure 1 and Figure 15) and of curved welds with the radiation source arranged off-centre (see Figure 2, Figure 3 and Figure 4 and Figure 8 to Figure 16) should be specified in accordance with technical requirements.

The ratio of the penetrated thickness at the outer edge of an evaluated area of uniform thickness to that at the centre beam shall not be more than 1,1 for class B and 1,2 for class A.

The densities resulting from any variation of penetrated thickness should not be lower than those indicated in **6.8** and not higher than those allowed by the available illuminator, provided that suitable masking is possible.

The size of the area to be tested includes the weld and the heat-affected zones. In general, about 10 mm of parent metal shall be tested on each side of the weld.

A recommendation for the number of radiographs is indicated in Annex A, which gives an acceptable test of a circumferential butt weld.

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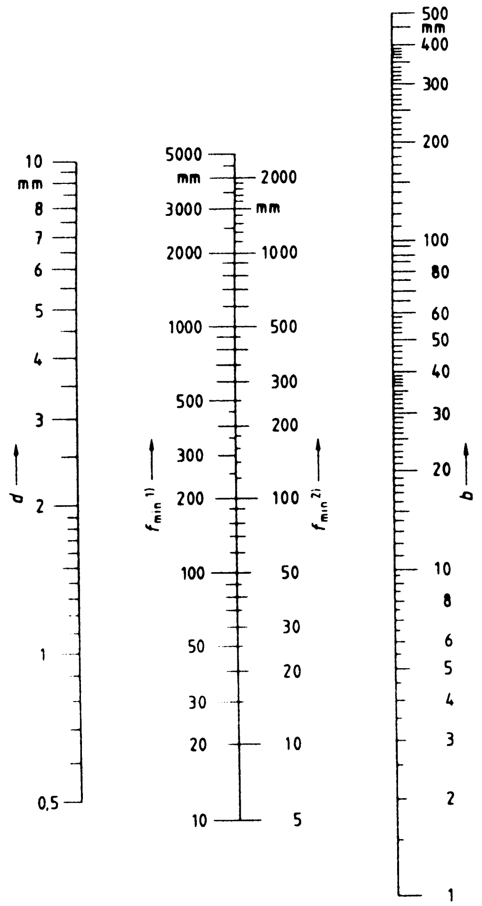

1) Class B 2) Class A

Figure 21 — Nomogram for the determination of minimum source-to-object distance f_{min} in relation to the object-to-film distance and the source size

6.8 Density of radiograph

Exposure conditions should be such that the minimum optical density of the radiograph in the area tested is greater than or equal to the value given in Table 4.

Table 4 — Optical density of the radiographs

Class	Optical density[1)]
A	$\geqslant$ 2,0[2)]
B	$\geqslant$ 2,3[3)]

[1)] A measuring tolerance of ±0,1 is permitted.
[2)] May be reduced [A1) if permitted by specification to 1,5. (A1]
[3)] May be reduced [A1) if permitted by specification to 2,0. (A1]

High optical densities can be used with advantage where the viewing light is sufficiently bright in accordance with **6.10**.

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 defined as the total density (emulsion and base) of a processed, unexposed film.

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When using a multi-film technique with interpretation of single films, the optical density of each film shall be in accordance with Table 4.

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

6.9 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 584-2. The radiographs should be free from defects due to processing or other causes which would interfere with interpretation.

6.10 Film viewing conditions

The radiographs should be tested 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.

7 Test report

For each exposure, or set of exposures, a test report shall be made giving information on the radiographic technique used, and on any other special circumstances which would allow a better understanding of the results.

The test report shall include at least the following information:

a) name of the testing body;

b) object;

c) material;

d) heat treatment;

e) geometry of the weld;

f) material thickness;

g) welding process;

h) specification of test, including requirements for acceptance;

i) radiographic technique and class, required IQI sensitivity in accordance with this standard;

j) test arrangement in accordance with **6.1**;

k) system of marking used;

l) film position plan;

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

n) film, screens and filters;

o) used tube voltage and current or source activity;

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

q) processing technique: manual/automatic;

r) type and position of image quality indicators;

s) results of test, including data on film density, reading of IQI;

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

u) name, [A1⟩ reference to certificate and signature of the responsible person(s); ⟨A1]

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

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Annex A (normative) Recommended number of exposures which give an acceptable test of a circumferential butt weld

The minimum number of exposures required is presented in Figure A.1, Figure A.2, Figure A.3 and Figure A.4, which are valid for pipes with an outside diameter exceeding 100 mm.

When the deviation of the wall thickness of the joint to be tested when using a single exposure, $\Delta t/t$, does not exceed 20 %, Figure A.3 and Figure A.4 are used. This technique is recommended only when the possibility of having transverse cracks is small or when the weld is tested for such imperfections by other non-destructive test methods.

When $\Delta t/t$ is less than or equal to 10 %, Figure A.1 and Figure A.2 are used. In this case it is likely that transverse cracks will also be detected.

If the object is examined for single transverse cracks, then the required minimum number of radiographs will increase compared with the values in Figure A.1, Figure A.2, Figure A.3 and Figure A.4.

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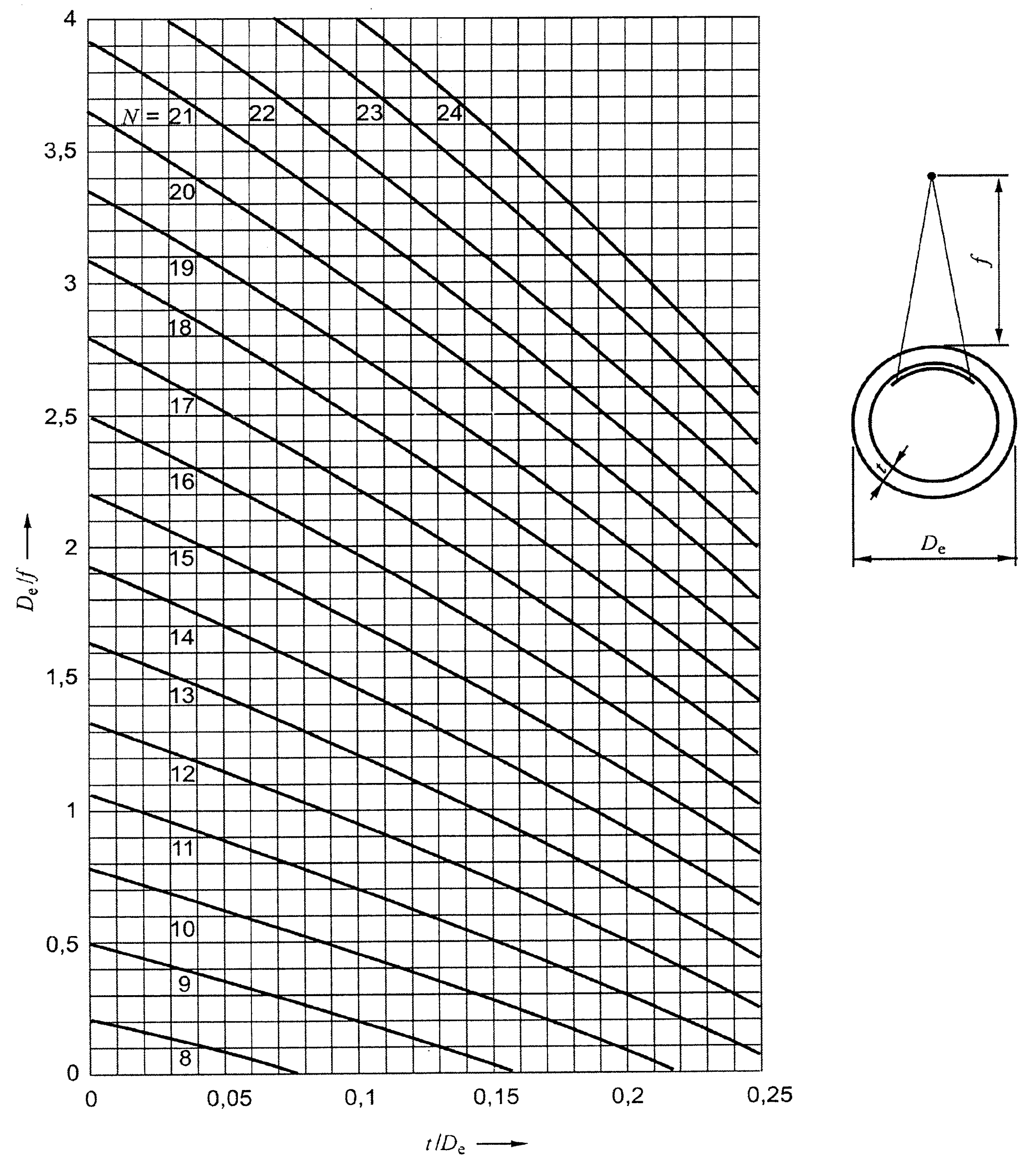
A1



Nominal thickness t/ outside pipe diameter D

Figure A.1 — Minimum number of exposures, N, for single-wall penetration with source outside, with a maximum permissible increase in penetrated thickness $\Delta t/t$ due to inclined penetration in the areas to be evaluated of 10 %, as a function of ratios t/D_e and D_e/f

A1

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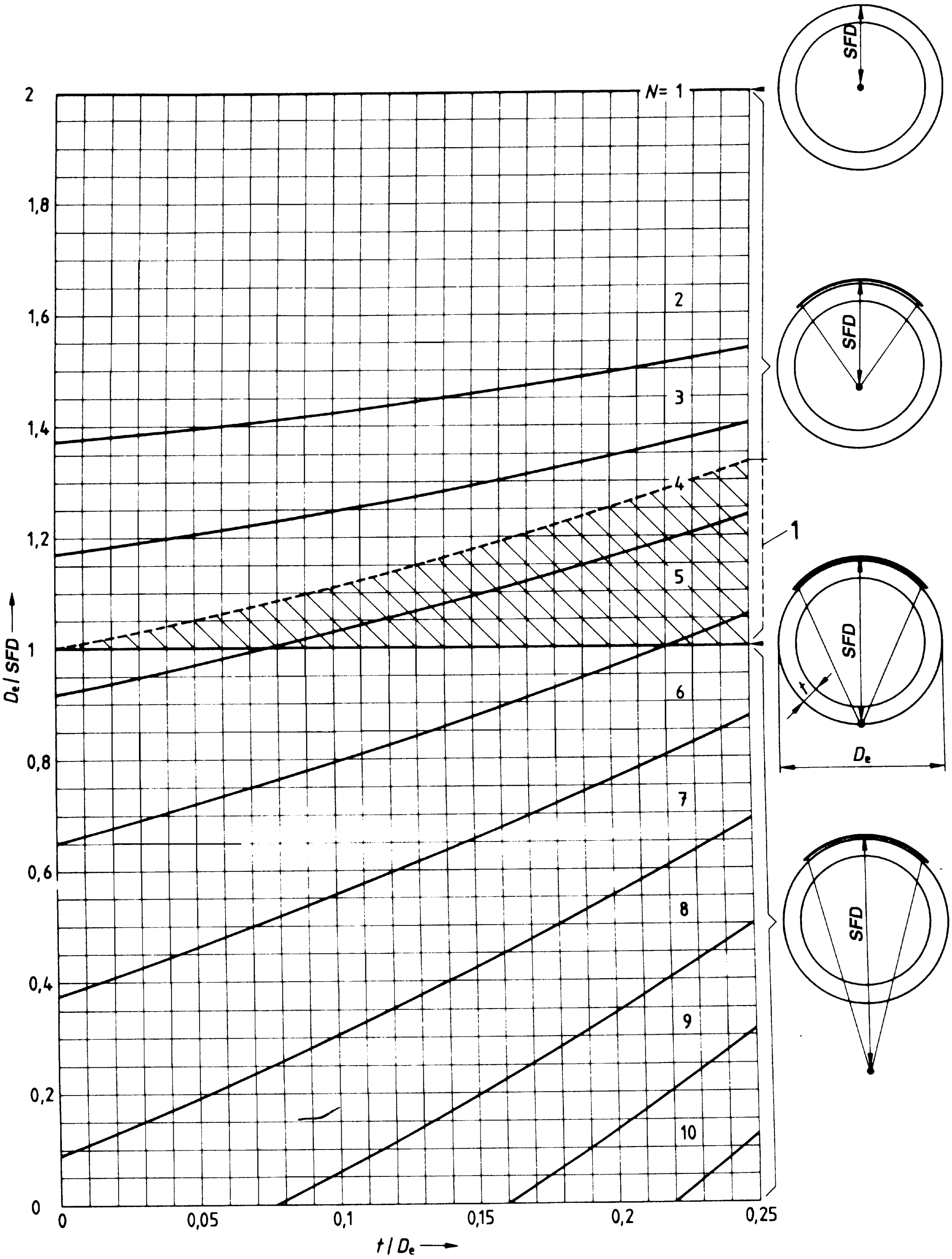
A1



1 Pipe wall

Nominal thickness t / outside pipe diameter D

Figure A.2 — Minimum number of exposures, N, for off-centre penetration with source inside and double-wall penetration, with a maximum permissible increase in penetrated thickness $\Delta t/t$ due to inclined penetration in the areas to be evaluated of 10 %, as a function of ratios t/D_e and D_e/SFD

A1

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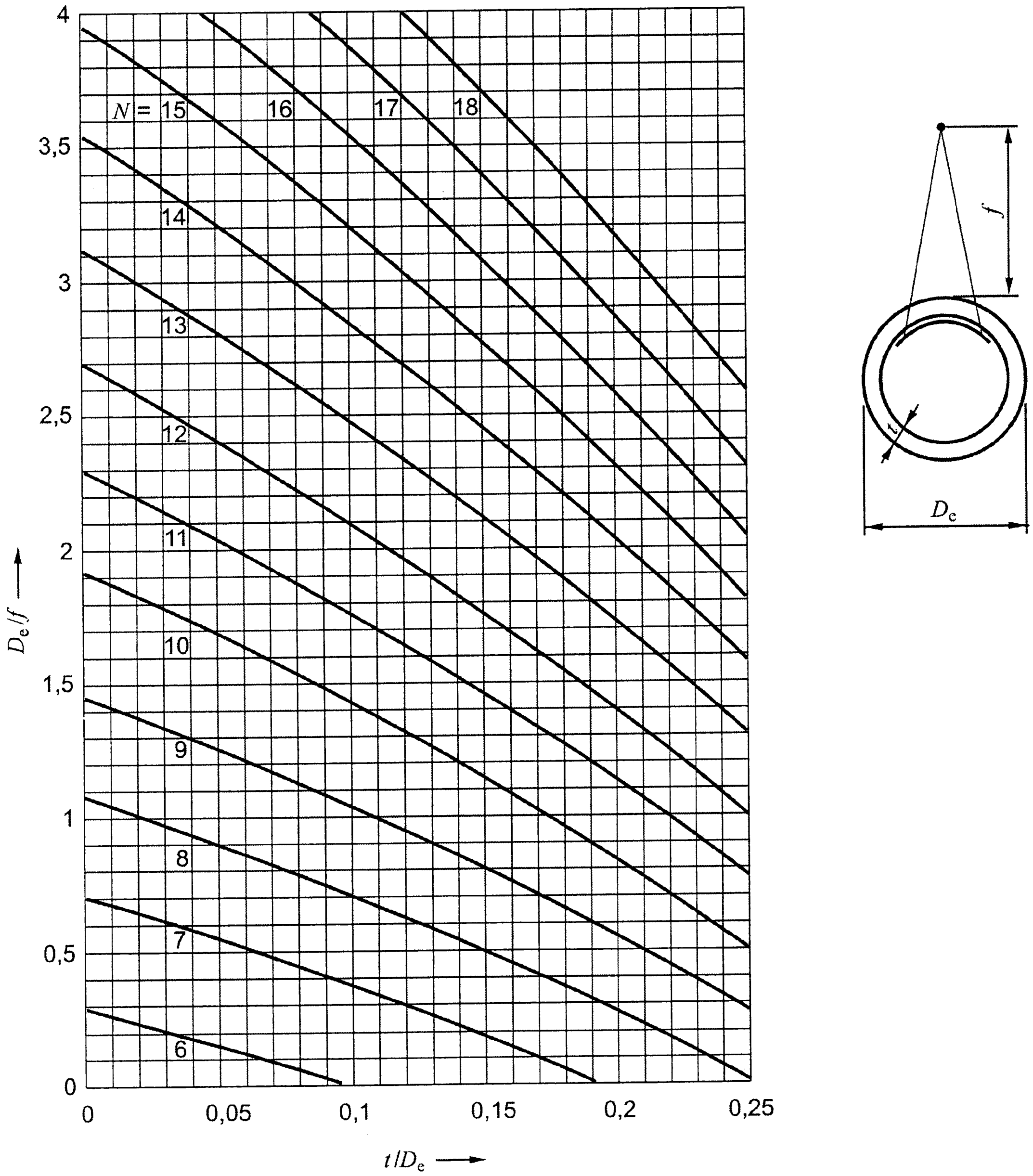
A1⟩



Nominal thickness *t*/ outside pipe diameter *D*

Figure A.3 — Minimum number of exposures, *N*, for single-wall penetration with source outside, with a maximum permissible increase in penetrated thickness $\Delta t/t$ due to inclined penetration in the areas to be evaluated of 20 %, as a function of ratios t/D_e and D_e/f

⟨A1

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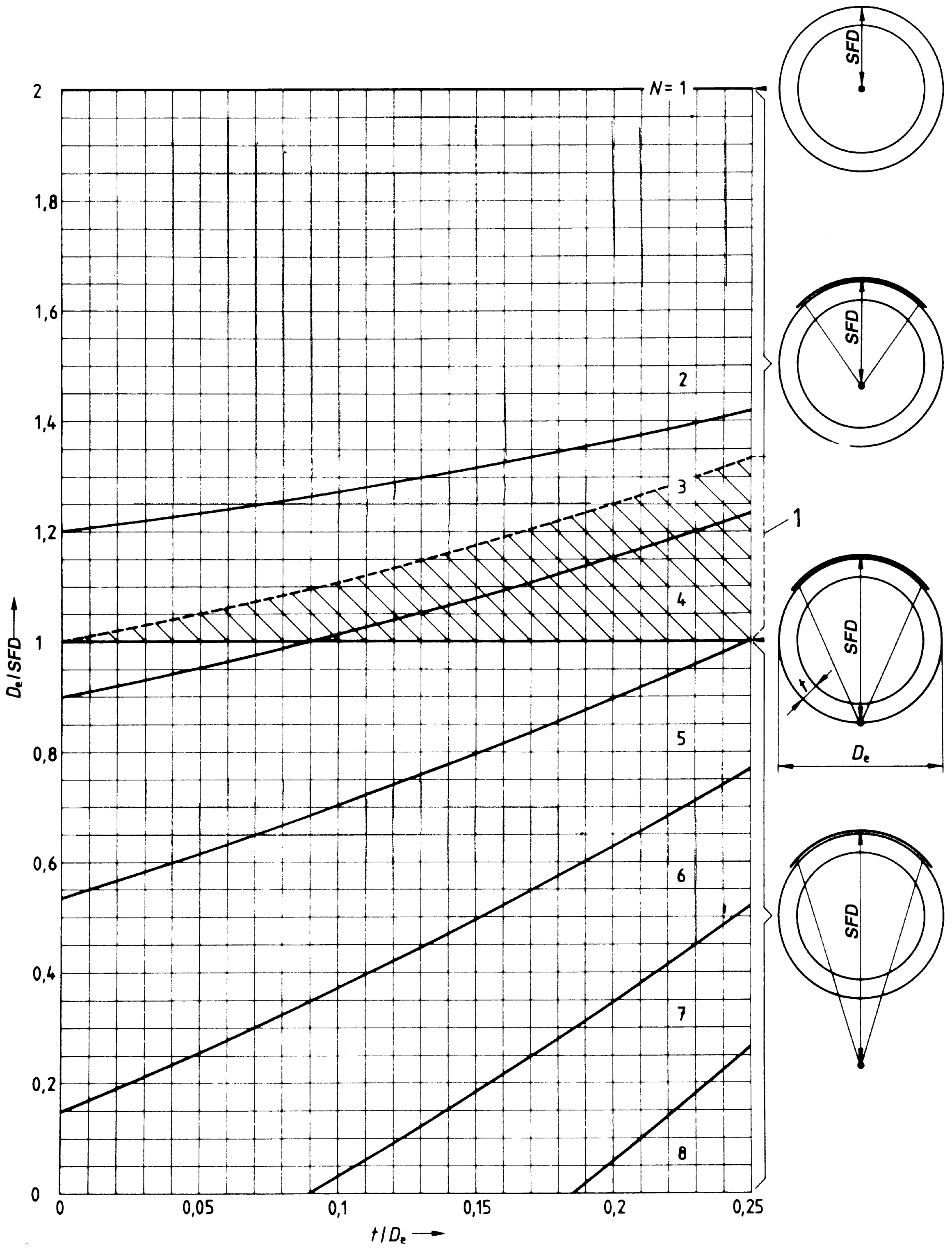
[A1⟩



1 Pipe wall

Nominal thickness t/ outside pipe diameter D

Figure A.4 — Minimum number of exposures, N, for off-centre penetration with source inside and double-wall penetration, with a maximum permissible increase in penetrated thickness $\Delta t/t$ due to inclined penetration in the areas to be evaluated of 20 %, as a function of ratios t/D_e and D_e/SFD

⟨A1]

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Annex B (normative)
Minimum image quality values

Single-wall technique; IQI on source side

Table B.1 — Wire IQI

Image quality class A	
Nominal thickness *t* mm	**IQI value**[1)]
up to 1,2	W 18
above 1,2 to 2,0	W 17
above 2,0 to 3,5	W 16
above 3,5 to 5,0	W 15
above 5,0 to 7	W 14
above 7 to 10	W 13
above 10 to 15	W 12
above 15 to 25	W 11
above 25 to 32	W 10
above 32 to 40	W 9
above 40 to 55	W 8
above 55 to 85	W 7
above 85 to 150	W 6
above 150 to 250	W 5
above 250	W 4

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
10 mm to 24 mm: up to two values;
above 24 mm to 30 mm; up to one value.

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Table B.2 — Step/hole IQI

Image quality class A	
Nominal thickness *t* mm	**IQI value**[1)]
up to 2,0	H 3
above 2,0 to 3,5	H 4
above 3,5 to 6	H 5
above 6 to 10	H 6
above 10 to 15	H 7
above 15 to 24	H 8
above 24 to 30	H 9
above 30 to 40	H 10
above 40 to 60	H 11
above 60 to 100	H 12
above 100 to 150	H 13
above 150 to 200	H 14
above 200 to 250	H 15
above 250 to 320	H 16
above 320 to 400	H 17
above 400	H 18

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
10 mm to 24 mm: up to two values;
above 24 mm to 30 mm: up to one value.

Single-wall technique; IQI on source side

Table B.3 — Wire IQI

Image quality class B	
Nominal thickness *t* mm	**IQI value**[1)]
up to 1,5	W 19
above 1,5 to 2,5	W 18
above 2,5 to 4	W 17
above 4 to 6	W 16
above 6 to 8	W 15
above 8 to 12	W 14
above 12 to 20	W 13
above 20 to 30	W 12
above 30 to 35	W 11
above 35 to 45	W 10
above 45 to 65	W 9
above 65 to 120	W 8
above 120 to 200	W 7
above 200 to 350	W 6
above 350	W 5

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
12 mm to 40 mm: up to one value.

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Table B.4 — Step/hole IQI

Image quality class B	
Nominal thickness *t* mm	**IQI value[1)]**
up to 2,5	H 2
above 2,5 to 4	H 3
above 4 to 8	H 4
above 8 to 12	H 5
above 12 to 20	H 6
above 20 to 30	H 7
above 30 to 40	H 8
above 40 to 60	H 9
above 60 to 80	H 10
above 80 to 100	H 11
above 100 to 150	H 12
above 150 to 200	H 13
above 200 to 250	H 14

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
12 mm to 40 mm: up to one value.

Double-wall technique; double image; IQI on source side

Table B.5 — Wire IQI

Image quality class A	
Penetrated thickness *w* mm	**IQI value**
up to 1,2	W 18
above 1,2 to 2	W 17
above 2 to 3,5	W 16
above 3,5 to 5	W 15
above 5 to 7	W 14
above 7 to 12	W 13
above 12 to 18	W 12
above 18 to 30	W 11
above 30 to 40	W 10
above 40 to 50	W 9
above 50 to 60	W 8
above 60 to 85	W 7
above 85 to 120	W 6
above 120 to 220	W 5
above 220 to 380	W 4
above 380	W 3

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[A1] Double-wall technique; double image; IQI on source side [A1]

Table B.6 — Step/hole IQI

Image quality class A	
Penetrated thickness ***w*** mm	**IQI value**[1)]
up to 1	H 3
above 1 to 2	H 4
above 2 to 3,5	H 5
above 3,5 to 5,5	H 6
above 5,5 to 10	H 7
above 10 to 19	H 8
above 19 to 35	H 9

1) When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
up to 3,5 mm: up to two values;
above 3,5 mm to 10 mm: up to one value.

Double-wall technique; double image; IQI on source side

Table B.7 — Wire IQI

Image quality class B	
Penetrated thickness ***w*** mm	**IQI value**
up to 1,5	W 19
above 1,5 to 2,5	W 18
above 2,5 to 4	W 17
above 4 to 6	W 16
above 6 to 8	W 15
above 8 to 15	W 14
above 15 to 25	W 13
above 25 to 38	W 12
above 38 to 45	W 11
above 45 to 55	W 10
above 55 to 70	W 9
above 70 to 100	W 8
above 100 to 170	W 7
above 170 to 250	W 6
above 250	W 5

Table B.8 — Step/hole IQI

Image quality class B	
Penetrated thickness ***w*** mm	**IQI value**[1)]
up to 1	H 2
above 1 to 2,5	H 3
above 2,5 to 4	H 4
above 4 to 6	H 5
above 6 to 11	H 6
above 11 to 20	H 7
above 20 to 35	H 8

1) When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
4 mm to 11 mm: up to one value.

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Double-wall technique; single or double image; IQI on film side

Table B.9 — Wire IQI

Image quality class A	
Penetrated thickness *w* mm	**IQI value**
up to 1,2	W 18
above 1,2 to 2	W 17
above 2 to 3,5	W 16
above 3,5 to 5	W 15
above 5 to 10	W 14
above 10 to 15	W 13
above 15 to 22	W 12
above 22 to 38	W 11
above 38 to 48	W 10
above 48 to 60	W 9
above 60 to 85	W 8
above 85 to 125	W 7
above 125 to 225	W 6
above 225 to 375	W 5
above 375	W 4

Table B.10 — Step/hole IQI

Image quality class A	
Penetrated thickness *w* mm	**IQI value**[1)]
up to 2	H 3
above 2 to 5	H 4
above 5 to 9	H 5
above 9 to 14	H 6
above 14 to 22	H 7
above 22 to 36	H 8
above 36 to 50	H 9
above 50 to 80	H 10

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
5 mm to 9 mm: up to two values;
above 9 mm to 22 mm: up to one value.

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Double-wall thickness; single or double image; IQI on film side

Table B.11 — Wire IQI

Image quality class B	
Penetrated thickness *w* mm	**IQI value**
up to 1,5	W 19
above 1,5 to 2,5	W 18
above 2,5 to 4	W 17
above 4 to 6	W 16
above 6 to 12	W 15
above 12 to 18	W 14
above 18 to 30	W 13
above 30 to 45	W 12
above 45 to 55	W 11
above 55 to 70	W 10
above 70 to 100	W 9
above 100 to 180	W 8
above 180 to 300	W 7
above 300	W 6

Table B.12 — Step/hole IQI

Image quality class B	
Penetrated thickness *w* mm	**IQI value**[1)]
up to 2,5	H 2
above 2,5 to 5,5	H 3
above 5,5 to 9,5	H 4
above 9,5 to 15	H 5
above 15 to 24	H 6
above 24 to 40	H 7
above 40 to 60	H 8
above 60 to 80	H 9

[1)] When using Ir 192 sources, IQI values worse than the listed values can be accepted as follows:
5,5 mm to 9,5 mm: up to two values;
above 9,5 mm to 24 mm: up to one value.

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Annex ZA (informative)
Clauses of this European Standard addressing essential requirements or other provisions of EU directives

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of Directive 97/23/EC of the European Parliament and the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

WARNING Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

The following clauses of this standard as detailed in Table ZA.1 and Table ZA.2, are likely to support requirements of the Directives 97/23/EC, and 87/404/EEC.

Compliance with these clause of this standard provides one with means of conforming to the specific essential requirements of the Directives concerned and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 97/23/EC

Clauses/sub-clauses of this European Standard	Essential requirements of Directive 97/23/EC	Qualifying remarks/notes
All	Annex I, **3.1.2**	Non-destructive tests

Table ZA.2 — Correspondence between this European Standard and Directive 87/404/EEC

Clauses/sub-clauses of this European Standard	Essential requirements of Directive 97/23/EC	Qualifying remarks/notes
All	Annex I, **3.2**	Welds on pressurized parts

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