BRITISH STANDARD

BS EN
13100-2:2004

Non-destructive testing of welded joints in thermoplastics semi-finished products —

Part 2: X-ray radiographic testing

The European Standard EN 13100-2:2004 has the status of a British Standard

ICS 25.160.40

BSI
British Standards

National foreword

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The UK participation in its preparation was entrusted to Technical Committee PRI/80, Welding of plastics, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/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.

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Zerstörungsfreie Prüfung von Schweißverbindungen thermoplastischer Kunststoffe - Teil 2: Röntgenprüfung

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Foreword

This document (EN 13100-2:2004) has been prepared by Technical Committee CEN/TC 249 “Plastics”, the secretariat of which is held by IBN.

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of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

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1 Scope

This document specifies fundamental radiographic techniques which enable repeatable results to be obtained economically.

This document applies to the X-ray radiographic examination of heated tool, electrofusion, extrusion and hot gas joints in plastics materials.

It applies to joints in single wall pipes and plates with a range of thicknesses from 5 mm to 100 mm. It only applies to pipes containing air or other gases at the time of X-ray testing.

This document does not specify acceptance levels of the indications.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

EN 473, *Non-destructive testing — Qualification and certification of NDT 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 values*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
nominal thickness
nominal thickness of the parent material

NOTE Manufacturing tolerances are not taken into account.

3.2
penetrated thickness
thickness of material in the direction of the radiation beam including the thickness of the weld beads on butt fusion joints (if appropriate), or the additional thickness of the socket for electrofusion joints, or the combined thickness of the top and bottom half of the joint for multiple wall techniques

3.3
object-to-film distance
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
size of the radiation source, e.g. the focal spot size of the X-ray tube

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

3.6
source-to-object distance
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
nominal outside diameter of the pipe

4 Symbols and abbreviations

Symbols and abbreviations are given in Table 1.

Table 1 — Symbols and abbreviations

Symbols and abbreviations	Designations	Units
b	Object-to-film distance	mm
d	Source size	mm
D_n	Diameter	mm
f	Source-to-object distance	mm
SFD	Source-to-film distance	mm
t	Nominal thickness	mm
w	Penetrated thickness	mm
S	Radiation source	—
F	Film	—
α	Inclination angle	
SDR	D_n/t	—

5 General

5.1 Security Measures

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

WARNING NOTICE - Exposure of any part of the human body to X-rays can be highly injurious to health. Wherever X-ray equipment is in use, appropriate legal requirements shall be applied.

5.2 Surface preparation and stage of manufacture

Prior to radiography the joint shall be cleaned to remove all traces of dirt etc. from the component surface, which might later cause difficulty in detecting defects.

In the case of heated tool butt welded pipes, the external weld bead shall be removed prior to radiography.

5.3 Location of the weld in the radiograph

Where the weld is not likely to be clearly visible on the radiograph, high-density markers (e.g. lead) shall be placed on either side of the weld before testing.

5.4 Identification of radiographs

Symbols (normally lead markers) 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 and shall ensure unambiguous 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 of each radiograph 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 position of image quality indicators (IQI)

The quality of image shall be verified by use of image quality indicator(s) (IQI) in accordance with EN 462-1 or EN 462-2. The IQI(s) shall be made from the same material as the inspected material or a material with a similar absorption with a tolerance of ± 10 % in the absorption coefficient. In accordance with EN 462-1 or EN 462-2 the applied IQI(s) shall have the inscription with the name of the document, the number of the thickest wire or the first step hole and the material. For plastic materials, this requires the name of the material (e.g.: PE- polyethylene, PP- polypropylene, PVC- polyvinylchloride, etc.) and the materials density given in g/cm^3 with at least two significant digits.

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 material beside the weld. The IQI shall be in close contact with the surface of the object.

It shall be located in a section of uniform thickness characterised 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 material adjacent to the weld. At exposures in accordance with Figures 3 and 4 the IQI 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 Figures 3 and 4 the IQI may be placed on the film side. In this case reference shall be made to Tables A.5 and A.6 given in Annex A.

Where the IQIs are placed at the film side, the lead 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 of 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 agreement between the contracting parties.

For panoramic exposures of pipes (see Figure 2) with diameter 200 mm and above, at least three IQIs shall be placed equally spaced around the circumference. The film(s) showing IQI images are then considered representative for the whole circumference.

5.8 Evaluation of image quality

The films shall be viewed in accordance with EN 25580.

From the examination of the image of the IQI on the radiograph, the number of the smallest wire or hole, which shall be discerned, shall be determined. The image of a wire shall be 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 is considered as visible.

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

5.9 Minimum image quality values

Tables A.1 to A.6 in Annex A show the minimum image quality values for plastics materials.

5.10 Personnel qualification

Personnel performing non-destructive examination in accordance with this document shall be qualified in accordance with the relevant document, e.g. EN 473.

6 Recommended techniques for making radiographs

6.1 Test arrangements

Normally radiographic techniques in accordance with Figures 1 to 9 shall be used.

In the case of heated tool butt welded pipes, the external weld bead shall be removed prior to radiography.

For test arrangements in accordance with Figures 3, 5 and 6, the inclination of the beam shall be kept as small as possible, but sufficient to prevent superimposition of the two images. The source-to-object distance, f, should be kept as small as possible, in accordance with 6.5. For Figures 5 and 6, the IQI shall be placed close to the film with a lead letter 'F'.

The elliptical technique (double wall/double image) in accordance with Figure 3 shall not be used for $D_n > 100$ mm and $t > 8$ mm.

Other radiographic techniques may be specified when appropriate, e.g. for reasons such as the geometry of the piece or differences in material thickness.

Annex B gives the minimum number of radiographs necessary to obtain an acceptable radiographic coverage of a butt weld in pipe of $D_n > 100$ mm.

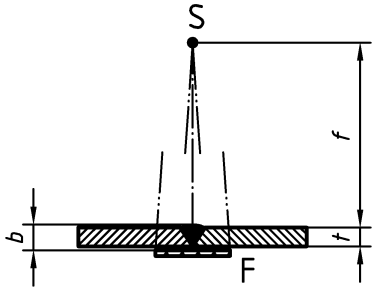


Figure 1 — Test arrangement for single-wall penetration of plates

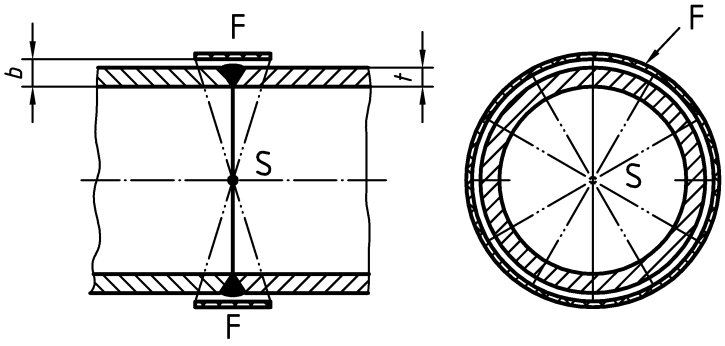


Figure 2 — Panoramic technique – Test arrangement for single-wall penetration of curved objects with the radiation source located centrally inside the object

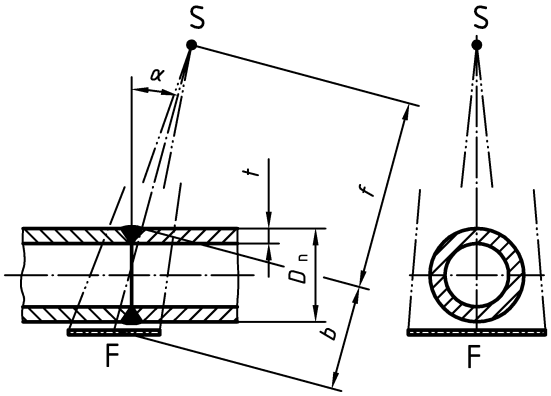


Figure 3 — Elliptical technique – Test arrangement for double-wall penetration, double image of curved objects for evaluation of both walls simultaneously

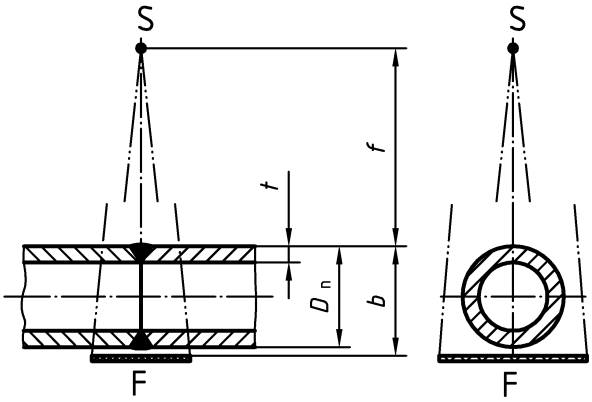


Figure 4 — Perpendicular technique – Test arrangement for double-wall penetration, double image of curved objects for evaluation of both walls simultaneously

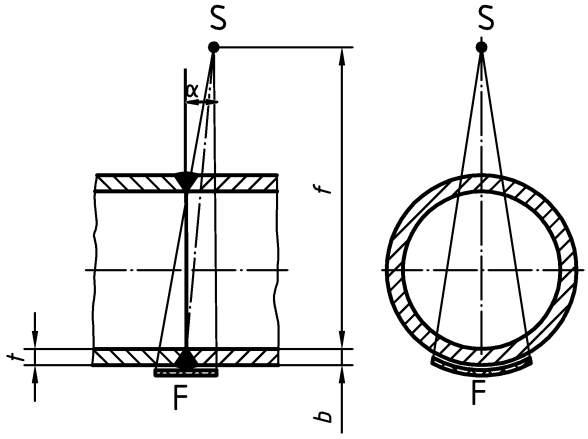


Figure 5 — Test arrangement for double-wall penetration, single image of curved objects for evaluation of the wall next to the film

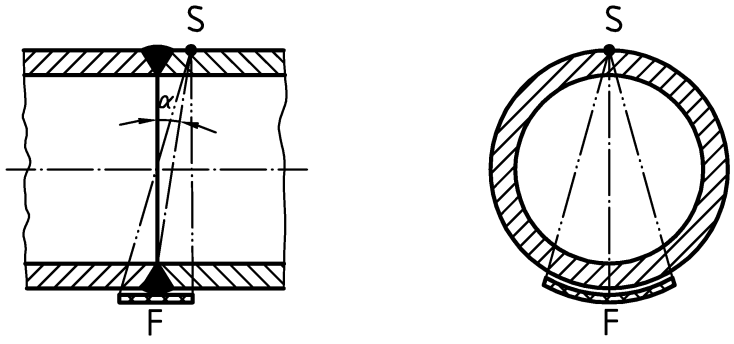


Figure 6 — Contact technique – Test arrangement for double-wall penetration, single image of curved objects for evaluation of the wall next to the film

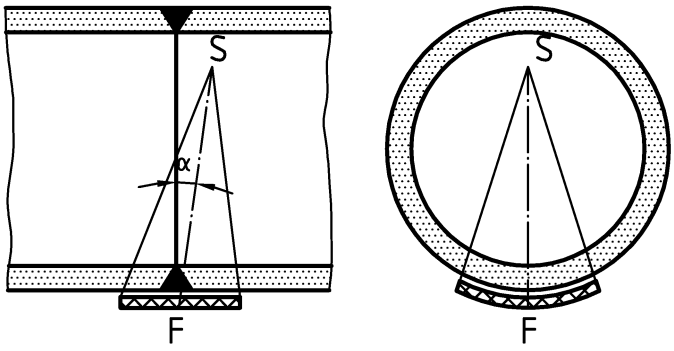


Figure 7 — Test arrangement for single-wall penetration of curved objects with the radiation source located off-centre inside the object

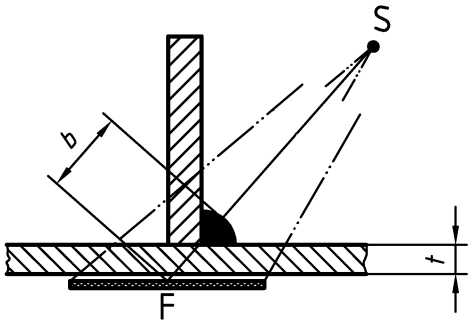


Figure 8 — Test arrangement for penetration of fillet weld with the radiation source located on the same side as the weld

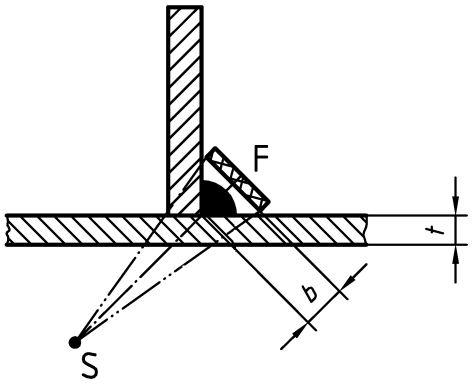
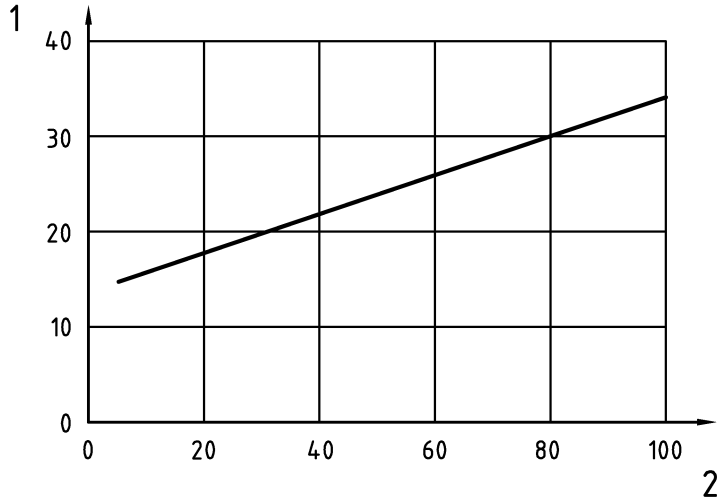


Figure 9 — Test arrangement for penetration of fillet weld with the radiation source located on the opposite side to the weld

6.2 Choice of tube voltage

To maintain a good flaw sensitivity in polyethylene (material density ≥ 0,94), the X-ray tube voltage shall be selected in accordance with Figure 10. For other plastic materials, the optimum X-ray tube voltage shall be determined in order to achieve the required image quality.



Key

1 Maximum X-ray voltage, kV
2 Thickness (mm)

Figure 10 — Maximum X-ray voltage as a function of penetrated thickness for polyethylene (density ≥ 0,94)

6.3 Film systems and screens

For radiographic examination, a film system class of C3 or better shall be used in accordance with EN 584-1. No intensifying screens shall be used.

6.4 Alignment of beam

The beam of radiation shall be directed to the centre of the area being examined 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.

For butt fusion joints, test arrangements where the X-ray beam is in-line with the fusion line shall be used wherever practicable (e.g. Figures 1, 2 and 4). These methods maximise the sensitivity to lack-of-fusion type flaws.

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 and is given in Equation (1).

$$f_{\min} = 15\, d \left(\frac{b}{[\mathrm{mm}]} \right)^{2/3} \tag{1}$$

If the distance $b < 1{,}2\ t$, the b in Equation (1) shall be replaced by the nominal thickness t.

When using the elliptical technique (Figure 3) or the perpendicular technique (Figure 4), b shall be replaced by D_n, in Equation (1).

For double-wall penetration, single image techniques (e.g. Figures 5 and 6), the object-to-film distance, *b*, shall be replaced by the wall thickness *t* in equation (1).

If the radiation source can be placed inside the object to be radiographed (Figures 2 and 7), this is preferable to a double-wall technique (e.g. Figures 3 and 4). It is still preferable to use the single-wall technique even if the minimum source-to-object distance needs to be reduced.

When the source is located centrally inside the object and the film is outside (Figure 2) and provided that the IQI requirements are met, this reduction can be up to but not exceeding 50 %. If the source is not located centrally (Figure 7) this reduction should not be greater than 20 %.

6.6 Maximum area for a single exposure

The number of radiographs for a complete examination of welds in plates (see Figures 1, 8 and 9) shall be specified.

For the panoramic technique (Figure 2) only one radiograph is required and for the elliptical technique (Figure 3), two 90° displaced images are sufficient for SDR values greater than 8.3. If the SDR value is less than 8.3, three 60° displaced images shall be used. For the other techniques, as described in Figures 4 to 7, the recommended number of radiographs which gives an acceptable examination of a circumferential butt joint is given in Annex B.

The densities resulting from any variation of penetrated thickness should not be lower than those indicated in 6.7 and not higher than those allowed by the available illuminator, according to 6.9.

The size of the area to be examined shall include the weld and the heat-affected zones. In general, about 10 mm of parent material should be examined on each side of the weld.

6.7 Density of radiograph

Exposure conditions shall be such that the minimum optical density of the radiograph in the area examined is greater than or equal to 2.3.

High optical densities can be used with advantage where the viewing light is sufficiently bright in accordance with 6.9.

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.

6.8 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 shall be free from defects due to processing or other causes, which would interfere with interpretation.

6.9 Film viewing conditions

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

7 Examination report

For each exposure, or set of exposures, an examination 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 examination report shall include at least the following information:

a) name of the examining body;

b) object;

c) material;

d) geometry of the weld;

e) material thickness;

f) welding process;

g) specification of examination, including requirements for acceptance;

h) radiographic technique and required IQI sensitivity in accordance with this document;

i) test arrangements in accordance with 6.1;

j) system of marking used;

k) film position plan;

l) focal spot size and identification of equipment used;

m) film type;

n) tube voltage and current used;

o) time of exposure;

p) source-to-film distance;

q) inclination angle (when applicable);

r) processing technique manual/automatic;

s) type and position of image quality indicators;

t) results of examination, including data on film density, reading of IQI;

u) any deviation from this document, by special agreement;

v) name, qualification and signature of the person(s) responsible;

w) date(s) of exposure and examination report.

Annex A
(normative)

Minimum image quality values

A.1 Single-wall technique; IQI on source side

Table A.1 — Wire IQI

Nominal thickness *t* mm	IQI value
5 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 100	W 8

Table A.2 — Step/hole IQI

Nominal thickness *t* mm	IQI value
5 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

A.2 Double-wall technique; double image; IQI on source side

Table A.3 — Wire IQI

Penetrated thickness *w* mm	IQI value
5 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

Table A.4 — Step/hole IQI

Penetrated thickness *w* mm	IQI value
5 to 11	H 6
above 11 to 20	H 7
above 20 to 35	H 8

A.3 Double-wall thickness; single or double image; IQI on film side

Table A.5 — Wire IQI

Penetrated thickness *w* mm	IQI value
5 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

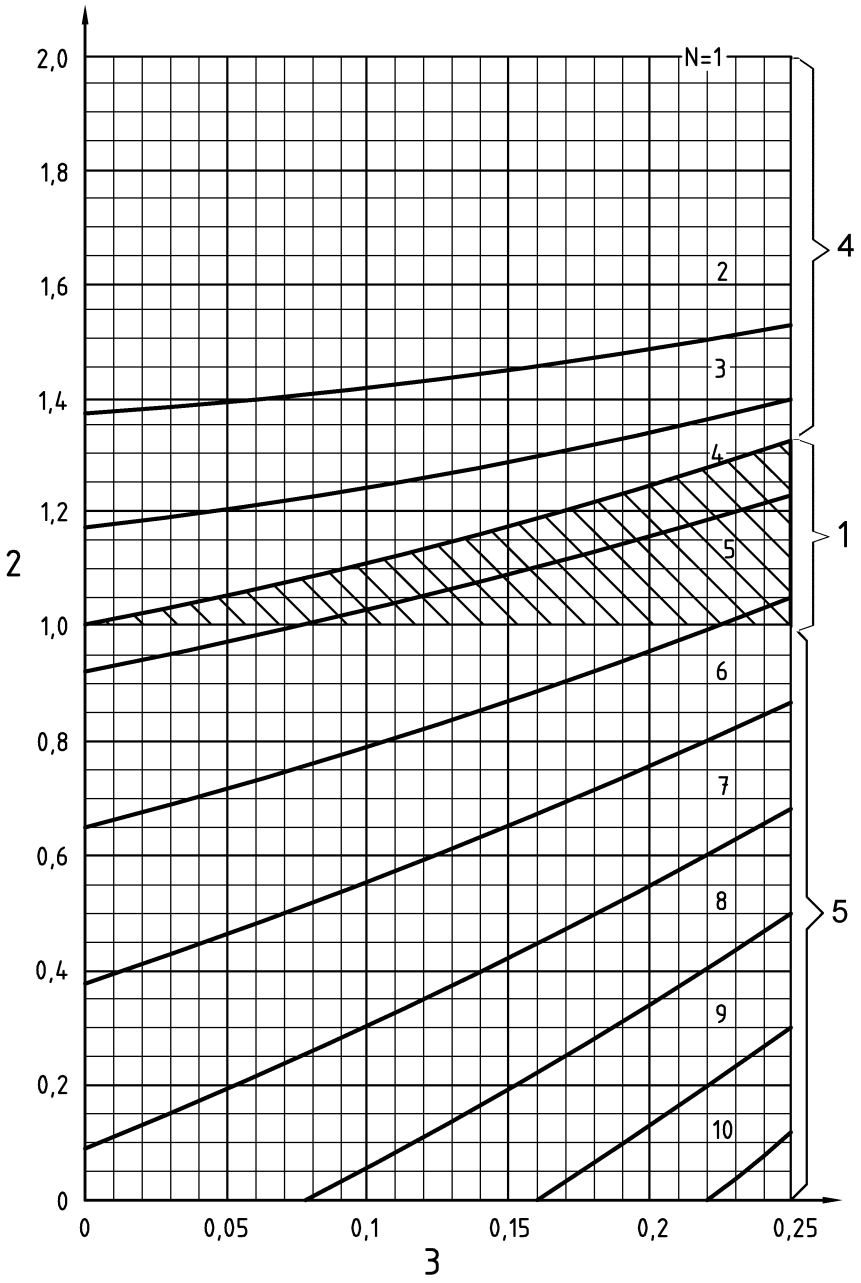
Table A.6 — Step/hole IQI

Penetrated thickness *w* mm	IQI value
5 to 10	H 4
above 10 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

Annex B
(informative)

Recommended number of exposures when using the perpendicular, double-wall, single-image and single-wall off-centre techniques for a circumferential butt weld

The recommended minimum number of exposures required is presented in Figure B.1. This is valid for pipes with D_n > 100 mm and when the maximum permissible increase in penetration thickness due to inclined penetration in the area being evaluated is 10 %.



Key

1 Pipe wall
2 D_n/SFD
3 t/D_n
4 Source inside the pipe
5 Source outside the pipe

Figure B 1 — Minimum number of exposures, N, as a function of ratios t/D_n and D_n/SFD

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