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Non-destructive testing of welds - Radiographic testing - Part 2: X- and gamma-ray techniques with digital detectors (ISO 17636-2:2022, Corrected version 2023-02)

Essais non destructifs des assemblages soudés - Contrôle par radiographie - Partie 2: Techniques par rayons X ou gamma à l'aide de détecteurs numériques (ISO 17636-2:2022, Version corrigée 2023-02)

Zerstörungsfreie Prüfung von Schweißverbindungen - Durchstrahlungsprüfung - Teil 2: Röntgen- und Gammastrahlungstechniken mit digitalen Detektoren (ISO 17636-2:2022, korrigierte Fassung 2023-02)

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7 Recommended techniques

7.1 Test arrangements

7.1.1 General

Radiographic techniques in accordance with 7.1.2 to 7.1.9 (Figures 1 to 19) shall be used, if possible.

The elliptical technique (double-wall and double-image) in accordance with 7.1.6 (Figure 11) should only be used for external diameter $D_e \leq 100$ mm and wall thickness $t \leq 8$ mm and weld width $\leq D_e/4$. Two 90° displaced images are sufficient if $t/D_e < 0{,}12$; otherwise, three elliptical images are needed. The distance between the two projected weld images shall be about one weld width. Due to the higher dynamic range of digital detectors than in film radiography, D_e and t may exceed the values given by 10 %.

When it is not possible to carry out an elliptical testing for $D_e \leq 100$ mm, the perpendicular technique in accordance with 7.1.7 (Figure 12) may be used. In this case, three exposures 120° or 60° apart are required, depending on the access around the pipe.

For test arrangements in accordance with 7.1.8 (Figures 13 and 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 for the technique shown in Figures 13 and 14, in accordance with 7.6. The IQI shall be placed on the detector side close to the detector with a lead letter F.

Digital radiographic techniques other than those in 7.1.2 to 7.1.9 (Figures 1 to 19) may be agreed by the contracting parties when it is useful, for reasons such as the geometry of the piece or differences in material thickness. In 7.1.9 (Figures 17 to 19), an example of such a case is presented. Additionally, thickness compensation with the same material may be applied.

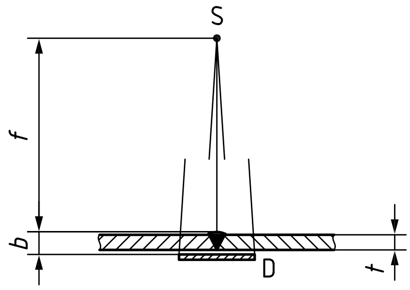
In Annex A, the minimum number of digital radiographs required is given in order to obtain an acceptable radiographic coverage of the total circumference of a butt weld in pipe.

If the geometric magnification technique is not used, the detector shall be placed as close as possible to the object.

If flexible detectors are not applicable and rigid cassettes or planar DDAs are used, as shown in Figures 2 b), 8 b), 13 b) and 14 b), the SDD shall be calculated from the wall thickness, t, the largest distance of the detector to the source side surface of the object, b, and the focal spot size or source size, d, as specified in 7.6, Formulae (2) to (13).

NOTE Unless otherwise noted, definitions of the symbols used in Figures 1 to 24 and in the annexes can be found in Clause 4.

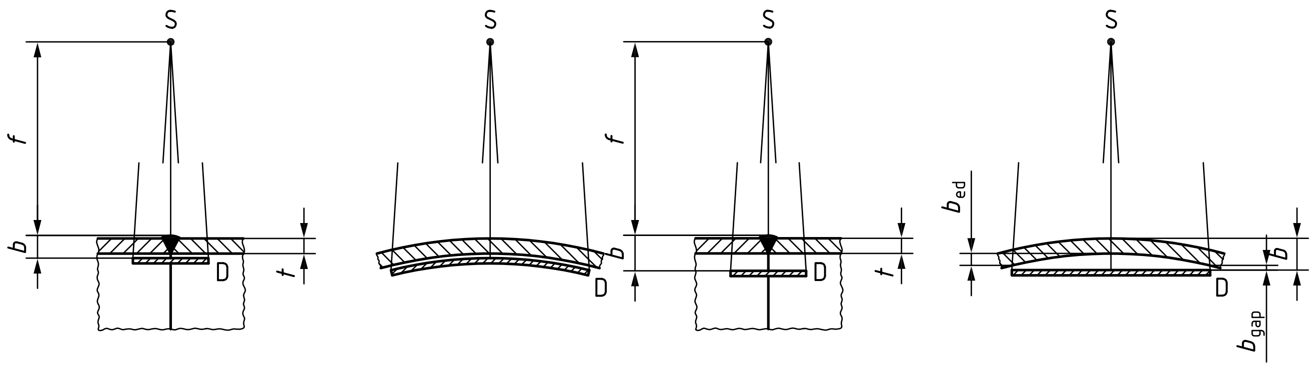
7.1.2 Single-wall penetration of plane objects (see Figure 1)



NOTE If the distance, *b*, in Figure 1 is less than 1,2 *t*, then the nominal thickness, *t*, can be used for *b* and *f* can be considered as the distance from the source to the parent material surface.

Figure 1 — Arrangement for testing of planar welds with radiation source on one side and the detector on the opposite side

7.1.3 Single-wall penetration of curved objects with the source outside the object (see Figures 2 to 4)



a) With curved detectors **b) With planar detectors**

NOTE If the distance, *b*, in Figure 2 is less than 1,2 *t*, then the nominal thickness, *t*, can be used for *b* and *f* can be considered as the distance from the source to the parent material surface.

Figure 2 — Arrangement for testing of curved objects with the radiation source outside and the detector inside

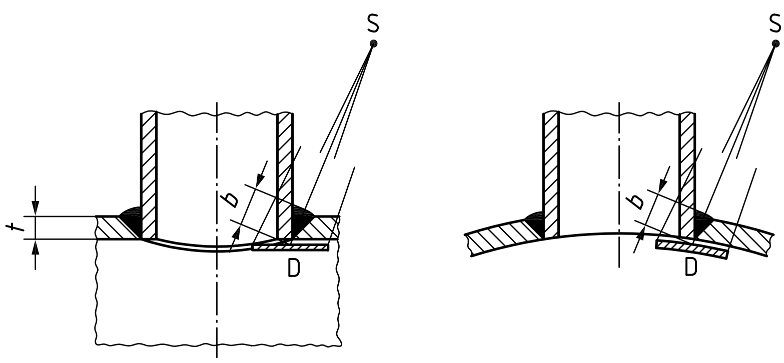


Figure 3 — Arrangement for testing of set-in welds with the radiation source outside and the detector inside

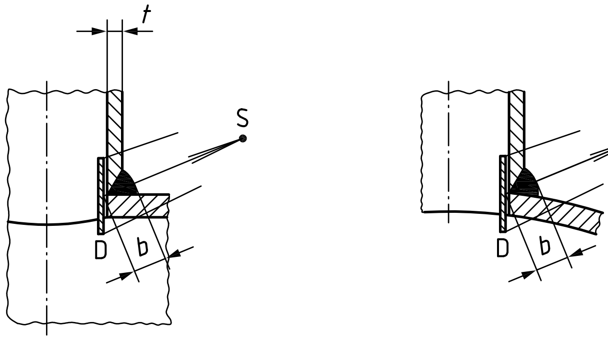
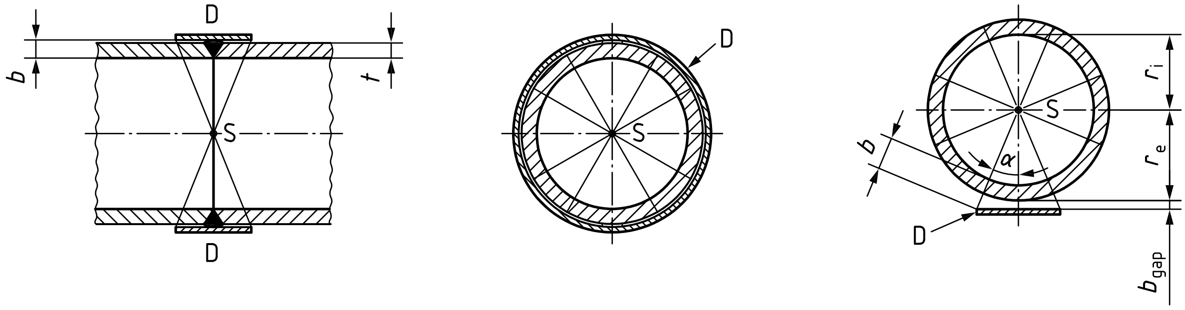


Figure 4 — Arrangement for testing of set-on welds with the radiation source outside and the detector inside

7.1.4 Single-wall penetration of curved objects with the source inside the object for panoramic exposure (see Figures 5 to 7)



a) With curved detectors

b) With planar detectors

Figure 5 — Arrangement for testing of welds with centrally located radiation source (central projection) and the detector outside

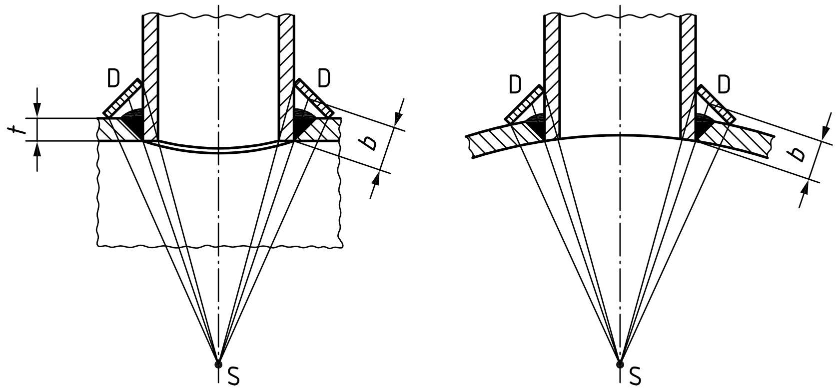


Figure 6 — Arrangement for testing of set-in welds with a radiation source, located on the central pipe axis and perpendicular to the weld centre, and the detector outside

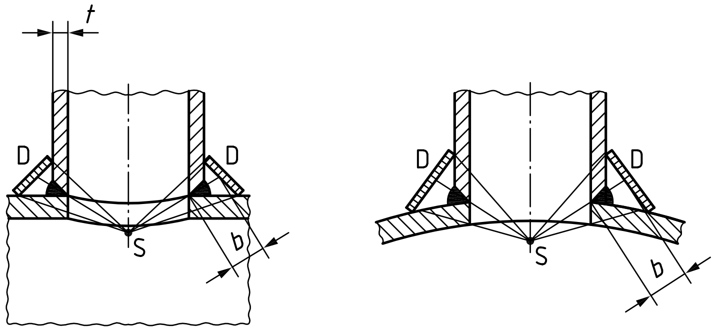
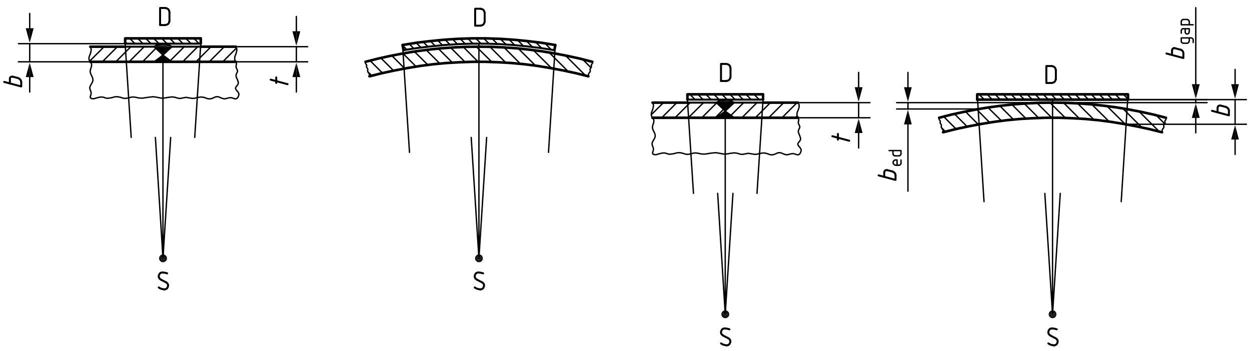


Figure 7 — Arrangement for testing of set-on welds with a radiation source, located on the central pipe axis and perpendicular to the weld centre, and the detector outside

7.1.5 Single-wall penetration of curved objects with the source located off-centre and inside the object (see Figures 8 to 10)



a) With curved detectors

b) With planar detectors

NOTE If the distance, *b*, in Figure 8 is less than 1,2 *t*, then the nominal thickness, *t*, can be used for *b*.

Figure 8 — Arrangement for testing of welds with the radiation source located off-centre inside the object and the detector outside

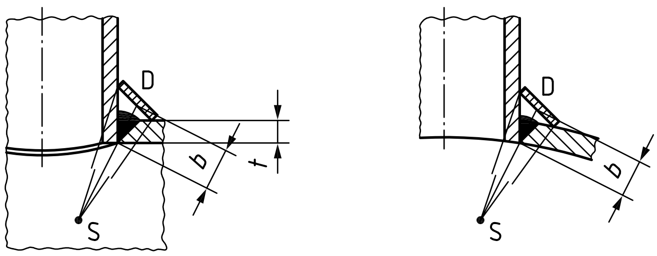


Figure 9 — Arrangement for testing of set-in welds with the radiation source located off-centre inside the object and the detector outside

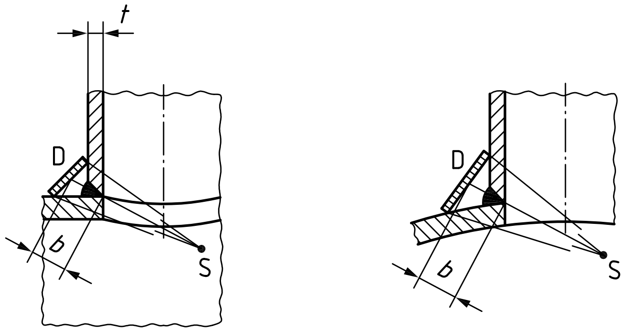
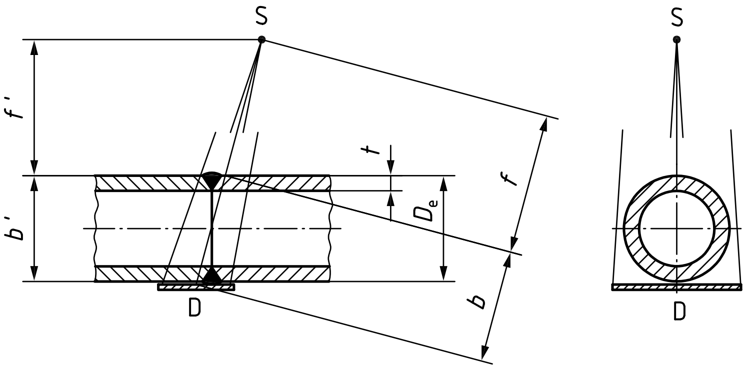


Figure 10 — Arrangement for testing of set-on welds with the radiation source located off-centre inside the object and the detector outside

7.1.6 Double-wall penetration and double-image evaluation (DWDI) of pipes with the elliptic technique and the source and the detector outside the object (see Figure 11)



NOTE The source-to-object distance can be calculated by the perpendicular distance *f '*, calculated from *b'*.

Figure 11 — Arrangement for testing of both walls of pipes with the elliptic technique

7.1.7 Double-wall penetration and double-image evaluation (DWDI) with the perpendicular technique and source and detector outside the object (see Figure 12)

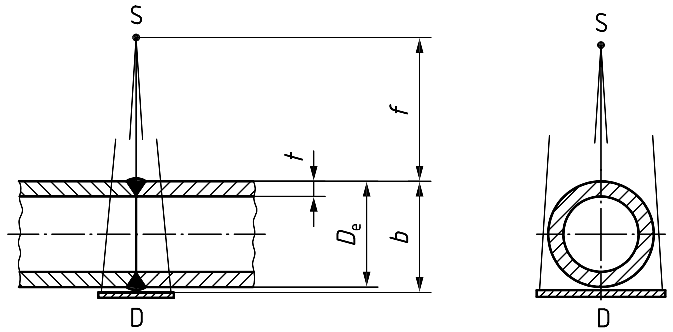
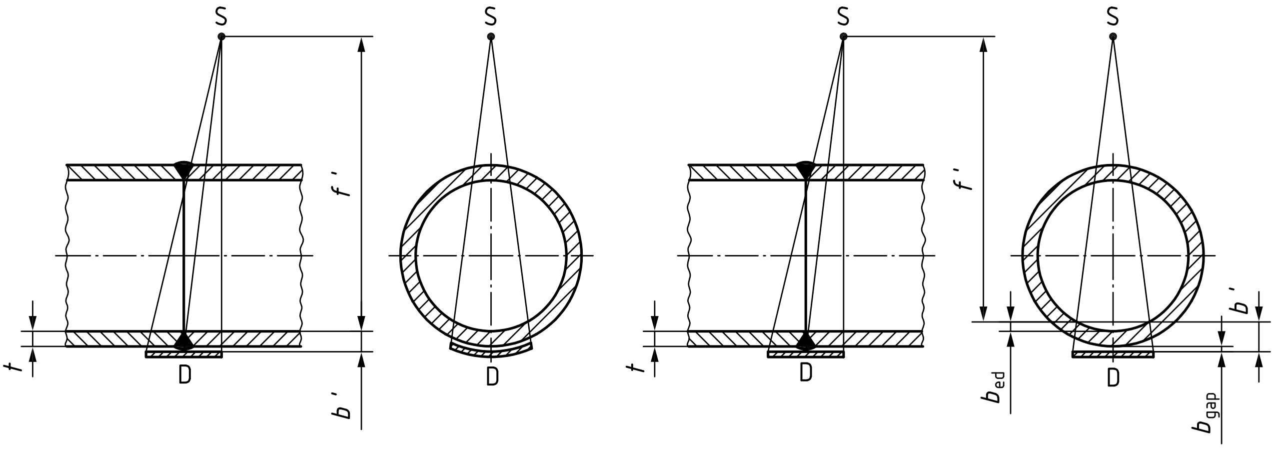


Figure 12 — Arrangement for testing of both walls of pipes with the perpendicular technique

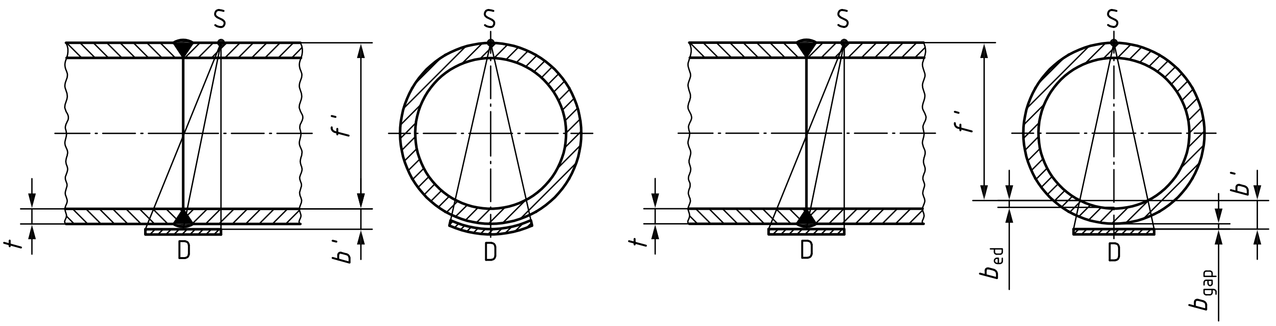
7.1.8 Double-wall penetration and single-image evaluation (DWSI) of curved objects for evaluation of the wall next to the detector (see Figures 13 to 16)



a) With curved detectors b) With planar detectors

NOTE If the distance, *b'*, in Figure 13 is less than 1,2 *t*, then the nominal thickness, *t*, can be used for *b'* and *f'* can be considered as the distance from the source to the parent material surface.

Figure 13 — Arrangement for testing of curved objects with the radiation source outside and evaluation of the wall next to the detector with the IQI placed close to the detector



a) With curved detectors b) With planar detectors

NOTE If the distance, *b'*, in Figure 14 is less than 1,2*t*, then the nominal thickness, *t*, can be used for *b'* and *f'* can be considered as the distance from the source to the parent material surface.

Figure 14 — Arrangement for testing of curved objects with the radiation source outside, located directly on the surface and evaluation of the wall next to the detector with the IQI placed close to the detector

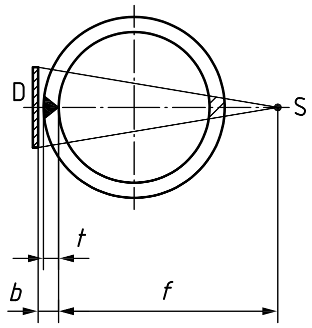


Figure 15 — Arrangement for testing of pipes with longitudinal welds with the radiation source outside and evaluation of the wall next to the detector with the IQI placed close to the detector

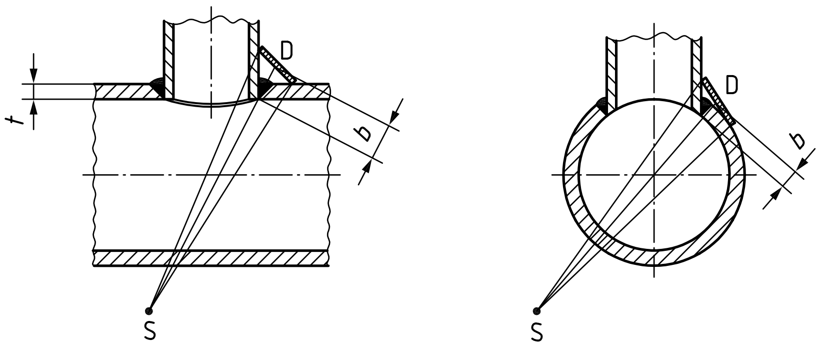


Figure 16 — Arrangement for testing of set-in welds with the radiation source outside and evaluation of the wall next to the detector with the IQI placed close to the detector

7.1.9 Penetration of objects with different material thicknesses (see Figure 17 to 19)

a) Arrangement for testing without compensating edge

b) Arrangement for testing with compensating edge

Key

1 compensating edge

Figure 17 — Arrangement for testing of fillet welds with an oblique detector position

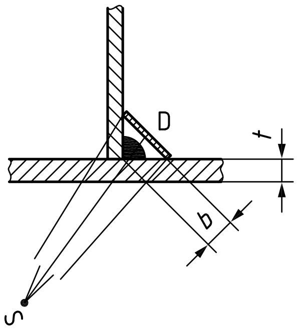


Figure 18 — Arrangement for testing of fillet welds with a perpendicular detector position

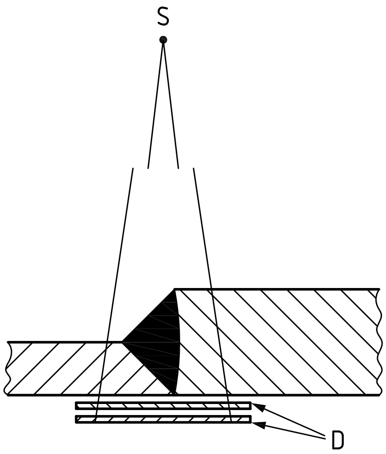


Figure 19 — Arrangement for testing with a multi-detector technique, applicable for CR

7.2 Choice of tube voltage and radiation source

7.2.1 X-ray devices up to 1 000 kV

To maintain a good flaw sensitivity, the X-ray tube voltage should be as low as possible and the SNR_N in the digital image should be as high as possible. Recommended values of X-ray tube voltage versus penetrated thickness are given in Figure 20. These values are best-practice values for film radiography.

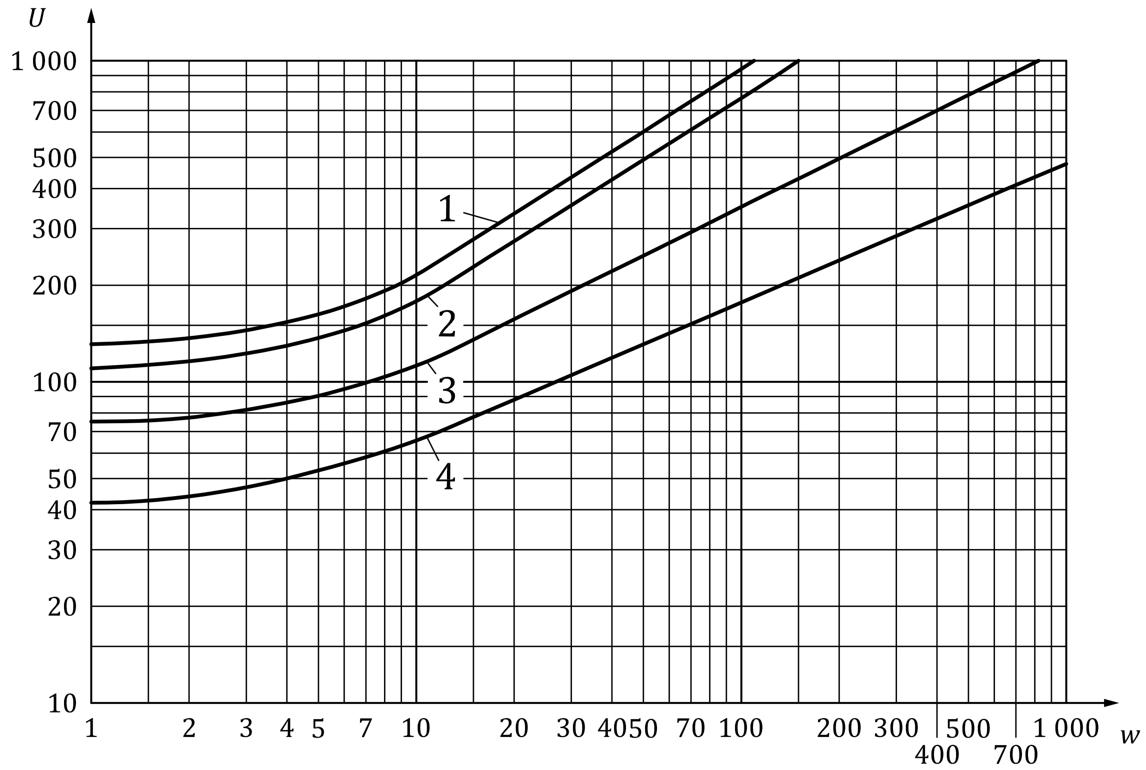
After accurate detector image correction (calibration), DDAs can provide sufficient image quality at significantly higher voltages than those shown in Figure 20.

Imaging plates with high structure noise in the sensitive IP layer (coarse grained) should be applied with about 20 % less X-ray voltage than indicated in Figure 20 for testing class B. High-definition imaging plates, which are exposed similarly to X-ray films and having low structure noise (fine grained), can be exposed with the X-ray voltages of Figure 20 or higher if the SNR_N is sufficiently increased.

NOTE CP I:

— An improvement in contrast sensitivity can be achieved by an increase in contrast at constant SNR_N, by reduction of tube voltage and compensation by higher exposure (e.g. milliampère minutes), or by an increase in SNR_N, by higher exposure (e.g. milliampère minutes), at constant contrast (constant kilovolt level).

— Increased tube voltage at a constant exposure (e.g. milliampère minutes) reduces the contrast and increases the SNR_N. The contrast sensitivity improves if the increase in SNR_N is higher than the contrast reduction due to the higher energy.



Key

U	X-ray tube voltage, kV	1	copper and nickel and its alloys
w	penetrated thickness, mm	2	steel
		3	titanium and its alloys
		4	aluminium and its alloys

NOTE The calculations for the curves are described in Annex G.

Figure 20 — Recommended X-ray tube voltage for X-ray devices up to 1 000 kV as a function of penetrated thickness and material

For some applications where there is a thickness change across the area of the object being radiographed, a modification of technique with a higher voltage may be used, but it should be noted that an excessively high tube voltage leads to a loss of defect detection sensitivity.

7.2.2 Other radiation sources

The recommended penetrated thickness ranges for gamma-ray sources and X-ray equipment above 1 MV are given in Table 2.

On a thin specimen, gamma rays from Se 75, Ir 192 and Co 60 sources do not produce digital 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 2 gives a range of thicknesses for which each of these gamma-ray sources may be used when the use of X-ray tubes is impractical and shall be noted in the report.

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

In cases where digital radiographs are produced by CR using gamma rays, the total travel time to and from the source position shall not exceed 10 % of the total exposure time. Using DDAs, the exposure time shall start after the source is in position and shall end before the source is moved back.

Annex B
(normative)

Minimum image quality values

B.1 General

The minimum image quality indicator values (IQI values) of Tables B.1 to B.14 shall be achieved or exceeded for acceptance of testing class A or testing class B testing quality.

B.2 Single-wall technique — IQI on source side

Table B.1 — Wire IQI

Minimum IQI values for testing class A				
Nominal thickness *t* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9.

Table B.2 — Step and hole IQI

Minimum IQI values for testing class A				
Nominal thickness *t* mm				IQI value[a]
		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

a For exceptions when using gamma ray sources, see 6.9.

Table B.2 *(continued)*

Minimum IQI values for testing class A				
Nominal thickness *t* mm				IQI value[a]
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

a For exceptions when using gamma ray sources, see 6.9.

Table B.3 — Wire IQI

Minimum IQI values for testing class B				
Nominal thickness *t* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9.

Table B.4 — Step and hole IQI

Minimum IQI values for testing class B				
Nominal thickness *t* mm				IQI value[a]
		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
[a] For exceptions when using gamma ray sources, see 6.9.				

B.3 Double-wall technique — Double-image evaluation (DWDI): IQI on source side

Table B.5 — Wire IQI

Minimum IQI values for testing class A				
Penetrated thickness *w* mm				IQI value[a]
		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
[a] For exceptions when using gamma ray sources, see 6.9.				

Table B.6 — Step and hole IQI

Minimum IQI values for testing class A				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9.

Table B.7 — Wire IQI

Minimum IQI values for testing class B				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9

Table B.8 — Step and hole IQI

Minimum IQI values for testing class B				
Penetrated thickness *w* mm				IQI value[a]
		to	1	H 2
above	1	to	2,5	H 3
above	2,5	to	4	H 4
above	4	to	6	H 5

[a] For exceptions when using gamma ray sources, see 6.9

Table B.8 *(continued)*

Minimum IQI values for testing class B				
Penetrated thickness *w* mm				IQI value[a]
above	6	to	11	H 6
above	11	to	20	H 7
above	20	to	35	H 8

[a] For exceptions when using gamma ray sources, see 6.9

B.4 Double-wall technique — Single-image (DWSI) or double-image evaluation (DWDI): IQI on detector side

Table B.9 — Wire IQI

Minimum IQI values for testing class A				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9

Table B.10 — Step and hole IQI

Minimum IQI values for testing class A				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9

Table B.10 *(continued)*

Minimum IQI values for testing class A				
Penetrated thickness *w* mm				IQI value[a]
above	22	to	36	H 8
above	36	to	50	H 9
above	50	to	80	H 10

[a] For exceptions when using gamma ray sources, see 6.9

Table B.11 — Wire IQI

Minimum IQI values for testing class B				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9

Table B.12 — Step and hole IQI

Minimum IQI values for testing class B				
Penetrated thickness *w* mm				IQI value[a]
		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

[a] For exceptions when using gamma ray sources, see 6.9