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British Standard Methods for

Radiographic examination of fusion welded circumferential butt joints in steel pipes

Méthodes d'examen radiographique des joints circonférentiels bout à bout soudés par fusion dans les tuyauteries en acier

Verfahren zur Durchstrahlungsprüfung von schmelzgeschweißten Stumpfrundnähten an Stahlrohren

British Standards Institution

Foreword

This standard has been prepared under the direction of the Welding Standards Committee and is a revision of BS 2910 : 1973 which is withdrawn.

It is essential to quote the technique number in addition to the BS number whenever this standard is used.

Contrary to the 1973 edition, no distinction in technique is now made between ultra-fine-grain and fine-grain film and the two types of film have been combined using the technique number of the ultra-fine-grain film but descriptively 'ultra' is no longer used. Although this has resulted in a reduced number of techniques, the original technique numbers have been retained.

The methods described in this standard are suitable for all types of application but no requirement is given as to when a particular technique should be used although guidance is given in a new appendix B. As so many factors affect the exposure time, minimum values have not been specified but are included as guidance. The extent of radiographic examination that should be applied and standards of acceptance are not specified as both of these aspects should be covered in the appropriate application standard or be agreed between the contracting parties.

This revision introduces ytterbium-169 and thulium-170 for the first time as gamma-ray sources, thus reducing the lower limit of thickness range covered by the standard to 2 mm for both X-rays and gamma-rays.

The explanatory information in appendix A has been retained to amplify and in some instances to give the reasons underlying what is stated in the standard. Some principles and background to flaw sensitivity have been introduced in a new appendix E.

Welds in some pipe thicknesses can be examined with X-ray television fluoroscopic systems and although it has not yet seemed appropriate to produce a detailed standard for these new methods, this revised standard is not intended to preclude the use of such methods if the attainable sensitivity values are acceptable to the contracting parties.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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Methods

1 Scope

This British Standard deals with methods for the radiographic examination of fusion welded circumferential butt joints in steel pipes primarily with wall thicknesses in the range 2 mm up to and including 50 mm. This standard covers the following methods:

(a) examination using the film inside and source of radiation outside;

(b) examination using film outside and source of radiation inside;

(c) examination using film and source of radiation both outside (known as the 'double wall, single image method');

(d) examination using film and source of radiation both outside (known as the 'double wall, double image method').

Because several techniques with different attainable sensitivities are detailed, it is necessary to specify for each particular application which technique is required to be used. **It is insufficient merely to state that BS 2910 be followed without specifying the technique number (see table 1).** No attempt is made to define which technique is to be used for any particular application because this is a matter for agreement between the contracting parties and will depend, amongst other things, on the accessibility of a particular weld.

The correct film for use with the different techniques is not specified but is a matter for agreement between the contracting parties (see clause 5).

The standard should be read in conjunction with BS 3971 : 1980 in which, in table 7, guidance is given on the attainable image quality indicator (IQI) values for:

'more critical techniques'; referred to as class A for the purposes of this standard;

'normal techniques'; referred to as class B for the purposes of this standard.

If a class A technique is required, it is essential that one of the techniques 1, 3, 7 or 9 is specified as it is well-known that the use of double wall methods, and generally the use of gamma-rays, cannot produce as good a flaw sensitivity as the single wall X-ray methods.

NOTE 1. The use of an ytterbium-169 source on pipe thicknesses between 2 mm and 10 mm can also qualify as a class A technique (see clause 4) when used with techniques 4 and 10.

Because this standard includes double wall methods on pipes which may be up to 50 mm single wall thickness, the use of X-ray voltages higher than 400 kV is permitted in some cases.

NOTE 2. In this standard the word 'pipe' alone or in combination is used to mean 'pipe' or 'tube' although these terms are often used for different categories of product by different industries.

NOTE 3. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 4727 : Part 5 : Group 1 and BS 3683 : Part 3 apply together with the following.

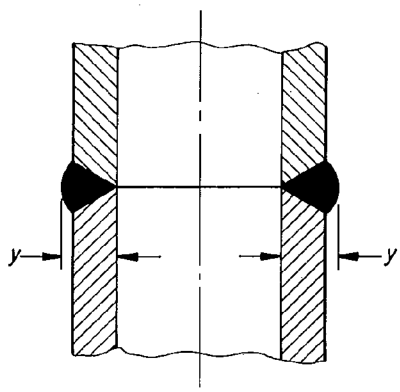
2.1 single wall method. A method of radiographic examination in which the source of radiation is outside the pipe and the film is close to the inside surface of the intervening wall, or in which the source is inside the pipe and the film is close to the outside of the pipe.

2.2 double wall method. A method of radiographic examination in which the source of radiation is outside the pipe and the film is close to the outside of the pipe on the side remote from the source of radiation, the radiation passing through both walls of the pipe.

NOTE. The penetrated thickness with normal radiation incidence is $2y$ as shown in figure 1.

2.3 double wall, single image method. An application of the double wall method producing a usable image of only a part of the weld adjacent to the film (see figure 2).

2.4 double wall, double image method. An application of the double wall method producing a usable image of the whole of the weld on three or more films (see figure 3).



y is the thickness of metal immediately adjacent to film where there is no backing ring

For single wall method, penetrated thickness is y

For double wall method, penetrated thickness is $2y$

Figure 1. Penetrated thicknesses

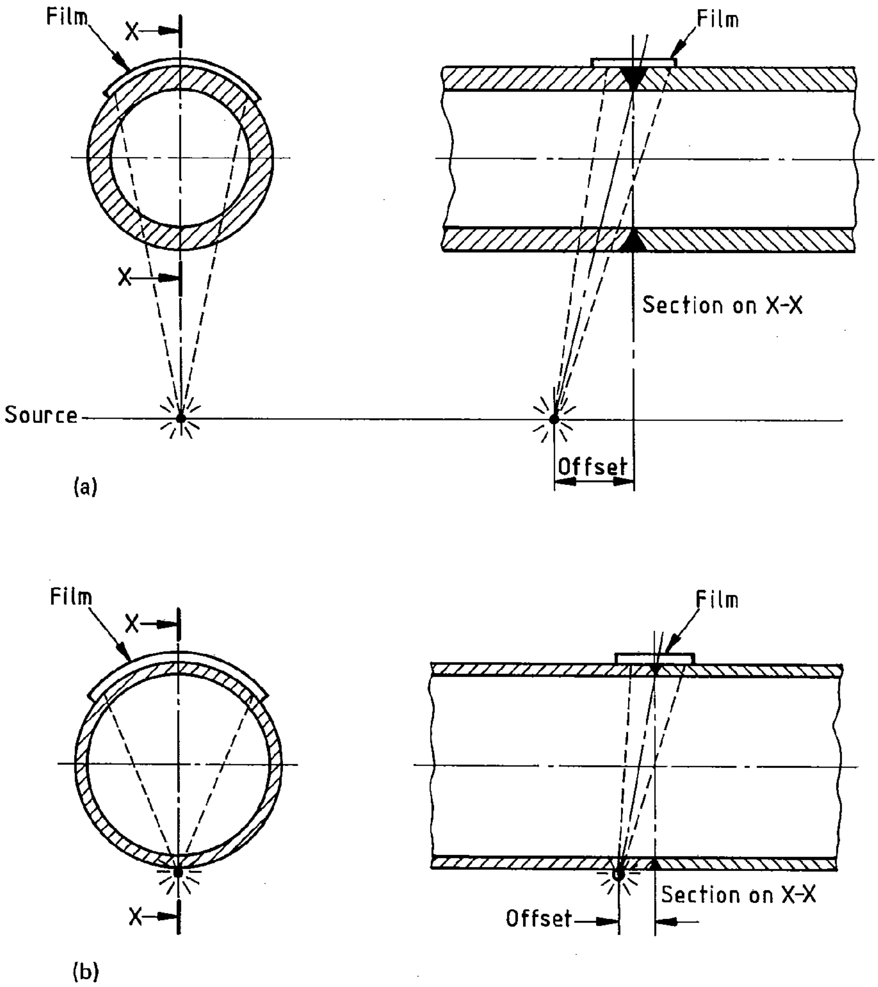
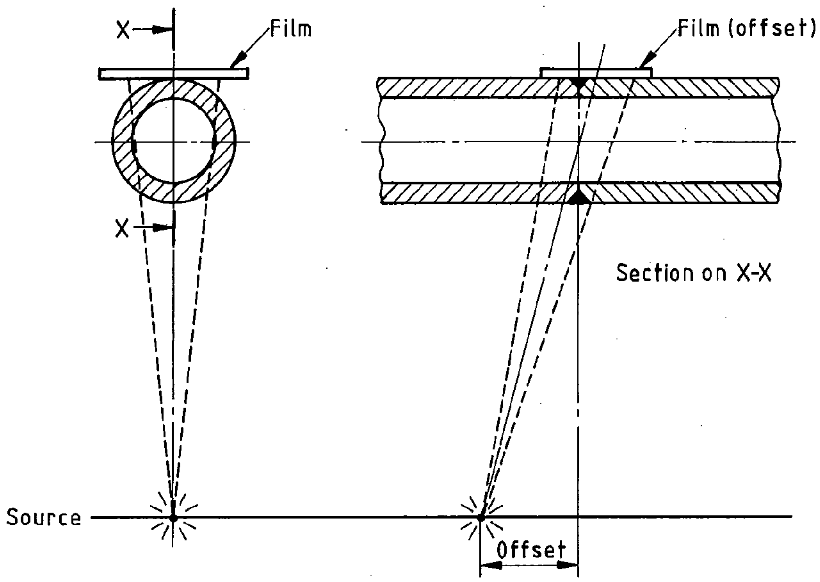


Figure 2. Double wall, single image method



NOTE. For clarity the offset distance has been drawn larger than required.

Figure 3. Double wall, double image method

3 Approval of personnel

The personnel employed in carrying out radiography in accordance with this standard shall be fully experienced, accustomed to the equipment to be used and to producing radiographs that will comply with this standard.

NOTE. It is recommended that radiographic personnel should have a nationally recognized certificate of competence such as that operated by the PCN* Scheme.

4 Techniques

The technique to be used shall be one of those given in table 1; fuller details of the techniques are given in the appropriate clauses and in appendix A and guidance on the choice of technique is given in appendix B.

NOTE. The flaw detection capability of a radiographic technique increases as the graininess of the film is reduced and is also dependent upon the film-screen combination. The basic philosophy of weld radiography is to recommend a technique that gives the best possible chance of detecting small planar flaws such as cracks.

In general, any gamma-ray technique will be less sensitive than an X-ray technique for penetrated thicknesses between 10 mm and 50 mm. The thinner the material, the larger is the difference in sensitivity between radiographs taken with X-rays and gamma-rays. On steel welds having a penetrated thickness of 50 mm and above, the difference in sensitivity is not so marked, if the correct gamma-ray techniques are used.

The correct use of an ytterbium-169 gamma-ray source on steel wall thicknesses between 2 mm and 10 mm will produce single wall radiographs of similar sensitivity to double wall X-radiographs on these thicknesses.

5 Film type

The type of film known as 'direct' or 'non-screen' type radiographic film shall be used in all techniques.

NOTE 1. BS 5230 gives methods of measuring film speeds and contrast gradients of industrial radiographic films, but as it has not yet been implemented by most film manufacturers, speed ranges for the two groups of films (fine-grain and medium-speed) for use with this standard are not specified.

NOTE 2. The correct film for use with the different techniques listed in table 1 should be agreed between the contracting parties.

For the purposes of this standard the film for use with techniques 1, 4, 7, 10, 13 and 16 and specified as fine-grain shall include very-fine-grain (ultra-fine grain) radiographic film.

NOTE 3. The use of two films of different speeds exposed simultaneously increases the range of metal thickness that may be recorded in one exposure.

*Personnel Certification for Non-destructive testing.

Table 1. Individual techniques*

Location of film and source of radiation	Technique		Limiting conditions
	No.†	Description	
Film inside, source of radiation outside (see clause **24**)	1	X-rays using fine-grain high-contrast direct-type film	For pipes of 100 mm bore and over. This technique can also apply to pipes of smaller diameter when it is practicable to put films inside them, but the radiography of the whole weld may necessitate making many exposures
	3	X-rays using medium-speed direct-type film	As for technique 1
	4	Gamma-rays using fine-grain high-contrast direct-type film	As for technique 1
Film outside, source of radiation inside (see clause **25**)	7	X-rays using fine-grain high-contrast direct-type film	The pipe diameter shall be sufficient to allow the use of the appropriate minimum focus-to-film distance (see also **25.1.3**)
	9	X-rays using medium-speed direct-type film	As for technique 7 (see also **25.2.3**)
	10	Gamma-rays using fine-grain high-contrast direct-type film	As for technique 7 (see also **25.3.3**)
Film and source of radiation both outside (see clause **26**)	13	X-rays using fine-grain high-contrast direct-type film	For pipes of all diameters except in the case of the double wall, double image method for which 90 mm is the maximum outside diameter
	15	X-rays using medium-speed direct-type film	As for technique 13
	16	Gamma-rays using fine-grain high-contrast direct-type film	As for technique 13

*See also foreword and clause 5.
†There are now fewer techniques than in previous editions, but established technique numbers have been retained.

6 Gamma-ray sources

The gamma-ray source to be used shall be one of those given in table 2 according to the thickness of steel to be penetrated.

Table 2. Minimum and maximum penetrated thicknesses for gamma-ray sources

Gamma-ray source	Minimum thickness of steel	Maximum thickness of steel
	mm	mm
Cobalt-60	50	150
Iridium-192	10	80
Caesium-137	25	100
Ytterbium-169	2	12
Thulium-170	2	12

NOTE. It is emphasized that the minimum thicknesses on which gamma-rays may be used, as given in table 2, should not be interpreted as implying that on these thicknesses the flaw sensitivity with gamma-rays is equivalent to the flaw sensitivity with X-rays. Gamma-rays should be used only on the understanding that apart from geometric considerations the flaw sensitivity will be inferior to that of a good X-ray technique.

7 Protection

Exposure of any part of the human body to X-rays or gamma-rays can be injurious. It is essential that whenever X-ray equipment or radioactive sources are in use, adequate precautions shall be taken to protect the radiographer and others in the vicinity.

NOTE. It should be noted that the use of X-ray equipment and gamma-radiography in factories, on sites and in certain other premises and works coming within the scope of the Factories Act 1961 is currently controlled by the Ionising Radiations (SI. 1985 No. 1333, ISBN 0 11 057 333 1) Regulations.

In addition, there may be local regulations and requirements which need to be taken into consideration.

These Ionising Radiation Regulations require the use of enclosures or other barriers where radiation levels are maintained and that notices be provided advising of the hazard. Similarly warning signals are required to be provided to indicate that the source of ionizing radiations is about to be exposed. Different and distinct signals are required during the actual exposure. Warning notices with adequately sized legends should be posted explaining the meaning of the signals. It is essential that these requirements are complied with; they are not detailed in this standard.

Some radiographic equipment requirements are specified in BS 5650.

Advice on radiation safety may be obtained from the National Radiological Protection Board, Harwell, Didcot, Oxon, OX11 0RQ, or other consultants who provide advice in radiation safety.

8 Surface condition

Where possible, the contour of the weld surface shall be smooth and any change in section shall be gradual.

NOTE 1. In order to obtain maximum flaw sensitivity the part of the work to be examined should be smooth and free from irregularities such as weld ripples, grinding or chipping marks.

NOTE 2. Where possible, temporary backing rings should be removed prior to radiography since this results in better sensitivity of the radiograph.

NOTE 3. If these conditions cannot be met, the expedients described in **A.2** may be used by agreement between the contracting parties.

9 Weld image location

Markers, usually in the form of lead arrows or other symbols, shall be placed alongside but clear of the outer edges of the weld to identify its position.

10 Identification of radiographs

10.1 Each section of weld radiographed shall have suitable symbols affixed to identify the following:

(a) the job or workpiece;

(b) the joint;

(c) the section of the joint.

The symbols, consisting of lead letters or numerals, shall be positioned so that their images appear in the radiograph to ensure unequivocal identification of the section.

10.2 Where feasible, the circumferential position of the portion under examination shall be positively located.

NOTE 1. On site this may be achieved by taking measurements around the circumference from an agreed datum by means of the 'clock face' method as follows:

(a) the '12 o'clock' position may be related to the '12 o'clock' welding position; or

(b) for horizontal or inclined pipes, the '12 o'clock' position is at the highest point of the joint when viewed from the lower numbered joint to the subsequent numbered joint; or

(c) for vertical pipes the '12 o'clock' position is due north when viewed vertically downwards.

Where this is not feasible, e.g. welds made on sub-assembli prior to shipment to site, other means of positional locatic shall be used.

NOTE 2. The means of location should be agreed between the contracting parties and can be achieved by reference to drawings, sketches or photographs and attached to the radiographic examination report.

11 Marking

In general, permanent marking of the workpiece shall be used to provide reference points for the accurate relocation of the position of each radiograph.

Stamping or centre punching shall not be permitted unless specifically indicated on the relevant fabrication specification, when low stress stamps shall be used. Under no consideration shall stamping or centre punching be permitted on material under 10 mm thick.

12 Density of radiograph

In the image of the length of weld under examination, the film density corresponding to the sound weld metal shall be not less than 2.0 and not greater than 3.0, unless special arrangements are made for the adequate viewing of higher density film.

NOTE. These values are inclusive of the fog density* of not greater than 0.3 (see also A.3).

13 Image quality indicators

13.1 Sensitivities

In order to provide a guide to the quality of the radiographic technique used, an image quality indicator (IQI) of either type I or type II as specified in BS 3971 shall be used, with dimensions appropriate to the thickness of the weld.

NOTE. The required sensitivity values for any specific application should be the subject of agreement between the contracting parties.

The method of assessing the radiographic sensitivity shall be as described in BS 3971.

The attained IQI sensitivity shall be expressed either as the diameter of the smallest wire or hole which can be seen on the radiographic image of the IQI, *or* this diameter expressed as a percentage of the weld metal thickness (*not* the total penetrated thickness). Thus, when a single wall or a double wall, single image method is being used, the single wall weld metal thickness shall be used to calculate the attained IQI sensitivity; when a double wall, double image method is being employed, the double wall weld metal thickness shall be used.

NOTE 1. For example, for a 6 mm weld metal thickness, using a wire type IQI and a single wall method, the IQI sensitivity expected should be approximately 1.6 %, whereas with a double wall, single image method the IQI sensitivity will be about 3.2 %.

NOTE 2. The type III IQI is not suitable for small diameter pipe radiography but may be used on large diameter pipes subject to prior agreement between the contracting parties.

NOTE 3. Table 3 gives indications of the values which should be obtained on different thicknesses if the techniques detailed in this standard have been correctly applied.

NOTE 4. If the sensitivities obtained are not better than the values given in table 3 for the appropriate weld thickness, it is a clear indication that the radiographic techniques are not being correctly applied.

Table 3. IQI sensitivity values* with IQIs of types I and II which should be obtained with single wall methods†

Weld thickness	Sensitivity values expressed as a percentage of the weld thickness								
	X-rays				Gamma-rays				
	Type I IQI (wire)		Type II IQI (step/hole)		Source	Type I (wire)		Type II (step/hole)	
mm	mm	%	mm	%		mm	%	mm	%
2	0.050	(2.5)	0.125	(6.3)		0.063	(3.1)	0.160	(8.0)
3	0.063	(2.0)	0.160	(5.3)	Ytterbium-169	0.080	(2.7)	0.160	(5.3)
6	0.100	(1.6)	0.200	(3.3)	Thulium-170	0.125	(2.1)	0.250	(4.2)
12	0.200	(1.6)	0.400	(3.2)		0.250	(2.1)	0.500	(4.1)
25	0.320	(1.3)	0.630	(2.5)	Iridium-192	0.400	(1.6)	0.800	(3.2)
35	0.400	(1.1)	0.800	(2.0)		0.500	(1.4)	0.800	(2.3)
50	0.500	(1.0)	1.000	(2.0)		0.630	(1.3)	1.000	(2.0)
75	0.630	(0.85)	1.250	(1.7)		0.800	(1.1)	1.250	(1.7)
100	0.800	(0.8)	1.600	(1.6)	Cobalt-60	1.00	(1.0)	1.600	(1.6)

*The values given are the actual wire or hole diameters which should be seen (in mm). The values in brackets are the corresponding percentage values. For a weld metal thickness intermediate between the table values the next value below in the table should be used.

†These values do not apply to double wall, single image methods.

*Density of a processed unexposed film.

13.2 Location of IQI

In the film inside, source outside method, i.e. techniques 1, 3 and 4, the IQI shall be placed on the surface of the weld facing the radiation source.

In the film outside, source inside method, i.e. techniques 7, 9 and 10, the IQI shall be placed on the side of the weld facing the source, if practicable, otherwise the IQI shall be placed between the weld and the film cassette or envelope and the test radiograph described in appendix C shall be produced.

In the film outside, source outside, double wall, single image methods (see figure 2), the IQI shall be placed on the film side of the weld between the weld and the film cassette or envelope and the test radiograph described in appendix C shall be produced. In the double wall, double image methods (see figure 3), the IQI shall be placed on the surface of the pipe nearest to the radiation source.

On any radiograph on which an IQI is used on the film side of the weld, the IQI shall have the letters FS placed next to it, to be visible on the radiograph.

13.3 Number of IQIs to be used

In general, one IQI per radiograph shall be used, applied as recommended in A.2 of BS 3971 : 1980. If long lengths of film are used with techniques 7, 9 and 10 where the source of radiation is on the centreline of the pipe, not less than four IQI shall be used, located at approximately 90° apart.

14 Intensifying screens

Intensifying screens shall be used in all the techniques. The material of which they are to be made and their thickness ranges shall be as given in table 4 (see also A.4) but it is permissible to use fluorometallic screens with the appropriate film and technique. Salt screens shall not be used.

15 Cassettes

In all cases, precautions shall be taken to ensure good film-screen contact irrespective of whether rigid cassettes, which are recommended, or flexible cassettes are used.

All cassettes, whether rigid or flexible, shall have sufficient compression to ensure positive film-to-screen contact. Flat, rigid cassettes shall be used wherever practicable; for welds in curved surfaces, rigid cassettes with a curvature to fit that of the plate or, alternatively, flexible cassettes may be used, provided that close film-to-screen and cassette to object contact can be ensured.

NOTE 1. When appropriate and agreed between the contracting parties, long lengths of film in commercial packs, with integral metal and intensifying screens, may be used.

For the double wall, double image methods on butt welds in pipes, the film shall be enclosed in a flat cassette which shall be placed as close as possible to the surface of the weld, remote from the source.

NOTE 2. For double wall, single image methods flexible cassettes may be used.

16 Object-film distance

The distance between the film and the adjacent weld surface shall be as small as possible. For the double wall, double image method, the object-film distance shall be taken to be the outside diameter of the pipe.

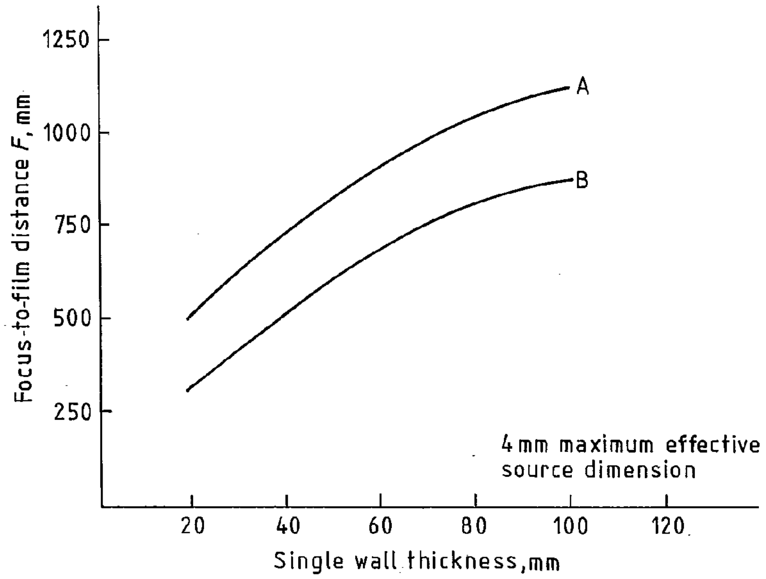
Where a gap between the surface of the weld nearest to the cassette and the cassette is unavoidable, the minimum focus- or source-to-film distance (s.f.d.) as derived from figures 4 or 5 shall be increased in the ratio $(a + b)/a$, where a is the thickness of the metal immediately adjacent to the film, and b is the gap (see also note to clause 26).

Table 4. Intensifying screens

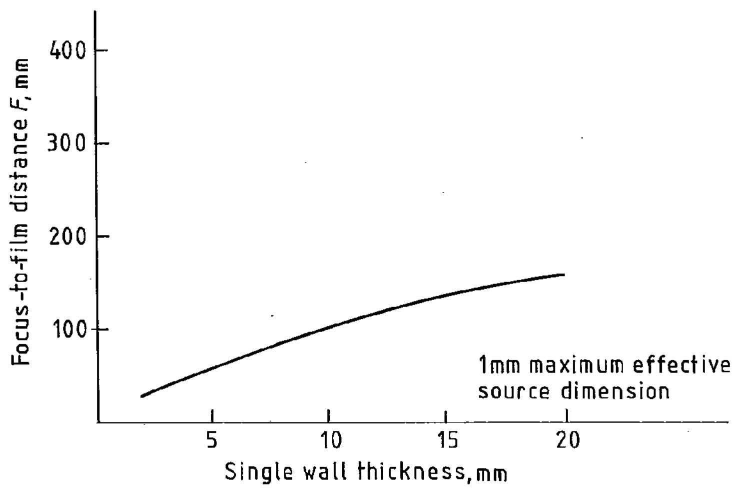
Radiation	Screen material	Front screen thickness	Back screen thickness
		mm	mm
X-rays: below 120 kV	Lead	None	0.1 min.
X-rays: 120 kV to 250 kV	Lead	0.02 to 0.125	0.1 min.
X-rays: above 250 kV to 400 kV	Lead	0.05 to 0.16	0.1 min.
Gamma-rays: ^{192}Ir, ^{137}Cs	Lead	0.02 to 0.16	0.16 min.
Gamma-rays: ^{169}Yb, ^{170}Tm	Lead	0.02 to 0.16*	0.1* min.
Gamma-rays: ^{60}Co	Copper† Steel† Lead†	0.5 to 2.0	0.25 to 1.0

*Below 5 mm, weld metal thickness image quality is improved at the expense of exposure times by the omission of the lead screens.

†The use of thick copper or steel screens produces the best flaw sensitivity but a longer exposure time is required than with lead screens (in the order of 2 to 1).

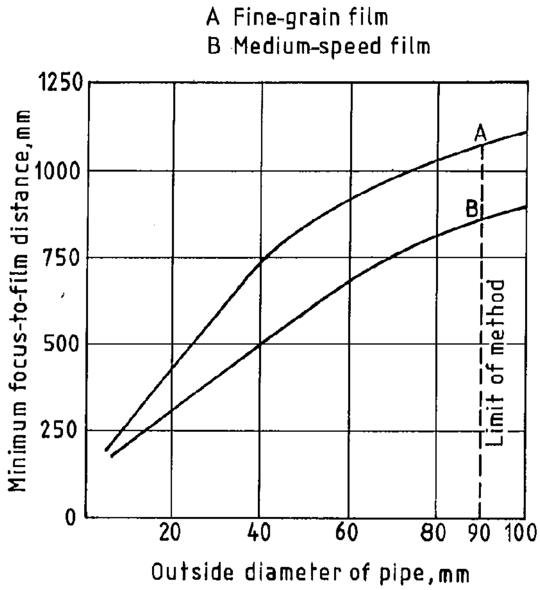


(a) For other than the double wall, double image method: thick wall



(b) For other than the double wall, double image method: thin wall

Figure 4. Minimum values of focus-to-film distances with X-ray source



(c) For the double wall, double image method

NOTE. For a focal spot of maximum effective dimensions (other than 4 mm) the focus-to-film distance F_2 should be equal to or greater than the value calculated from the following equations:

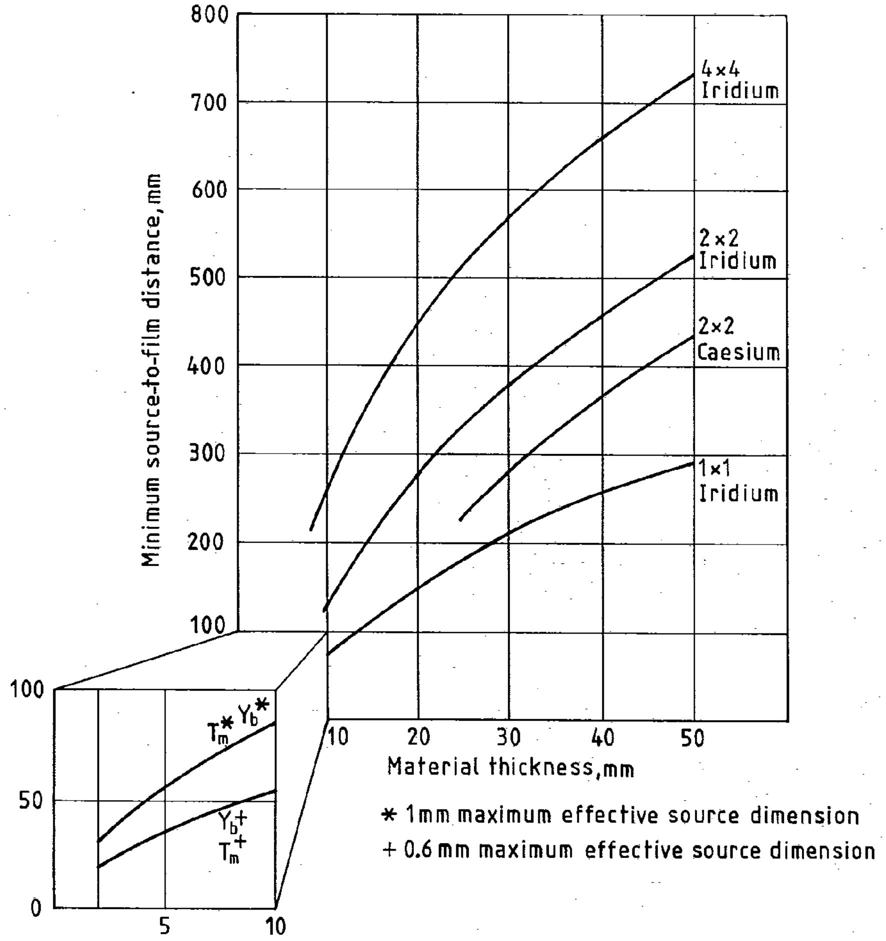
$F_2 = sF_1/4$ for the curves given in figure 4(a)

$F_2 = sF_1$ for the curves given in figure 4(b)

where

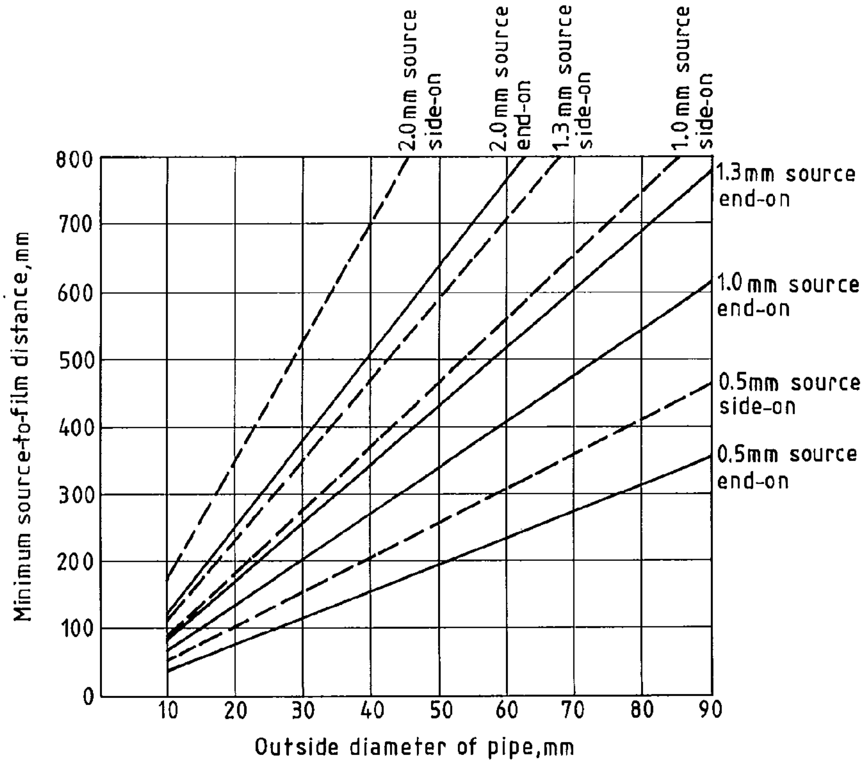
F_1 is the focus-to-film distance for a 4 mm effective focal spot.

Figure 4 *(concluded)*



(a) For other than the double wall, double image method

Figure 5. Minimum values of s.f.d. with gamma-ray source



(b) For the double wall, double image method

Figure 5 *(concluded)*

17 Overlap of film

The separate radiographs of a welded joint shall overlap sufficiently to ensure that no portion of the joint remains unexamined (see also **A.5**).

18 Useful (diagnostic) length of weld to be examined on each radiograph and number of films required

In order to meet the density requirements of clause **12**, and allowing for the fall-off in flaw sensitivity towards the ends of the radiograph due to an increase in penetrated thickness and to geometric effects, the useful length of a radiograph is limited. The increase in penetrated thickness at the ends of the useful (diagnostic) length of a radiograph therefore shall not exceed the penetrated thickness at the centre of the radiograph by more than 10 %. For various techniques, this geometric requirement leads to the minimum numbers of radiographs required to cover a complete circumferential weld as follows:

(a) *Single wall, source outside, film inside technique.* For this technique, the minimum number of radiographs required to cover a complete circumferential weld shall be as given in the curves in figure 6, in terms of the values of:

(1) outside pipe diameter, D;

(2) pipe wall or weld thickness on centreline of weld, t;

(3) s.f.d., F.

NOTE 1. These curves do not apply to pipes in which the (wall thickness/outside diameter) ratio is greater than 0.25 (see figure 6).

(b) *Single wall, source inside on centreline.* The film (or films) shall be wrapped round the pipe and only one exposure is necessary.

(c) *Single wall, source inside, offset.* The minimum number of radiographs required shall be as shown in figure 7 for various D/F and t/D ratios.

(d) *Double wall, single image technique, with source and film both outside the pipe.* For this technique, the minimum number of radiographs required to cover a complete circumferential weld shall not be less than the number shown in figure 8, for various D/F and t/D ratios.

(e) *Double wall, double image technique.* A minimum of three radiographs shall be taken, with the radiation beam centreline at 0 °, 120 ° and 240 °, and with the pipe marked at 60 ° intervals or where this is impractical, three radiographs taken at 60 ° intervals are permitted, provided this is recorded in the report.

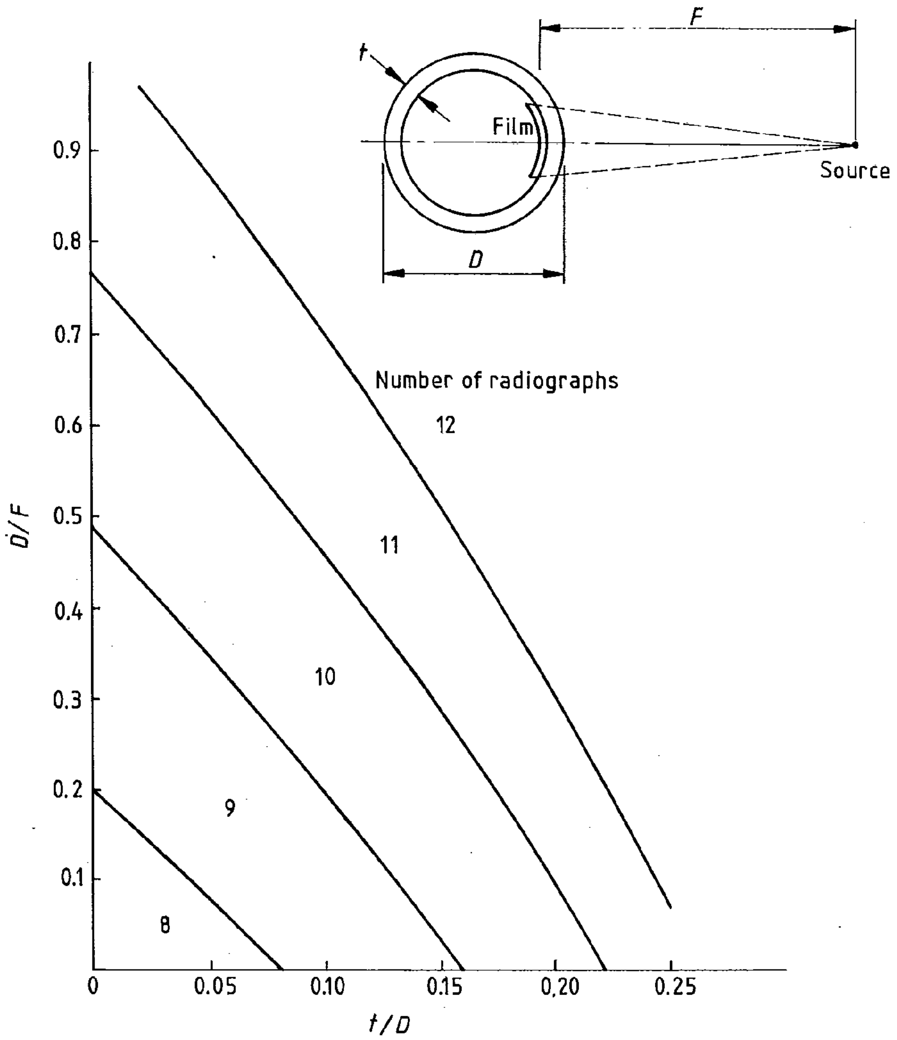


Figure 6. Minimum number of radiographs required with source outside, film inside to cover full circumferential weld (see clause 18(a))

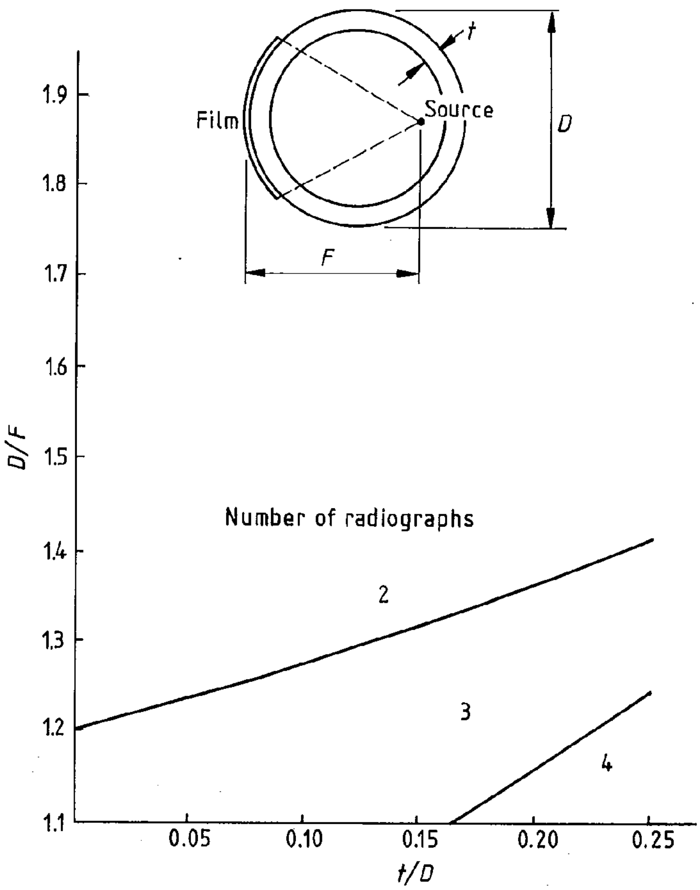


Figure 7. Minimum number of radiographs required with source offset inside, film outside to cover full circumferential weld (see clause **18**(c))

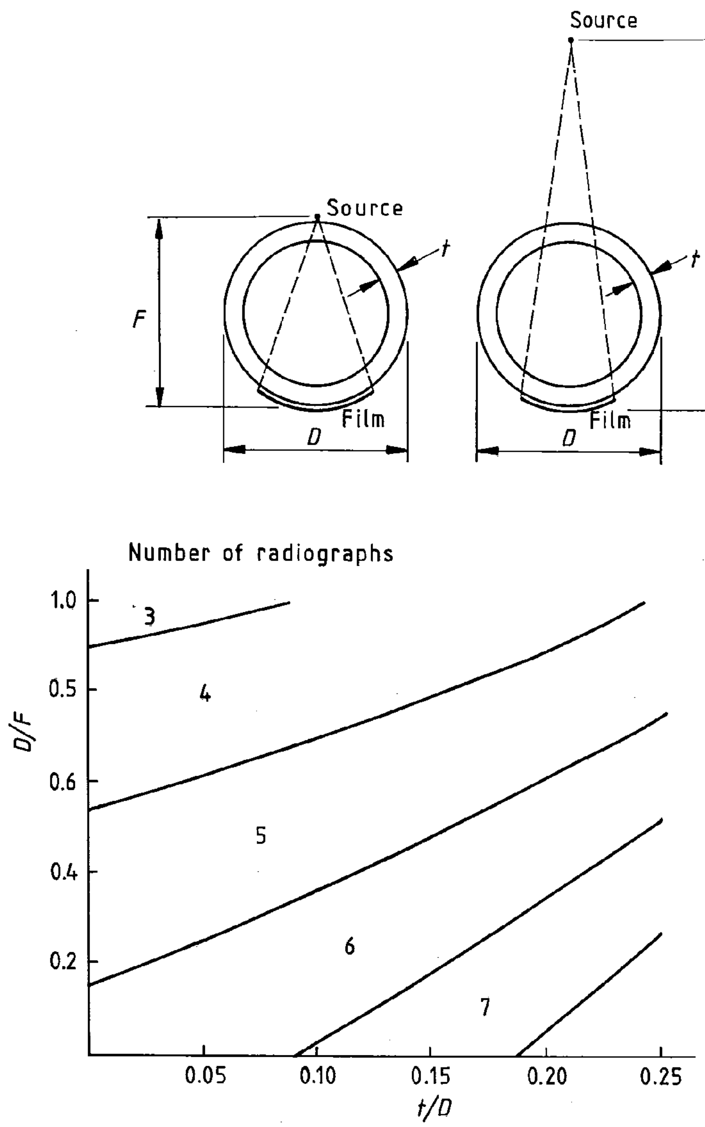


Figure 8. Minimum number of radiographs required with source and film both outside to cover full circumferential weld (see clause **18**(d))

19 Interception of unwanted and scattered radiation

The film shall be shielded from back-scattered radiation by lead sheet at least 1 mm thick placed behind the film-screen combination, except when using ytterbium-169 radiation when the backing shall be aluminium or other low-Z* material.

In order to reduce the effects of scattered radiation, both on the radiograph and for personnel protection purposes, the beam of radiation from the source shall be collimated to approximately the size of the radiograph to be covered and, if the specimen has a smaller area than the radiation field, adequate masking shall be provided so as to limit the area irradiated, as far as possible, to the section being radiographed.

NOTE. If there is any question about the adequacy of protection from back-scattered radiation, a characteristic symbol (frequently a 3.2 mm thick letter B) should be attached to the back of the cassette or film holder, and a radiograph made in the normal manner. If the image of this symbol appears on the radiograph as a lighter density than background, it is an indication that protection against back-scattered radiation is insufficient and it is essential that additional precautions be taken.

20 Processing

The film shall be processed in accordance with recognized good practice using either manual or automatic equipment. A standard type of X-ray developer shall be used and the processing solutions shall be maintained in good working condition. In manual development, the film or the processing solution, or both, shall be agitated during development. The development time and temperature shall be in accordance with the film manufacturer's recommendations.

NOTE 1. Extended development may be used to increase radiographic contrast and effective film speed but such an extension should be within the limits recommended by the manufacturer.

The radiographs shall be free from imperfections due to processing defects that would interfere with interpretation.

NOTE 2. Attention is drawn to the need on some contracts for the radiographs to be retained for long periods.

The main factor determining the archival quality of a radiograph is the amount of residual thiosulphate and silver thiosulphate complexes present in the processed film. The points requiring particular attention are the thoroughness of the fixing process, the film washing conditions and the draining before drying.

Details on suitable procedures and methods of testing film for storage quality can be found in the film manufacturer's literature.

21 Viewing

The radiograph shall be examined by diffused light in a darkened room and the illuminated area shall be masked to the minimum required for viewing the radiographic image; the edges of the radiograph shall always be masked. The luminance (or brightness) of the illuminated radiograph shall be not less than 30 cd/m^2 and whenever possible approximately 300 cd/m^2 (see also **A.6**).

Sufficient time shall be allowed for the film reader's eyes to become adapted to the lighting conditions in the viewing room before radiographs are examined.

The film reader shall have his eyes tested annually for ability to see small detail at the normal film viewing distance. This film viewing distance should be about 400 mm and the film reader shall be able to read a clear print type of 0.5 mm letter height at this distance with suitably corrected vision if necessary.

NOTE. The use of a low power magnifying lens (X 2 or X 3) of reasonable area is recommended.

22 Approved radiographic procedures

Where approved radiographic procedures are required, test radiographs and the details of the radiographic technique shall be submitted to the purchaser for approval. The details shall include the following, as appropriate:

(a) technique;

(b) type of equipment, exposure container† and kV rating;

(c) type of film;

(d) intensifying screens;

(e) cassette (film) shielding and beam collimation;

(f) source dimensions or focal spot size (in mm);

(g) geometric relationship defined by sketch;

(h) length of weld covered on each radiograph and number of radiographs to be taken (see clause **18**);

(i) tube voltage, type and strength of source strength;

(j) material thickness range;

(k) surface condition and profile;

(l) type, size and position of IQI;

(m) IQI sensitivity required (see table 3);

(n) film density;

(o) processing;

(p) limitations of the procedure.

NOTE. An example of a record form for radiographic procedures is given in appendix D.

*Z is the atomic number.

†See BS 5650.

23 Report

The report on an individual radiograph shall include the following:

(a) approval procedure number (if any);

(b) technique number;

(c) name of operator;

(d) company;

(e) sensitivity;

(f) density;

(g) radiograph number;

(h) job identification.

24 Examination with film inside and source of radiation outside

(see table 1 for limiting conditions)

24.1 Technique 1. X-rays using fine-grain direct-type film

24.1.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

24.1.2 *Focus-to-film distance**. For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for different penetrated thicknesses shall be determined from figure 4(a), curve A.

24.1.3 *Alignment of X-ray beam.* The beam of radiation shall be directed to the centre of the section under examination and shall be normal to the pipe surface at that point.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.

24.1.4 *X-ray tube voltage**. The voltage values for different penetrated thicknesses obtained from figure 9, curve S, shall not be exceeded.

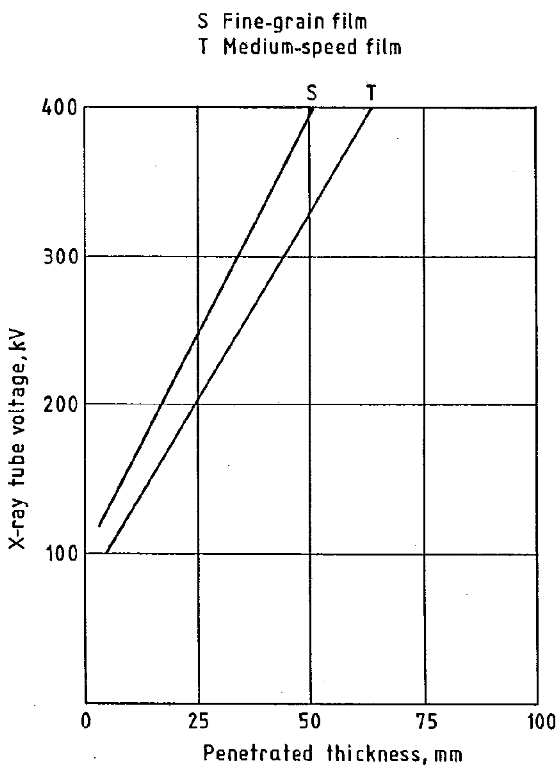
24.2 Technique 3. X-rays using medium-speed direct-type film

24.2.1 *Type of film.* The film shall be of the medium-speed direct type.

24.2.2 *Focus-to-film distance**. For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for different penetrated thicknesses shall be determined from figure 4(a), curve B.

24.2.3 *Alignment of X-ray beam.* The beam of radiation shall be directed to the centre of the section under examination and shall be normal to the pipe surface at that point.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.



NOTE. The curves for voltage are not extended beyond 400 kV as there is no commercial X-ray equipment in use in this country operating between about 400 kV and 1000 kV.

Figure 9. Maximum X-ray tube voltage

24.2.4 *X-ray tube voltage**. The voltage values for different penetrated thicknesses obtained from figure 9, curve T, shall not be exceeded.

24.3 Technique 4. Gamma-rays using fine-grain direct-type film

24.3.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

24.3.2 *S.F.D.**. The minimum s.f.d. for different penetrated thicknesses shall be determined from figure 5(a).

*See also appendix A.

24.3.3 *Alignment of gamma-ray beam.* The beam of radiation shall be directed to the centre of the section under examination and shall be normal to the pipe surface at that point.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.

25 Examination with film outside and source of radiation inside

(see table 1 for limiting conditions)

25.1 Technique 7. X-rays using fine-grain direct-type film

25.1.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

25.1.2 *Length of weld examined.* Where a 360 ° emitting tube is used along the axis of the pipe, the whole of the circumferential weld may be radiographed in one exposure but the requirements of clause **17** and **25.1.3** shall be satisfied.

25.1.3 *Focus-to-film distance*.* For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for different penetrated thicknesses shall be determined from figure 4(a), curve A.

25.1.4 *Alignment of X-ray beam.* The X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the weld under examination and the beam shall be normal to the pipe surface.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.

25.1.5 *X-ray tube voltage*.* The voltage values for different penetrated thicknesses obtained from figure 9, curve S, shall not be exceeded.

25.2 Technique 9. X-rays using medium-speed direct-type film

25.2.1 *Type of film.* The film shall be of the medium-speed direct-type.

25.2.2 *Length of weld examined.* Where a 360 ° emitting tube is used along the axis of the pipe, the whole of the circumferential weld may be examined in one exposure but the requirements of clause **17** and **25.2.3** shall be satisfied.

25.2.3 *Focus-to-film distance*.* For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for different penetrated thicknesses shall be determined from figure 4(a), curve B.

25.2.4 *Alignment of X-ray beam.* The X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the weld under examination and the beam shall be normal to the pipe surface.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.

25.2.5 *X-ray tube voltage*.* The voltage values for different penetrated thicknesses obtained from figure 9, curve T, shall not be exceeded.

25.3 Technique 10. Gamma-rays using fine-grain direct-type film

25.3.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

25.3.2 *Length of weld examined.* Where a source is used along the axis of the pipe, the whole of the circumferential weld may be examined in one exposure, but the requirements of clause **17** and **25.3.3** shall be satisfied.

25.3.3 *S.F.D.*.* The minimum s.f.d. for different penetrated thicknesses shall be determined from figure 5(a).

25.3.4 *Alignment of gamma-ray beam.* The source of radiation shall be positioned so that the beam passes through the centre of the weld under examination. The beam shall be normal to the pipe surface.

In addition, other beam directions shall be used when these are known to be necessary to determine the position and extent of a particular defect, e.g. defects at a fusion face, for which the beam may be directed along that fusion face.

NOTE. In the film outside, source inside method, it is advantageous to have the source of radiation on the centreline of the weld, as shown in figure 10 when a single exposure can cover the whole length of a circumferential weld. In some applications however, the pipe diameter, wall thickness, and source diameter may not permit the criteria of figures 4 or 5 to be met. It may be possible to meet these criteria by using the radiation source in an offset position such as shown in figure 11. In this case a minimum number of three radiographs per circumferential weld should be taken.

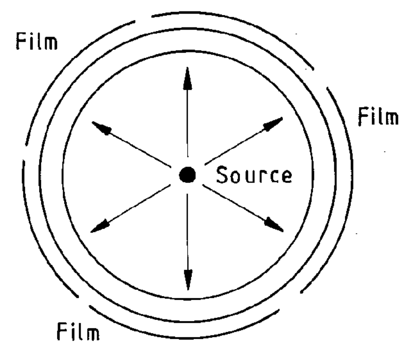


Figure 10. Source of radiation on centreline

*See also appendix A.

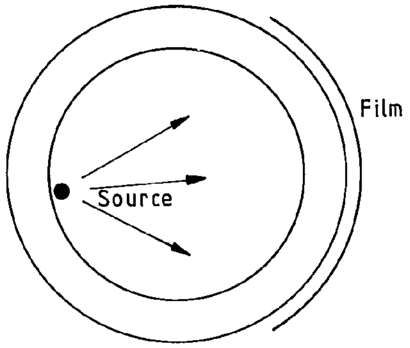


Figure 11. Source of radiation offset

26 Examination with film and source of radiation both outside

(see table 1 for limiting conditions)

NOTE to clause **26**. The cassette should be in close contact with the weld, but where the outside diameter of the pipe does not exceed 90 mm, flat cassettes are permissible. A flat cassette may be used for the 'double wall, double image' method for which 90 mm is the maximum outside diameter.

26.1 Technique 13. X-rays using fine-grain direct-type film

26.1.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

26.1.2 *Focus-to-film distance**. For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for the double wall, single image method shall be determined from figure 4(a), curve A, and for the double wall, double image method from figure 4(b).

26.1.3 *Alignment of X-ray beam*

26.1.3.1 *Double wall, single image* (see figure 2). The X-ray tube shall be placed so as to use a focus-to-film distance which is greater than the minimum determined from figure 4(a), curve A, compatible with the focal spot size and penetrated thickness. The X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the section being examined and shall be offset from the plane through the weld by the minimum distance necessary to prevent the image of one side of the weld confusing the image of the other side. If a square edge preparation of the weld has been used, the offset shall be zero. If possible, the X-ray tube shall be close to the pipe with the radiation passing through the parent metal adjacent to the weld.

The film shall be placed diametrically opposite the X-ray tube, in close contact with the weld.

26.1.3.2 *Double wall, double image* (see figure 3). Normally the X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the pipe in the plane of the weld.

If the superimposing of the images of the two sides of the weld causes difficulty in interpretation, it is permissible for the X-ray tube to be offset the minimum amount required to eliminate superimposed images.

NOTE. Generally, at least three exposures will be required to completely cover a circumferential butt joint.

26.1.4 *X-ray tube voltage**. The voltage values for different penetrated thicknesses obtained from figure 9, curve S shall not be exceeded.

26.2 Technique 15. X-rays using medium-speed direct-type film

26.2.1 *Type of film.* The film shall be of the medium-speed direct-type.

26.2.2 *Focus-to-film distance**. For a focal spot with a maximum effective dimension of 4 mm, the minimum focus-to-film distances for the double wall, single image method shall be determined from figure 4(a), curve B and for the double wall, double image method from figure 4(b).

26.2.3 *Alignment of X-ray beam*

26.2.3.1 *Double wall, single image* (see figure 2). The X-ray tube shall be placed so as to use a focus-to-film distance which is greater than the minimum determined from figure 4(a), curve B, compatible with the focal spot size and penetrated thickness. The X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the section being examined and shall be offset from the plane through the weld by the minimum distance necessary to prevent the image of one side of the weld confusing the image of the other side. If possible, the X-ray tube shall be close to the pipe with the radiation passing through the parent metal adjacent to the weld.

The film shall be placed diametrically opposite the X-ray tube, in close contact with the weld.

26.2.3.2 *Double wall, double image* (see figure 3). Normally the X-ray tube shall be positioned so that the centre of the projected beam passes through the centre of the pipe in the plane of the weld.

If the superimposing of the images of the two sides of the weld causes difficulty in interpretation, it is permissible for the X-ray tube to be offset the minimum amount required to eliminate superimposed images.

NOTE. Generally, at least three exposures will be required to completely cover a circumferential butt joint.

26.2.4 *X-ray tube voltage**. The voltage values for different penetrated thicknesses obtained from figure 9, curve T shall not be exceeded.

*See also appendix A.

26.3 Technique 16. Gamma-rays using fine-grain direct-type film

26.3.1 *Type of film.* The film shall be of the fine-grain high-contrast direct-type.

26.3.2 *S.F.D.**. The minimum s.f.d. for the double wall, single image method shall be determined from figure 5(a) and for the double wall, double image method from figure 5(b).

26.3.3 *Alignment of gamma-ray beam*

26.3.3.1 *Double wall, single image* (see figure 2). The source of radiation shall be placed so as to use a s.f.d. which is greater than the minimum determined from figure 5(a), compatible with the source diameter and penetrated thickness. The source shall be positioned so that the beam passes through the centre of the section being examined and shall be offset from the plane through the weld by the minimum distance necessary to prevent the image of one side of the weld confusing the image of the other side.

If possible, the source of radiation shall be close to the pipe with the radiation passing through the parent metal adjacent to the weld.

The film shall be placed diametrically opposite the source, in close contact with the weld.

26.3.3.2 *Double wall, double image* (see figure 3). Normally the source of radiation shall be placed so as to use the minimum s.f.d., determined from figure 5(b), compatible with the source diameter and outside diameter of the pipe. The source of radiation shall be positioned so that the beam passes through the centre of the pipe in the plane of the weld.

If the superimposing of the images of the two sides of the weld causes difficulty in interpretation, it is permissible for the source to be offset the minimum amount required to eliminate superimposed images.

NOTE. Generally, at least three exposures will be required to completely cover a circumferential butt joint.

*See also appendix A.

Appendices

Appendix A. Explanatory information on the techniques

A.1 General

While some latitude may be permissible in the techniques described, it will be found that an alteration in any one factor will, in general, involve changes in other factors such that the overall result may be worse than before. The techniques represent the best balance between the many factors.

A.2 Surface condition

Excess weld metal and weave marks can produce sudden changes of film density, particularly in thin sections, which may obscure flaws in the deposited weld metal and at the junctions of weld and parent metal.

For critical examination, excess weld metal should be either removed or ground to a smooth contour merging into the parent metal at the weld boundaries. An increase of up to 10 % in the weld throat thickness will not seriously reduce the flaw sensitivity.

Where excess weld metal is not removed, the permissible coverage, i.e. length of weld per exposure, may be reduced, but where the coverage is to be maintained, radiographs may be obtained in one of the following ways.

(a) Make separate exposures, each to cover part of the range of thickness.

(b) Simultaneously expose films of different speeds interpreting the fastest film for the maximum thickness.

(c) Increase the X-ray energy slightly and use a filter on the X-ray tube (the resulting flaw sensitivity may be appreciably reduced by this method).

It is emphasized that the techniques in (a) to (c) are expedients only and are not, therefore, included in the special techniques.

A.3 Density of radiograph*

Optical density, D, is expressed as:

$$D = \log_{10} \frac{I_O}{I_T}$$

where

I_O is the intensity of the incident light;

I_T is the intensity of the transmitted light.

With films of density 2.0 or 3.0 therefore the transmitted light has an intensity of 1/100 or 1/1000 respectively of its original value. Densitometers are available for density measurement; alternatively, a visual comparison can be made using a calibrated density step-wedge.

Routine checks should be made to ensure that the fog level of the films used is within the limit quoted.

With direct-type film the contrast increases with film density up to very high densities. A maximum density of 3.0 has been quoted as this represents the usual limit of most film viewing equipment, but higher densities may be used with advantage where the viewing light is sufficiently bright to permit adequate interpretation (see also **A.6**).

A.4 Intensifying screens

With X-ray energies below about 120 kV, the absorption of the front screen is greater than the intensifying action produced if lead screens of the usual thickness are employed. For this reason a front screen of tin is sometimes recommended for use at low X-ray energies.

In general, the thickness of lead intensifying screens to be employed is not critical within the ranges given in table 4. A thicker front screen tends to absorb more scattered radiation but gives a smaller intensifying factor. This additional filtration is sometimes employed with advantage on material of irregular section.

The thickness of the back screen also is not critical, provided it exceeds 0.1 mm. There seems to be no deleterious effect from using a very thick back screen, except with X-rays generated at energies greater than about 10 MeV.

A.5 Overlap of film

The requirements of this standard can be met by the careful positioning of identification markers at the end of each section of every seam to be radiographed. To ensure adequate overlap, markers should be placed at each end of the section to be examined. Whenever possible, they should be placed on the source side of the weld.

A.6 Viewing

The conditions under which radiographs are viewed are very important. To achieve a luminance of the illuminated radiograph of 30 cd/m^2 minimum, the luminance of the illuminator needs to be:

3 000 cd/m^2 for a film density of 2.0;
30 000 cd/m^2 for a film density of 3.0.

The brightness of a viewing screen can be checked with most ordinary photographic exposure meters, if a suitable light meter is not available. The exposure meter should be set for a film speed of 100 ASA with its sensitive element close to the screen. Then a meter reading of an exposure of 1/100 s at f:10 corresponds to a screen brightness of 1000 cd/m^2.

*See BS 1384.

A.7 Focus-to-film distance (source-to-film distance)

The distances quoted in the techniques have been chosen having in mind the related factors of definition, film grain, exposure time and the size of the field irradiated.

To obtain the best definition the geometric unsharpness should be as small as possible, but in any case it is desirable that it should not exceed the inherent unsharpness of the film-screen combination. The latter condition is fulfilled in gamma-radiography by the requirements of the appropriate clauses, but an improvement in sharpness may result from the use of larger s.f.d. than those calculated from these clauses.

With X-rays the inherent unsharpness of direct-type films is much smaller than for gamma-rays. For some X-ray techniques the focus-to-film distances calculated to satisfy this criterion are so large that to use them without very long exposure times would require such an increase in voltage that the loss in contrast may completely offset the gain in definition. Accordingly, a compromise has been made in some cases between the desirable focus-to-film distance and exposure time (see figures 4 and 5).

For the calculation of the desirable focus-to-film distance or s.f.d., the following values of inherent film unsharpness have been used.

Radiation	Inherent unsharpness mm
X-rays:	
100 kV	0.05
200 kV	0.09
300 kV	0.12
400 kV	0.15
1000 kV	0.18
Gamma-rays:	
^{192}Ir	0.17
^{60}Co	0.35
^{169}Yb	0.07 to 0.13
^{170}Tm	0.1 to 0.2

The geometric unsharpness is calculated as follows:

$$\text{Geometric unsharpness} = s \times \frac{t}{F - t}$$

where

s is the focal spot size (or source diameter) (in mm);

t is the thickness of metal penetrated (in mm);

F is the focus-to-film distance (or s.f.d.) (in mm).

If the film is not close to the weld surface, the thickness of metal penetrated plus the gap thickness, should be taken instead of t (see also clause 16).

The use of a greater distance than the recommended minimum may often be more convenient, since a larger area can thereby be examined in one exposure. On the other hand, in gamma-radiography the total time of examination can often be reduced appreciably by examining shorter lengths of weld at each exposure and using a correspondingly shorter s.f.d.

The application of the recommended distances depends on the knowledge of the effective size of the focal spot or source of radiation which should be taken as the greatest projected dimension. Therefore, the radiographer should determine the size of the focal spot of each new X-ray tube when installed and periodically throughout its life.

For a focal spot of maximum effective dimension, s (other than 4 mm), the focus-to-film distance, F_2, should be equal to or greater than the value calculated from the following formula:

$$F_2 = \frac{sF_1}{4}$$

where F_1 is the focus-to-film distance for a 4 mm effective focal spot.

A.8 Tube voltage and exposure

The X-ray tube voltage used depends on such factors as the thickness of material to be penetrated, type of film and screens, focus-to-film distance and exposure time.

The maximum voltages given in figure 9 are intended to serve as a guide to the rating of the X-ray equipment required.

An improved radiographic sensitivity can usually be obtained by reducing the X-ray tube voltage, but this entails an increase in exposure time, assuming that other conditions are maintained constant. Conversely, the exposure time can be reduced by increasing the X-ray tube voltage, but this will usually result in an inferior radiographic sensitivity owing to the lower image contrast.

Fine-grain high-contrast films are slower than other types and therefore for the same exposure the voltage has to be increased. The loss in contrast owing to the increased voltage is more than counter-balanced, however, by the higher contrast of these films compared with other types.

For penetrated thicknesses above about 40 mm with fine-grain film, the absence of X-ray equipment between about 400 kV and 1000 kV makes the choice of factors for specifying suitable techniques rather complex.

For penetrated thicknesses greater than 60 mm, there is only a limited range of suitable radiographic equipment. For these thicknesses, the X-ray energy is not critical.

Appendix B. Guide to choice of technique

B.1 In radiography the best possible flaw sensitivity is obtained when the thickness of metal which the radiation has to penetrate is kept to a minimum. Therefore preference should always be given to a single wall method, if this is possible. If a double wall method has to be used, it is essential to bear in mind that the flaw sensitivity is always approximaely half the value obtainable with a single wall method, on the same weld thickness, i.e. if 1.5 % sensitivity can be obtained with a single wall technique, the sensitivity with a double wall technique is likely to be about 3.0 % (see **13.1**).

B.2 Preference should be given to a source inside/film outside method if this is possible. If a gamma-ray source is to be used, it is essential that the criteria of clauses **6** and **16** for type of source and size of source are met.

B.3 Preference should be given to an X-ray method for pipe wall thicknesses less than 12 mm (except see clause **4**).

B.4 If a double wall method is necessary, it should be with X-rays whenever possible.

B.5 Where there is a choice between gamma-ray source inside, single wall, and X-rays outside, double wall, single image, the former is preferable for the following:

(a) pipe wall thicknesses between 2 mm and 12 mm, with an ytterbium-169 source;

(b) pipe wall thicknesses between 12 mm and 25 mm, with an iridium-192 source;

provided the criteria for source dimensions in figure 5 can be met.

B.6 For critical methods it is essential to use fine-grain techniques. For 'normal' methods, medium-speed film may be used.

Appendix C. Alternative procedure for placement of IQI

If the surface of the weld facing the source of radiation is inaccessible for placement of an IQI it is permissible to use the following procedure.

A test weld of the same dimensions as the weld to be examined and on which IQI's can be placed shall be set up on both source and film sides. A reference radiograph shall be taken of this test weld using the same technique as will be used on the production weld. The source side IQI shall be used to achieve the contractual sensitivity and, for correlation with the radiographic sensitivity for production welds, the corresponding sensitivity on the film side IQI shall be recorded.

When the IQI is on the film side, the sensitivity data given in BS 3971 and in table 3 do not apply.

NOTE 1. With identical radiographic techniques the numerical value of the IQI sensitivity will generally be different for different types of IQI.

NOTE 2. IQI sensitivity is a means by which the quality of radiographic techniques may be compared and is not a measure of flaw sensitivity. The latter is a complex function of the geometry, absorption and location of the flaw.

Appendix D. Example of record form for radiographic examination

Project/contract Date

Contractor Procedure no.

Radiographic examination subcontractor

Technique number as specified in BS 2910

Type of equipment: *External *Manually operated/cable

*Internal *Battery crawler device

Exposure container

kV rating

Film: Make Type Density

Intensifying screens: Type

Thickness:
Front Back

Shielding

Source size

Geometric relationship: (Sketch)

Focal film distance

Object film distance

Radiation angle with respect to weld and film

Film coverage

Tube voltage or source strength Exposure

Material thickness range Surface condition

Type of IQI Size Position Sensitivity

Processing

Limitations

Signed by contractor Approved by employer

Date Date

*Delete as necessary

Appendix E. Flaw sensitivity in radiography: principles and background

E.1 General

On a film radiograph, flaws and variations in metal thickness are shown as variations in film blackening (film density). With the techniques detailed in this standard, the images of flaws are closely approximate in size to the cross-sectional dimensions of the flaws themselves, except that the images of very narrow planar flaws such as cracks or lack of penetration are spread out to considerably greater than the true flaw width.

The position of the flaw through the weld thickness does not greatly affect its detectability.

In all other respects, a description of attainable flaw sensitivity is necessarily complicated.

Most weld flaws have three dimensions:

length, l;
width, W;
through thickness height, h;

and planar flaws have a fourth parameter, i.e. the angle between the plane of the defect and the radiation beam plane, θ. In addition, this standard details a range of radiographic techniques, including both X-rays and gamma-rays, over which there is also a variation in attainable flaw sensitivity.

A summarized and simplified statement on flaw sensitivity is given in **E.2** to **E.4**.

E.2 Air-filled cavities (wormholes, porosity)

There is a good correlation between attained IQI sensitivity and flaw sensitivity:

Minimum dimension of detectable cavity (in mm)

$$= \frac{3}{2} \times \frac{\text{hole sensitivity (in \%)}}{100} \times \text{weld thickness (in mm)}$$

i.e. if the step/hole sensitivity is 3 % on a 9 mm weld, gas pores down to 0.4 mm in diameter will be detectable.

E.3 Inclusions (slag, oxide)

The flaw sensitivity will be a function of both the radiographic technique and the material of the inclusions.

For typical slag material and thin welds, the sensitivity will be about half the value for gas cavities, i.e. a 0.8 mm slag inclusion, in the example quoted in **E.2**.

E.4 Planar flaws such as cracks and lack of penetration

There is a complex relationship between the flaw parameters h, W, l and the radiographic parameters of contrast and unsharpness. Typical calculations show that for a 25 mm steel weld, using techniques 1 or 7, a crack will be detectable if:

$l > 1$ mm; $h = 5$ mm $W = 0.04$ mm $\theta < 20°$
$h = 5$ mm $W = 0.02$ mm $\theta < 9°$

For techniques 4 or 10, the corresponding values are:

$l > 2$ mm $h = 5$ mm $W = 0.04$ mm $\theta < 8.5°$
$h = 5$ mm $W = 0.02$ mm $\theta < 3°$

It is emphasized that these quoted values are only for guidance on the general capabilities of a radiographic inspection technique. The relationship between wire IQI sensitivity and welding imperfections is complex and has no practical correlation in the context of this standard.

Publications referred to

BS 1384 Measurement of photographic transmission density
BS 3683 Glossary of terms used in non-destructive testing
Part 3 Radiological flaw detection
BS 3971 Specification for image quality indicators for industrial radiography (including guidance on their use)
BS 4727 Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour
Part 5 Terms particular to electromedical equipment
Group 01 Radiology and radiological physics terminology
BS 5230 Method for the measurement of speed and contrast of direct-type films for industrial radiography
BS 5650 Specification for apparatus for gamma radiography

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