
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

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has been prepared under the direction of the Welding Standards Committee and is a revision of BS 2910 : 1973 which is withdrawn.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

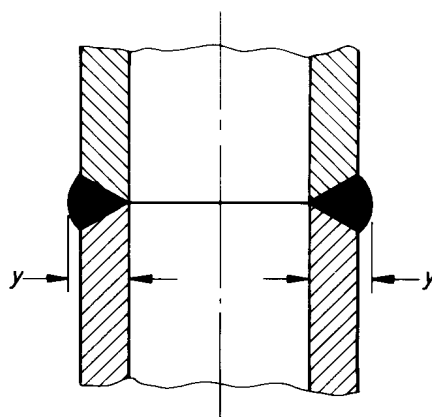
2.1 single wall method. A method of radiographic examination in which the source of radiation is outside the pipe and the film is close to the inside surface of the intervening wall, or in which the source is inside the pipe and the film is close to the outside of the pipe.

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 2γ 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).



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

For single wall method, penetrated thickness is γ
For double wall method, penetrated thickness is 2γ

Figure 1. Penetrated thicknesses

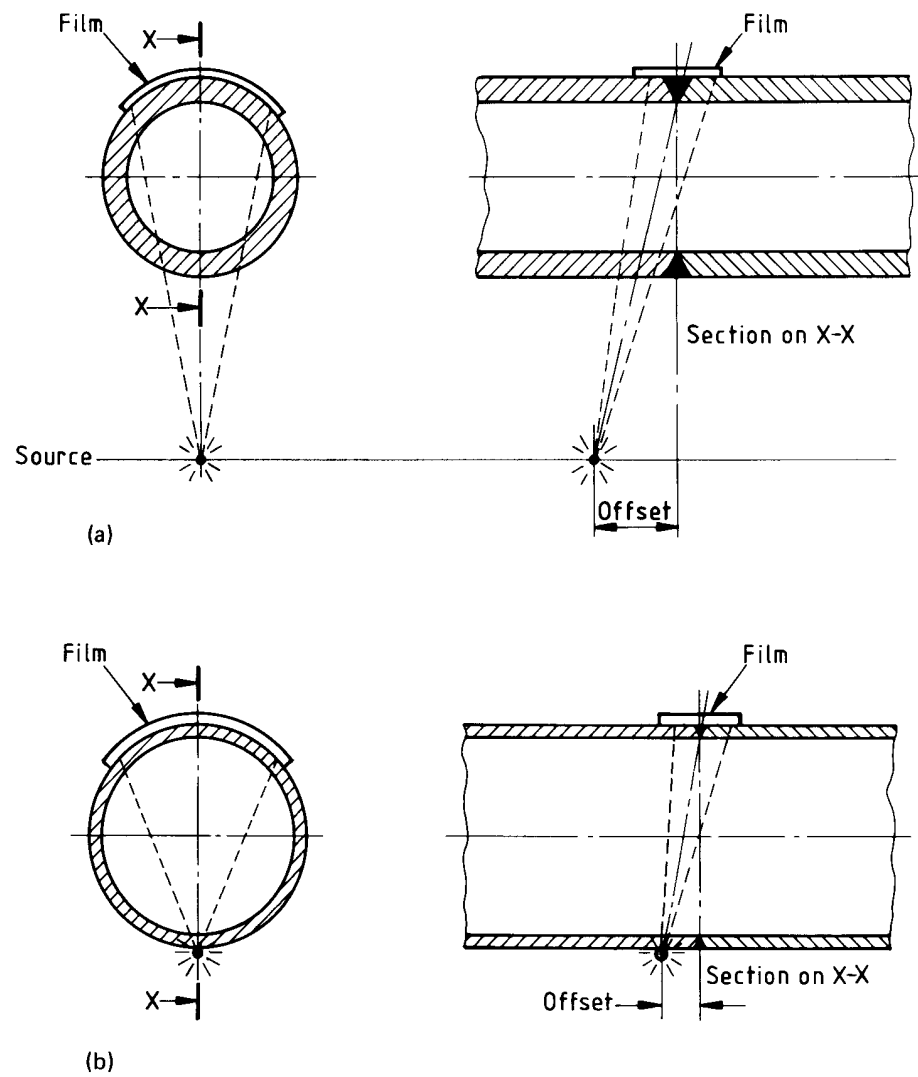
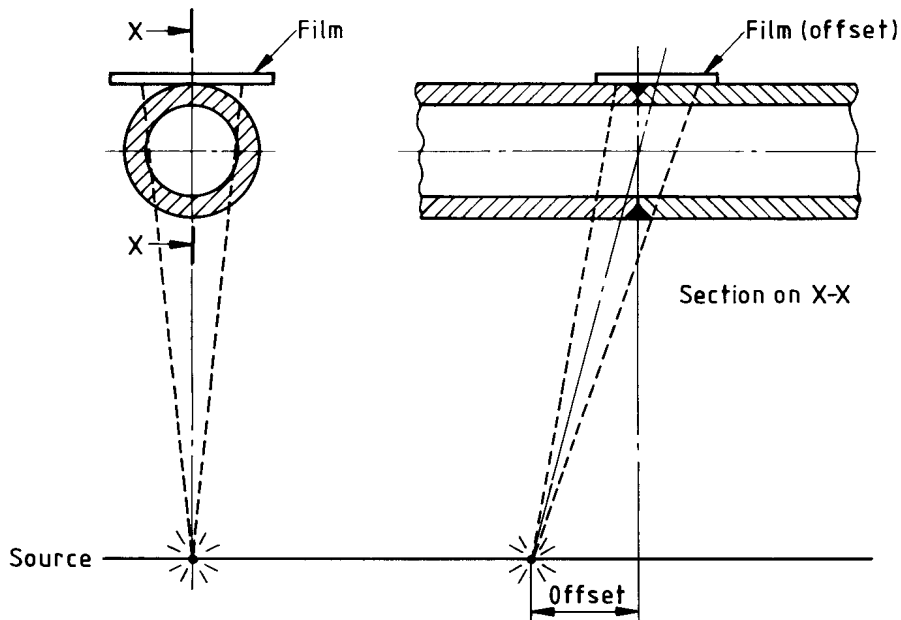


Figure 2. Double wall, single image method



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-assembly prior to shipment to site, other means of positional location 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	%	Ytterbium-169 Thulium-170	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)		0.080	(2.7)	0.160	(5.3)
6	0.100	(1.6)	0.200	(3.3)		0.125	(2.1)	0.250	(4.2)
12	0.200	(1.6)	0.400	(3.2)	Iridium-192	0.250	(2.1)	0.500	(4.1)
25	0.320	(1.3)	0.630	(2.5)		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.