
British Standard Methods for Radiographic examination of fusion welded branch and nozzle joints in steel

Méthodes d'examen radiographique des assemblages de tubulures
et d'ajutages en acier soudés par fusion

Durchstrahlungsprüfung von schmelzgeschweißten Abzweigverbindungen und
Stutzenverbindungen aus Stahl

Foreword

This British Standard has been prepared under the direction of the Welding Standards Policy Committee.

It is essential to quote the technique number in addition to the BS number whenever this standard is used. It should be noted that the technique numbers used in this standard correspond with those used in BS 2910.

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 appendix B which includes a flow chart to assist in the selection of technique. As so many factors affect 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 agreed between the contracting parties.

Although this standard has been prepared to deal with branch and nozzle joints in steel, the general principles and techniques may be applicable to similar joints in other non-ferrous materials.

The explanatory information in appendix A has been included to amplify and in some instances gives the reason underlying what is stated in the standard. Some principles and background to flaw sensitivity are included in appendix E.

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.

Amendment No. 1
published and effective from 21 December 1990
to BS 7257 : 1989

Methods for radiographic examination of fusion
welded branch and nozzle joints in steel

Corrections

AMD 6641
December 1990

Table 1. Individual techniques

Delete columns 1 and 2 and substitute the following:

Location of film and source of radiation	Technique
	No.†
Film inside, source of radiation outside (see clause 24)	1
	3
	4
Film outside, source of radiation inside (see clause 25)	7
	9
	10
Film and source of radiation both outside (see clause 26)	13
	15
	16

AMD 6641
December 1990

Clause 26.1.3 Alignment of X-ray beam

Delete sentence 2 and substitute the following:

‘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 aligned with the specific features of interest, e.g. fusion face or weld root where this is practicable.’

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December 1990

Clause 26.2.3 Alignment of X-ray beam

Delete sentence 2 and substitute the following:

'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 aligned with the specific features of interest, e.g. fusion face or weld root where this is practicable.'

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December 1990

Clause 26.3.3 Alignment of gamma-ray beam

Delete sentence 2 and substitute the following:

'The source of radiation shall be positioned so that the centre of the projected beam passes through the centre of the section being examined and shall be aligned with the specific features of interest, e.g. fusion face or weld root where this is practicable.'

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Methods

1 Scope

This British Standard describes methods for the radiographic examination of fusion welded branch and nozzle joints in steel primarily with wall thicknesses in the range 2 mm up to and including 150 mm and with internal pipe diameters from 6 mm up to and including 1500 mm. This standard covers the following methods:

- (a) examination using the film inside and source of radiation outside;
- (b) examination using the film outside and source of radiation inside;
- (c) examination using the film and source of radiation both outside.

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 7257 shall 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.

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

'more critical techniques', referred to as class A in this standard;

'normal techniques', referred to as class B in this standard.

If a class A technique is required, it is essential that one of the techniques 1, 3, 4, 7, 9 or 10 is specified as it is well-known that the use of double wall techniques cannot produce as good a flaw sensitivity as the single wall techniques.

NOTE 1. In order that a gamma-ray technique should qualify as a class A technique (techniques 4 and 10) the penetrated thickness has to correspond to the appropriate range shown in table 2.

NOTE 2. 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 3683 : Part 3 and BS 4727 : Part 5 : Group 01 apply together with the following.

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

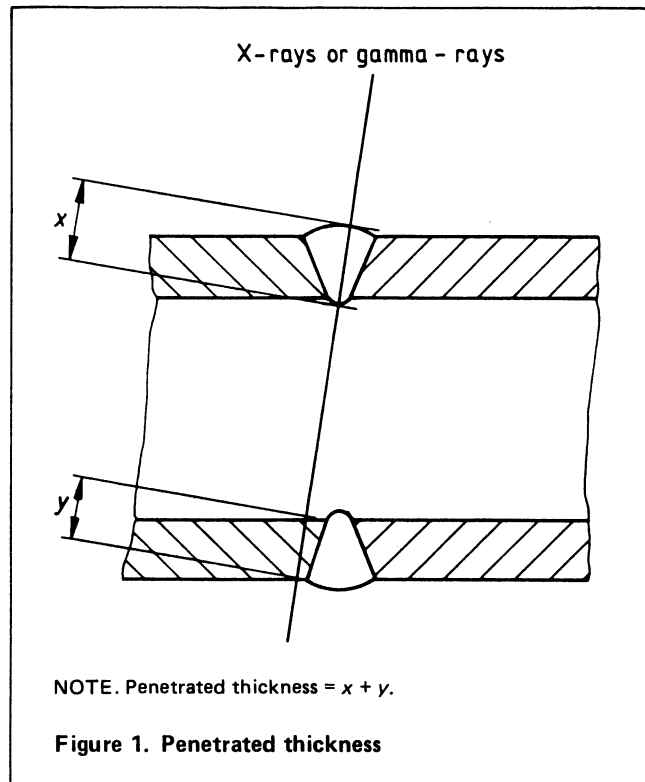
is inside the nozzle joint and the film is close to the outside surface of the intervening wall.

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

NOTE. The penetrated thickness is $x + y$ as shown in figure 1.

2.3 nozzle weld. A form of welded joint between two connecting cylinders in which the diameter of the smaller cylinder is less than half the diameter of the larger.

2.4 branch weld. A form of welded joint between two connecting cylinders in which the diameter of the smaller cylinder is equal to or greater than half the diameter of the larger.



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 in radiography such as that operated by the PCN* Scheme.

* Personnel Certification for Non-destructive Testing. Details obtainable from the Central Certification Board, c/o British Institute of Non-Destructive Testing, 1 Spencer Parade, Northampton NN1 5AA.

4 Techniques

The technique to be used shall be one of those given in table 1, fuller details are given in the appropriate clauses and in appendix A. 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 less than 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 technique is used. The use of gamma-rays may also become necessary if X-ray techniques give rise to diffraction effects in the radiograph, a problem which may be more likely where thin stainless steel and cast components are involved.

The correct use of a ^{169}Yb gamma-ray source on steel wall thicknesses between 2 mm and 12 mm will produce single wall radiographs of similar sensitivity to double wall X-radiographs on these thicknesses.

On very thick sections, greater than 80 mm penetrated thickness, the use of high energy X-rays from equipment such as linear accelerators, when such equipment is available, is preferable to the use of gamma-rays.

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 nozzle joints in which the bore of the pipe or main vessel is such that it is practicable to position film inside. In some circumstances, this may require the use of specially prepared film-screen-cassette combinations. 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 bore of the pipe or main vessel shall be sufficient to allow the use of the appropriate minimum focus-to-film distance
	9	X-rays using medium-speed direct-type film	As for technique 7
	10	Gamma-rays using fine-grain high-contrast direct-type film	As for technique 7
	13	X-rays using fine-grain high-contrast direct-type film	For nozzle joints of all sizes where access is limited to the outside only
Film and source of radiation both outside (see clause 26)	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. † These technique numbers have been chosen to be in accordance with BS 2910 technique numbers and therefore the nine techniques are not numbered consecutively.			

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 film, 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 thicknesses that may be recorded in one exposure.

6 Radiation sources

6.1 X-rays

The X-ray voltages to be used shall be as shown in figure 6 and detailed in clause 24 (see also appendices A and B).

6.2 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
^{60}Co	50	150
^{192}Ir	10	80
^{137}Cs	25	100
^{169}Yb	2	12
^{170}Tm	2	12

NOTE. It is emphasized that the minimum thickness on which gamma-rays may be used, as given in table 2, should not be interpreted as implying that on those 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 the human body to X-rays or gamma-rays (ionizing radiations) can be harmful. It is essential that whenever X-ray generators or radioactive sources are in use, adequate precautions shall be taken to protect the radiographers and others in the vicinity. All exposures of people to ionizing radiation shall be kept to a minimum.

NOTE. The use of all X-ray generators and radioactive sources is subject to the requirements of the Ionising Radiations Regulations (SI 1985 No. 1333, ISBN 0 11 057 333 1) and its Approved Code of Practice 'The Protection of Persons against Ionising Radiations arising from any work activity' (ISBN 0 11 883 838 5), available from HMSO.

In addition, employers may have written local rules which need to be taken into consideration.

Where possible, radiography should be carried out in enclosures that provide adequate shielding (see Approved Code of Practice, Part 2, Section 6). Where the radiography cannot be carried out in a shielded enclosure, then it should be done in a controlled area segregated from other work. The dose rate outside the barrier demarcating the controlled area should not exceed $7.5 \mu\text{Sv/h}^{-1}$ (see Approved Code of Practice, Part 2, Section 7).

Warning signals should be provided to indicate that a radiation exposure is about to start. A different and distinct signal is needed during the exposure. Warning notices should explain the significance of the barrier and the meaning of the warning signals to all people approaching the boundary of the controlled area.

Further advice for site radiography is given in 'Radiation Safety for Site Radiography' (ISBN 0 903 393 86 7) published by Kluwer Publishing Ltd., 1 Harlequin Avenue, Great West Road, Brentford, Middlesex TW8 9EW.

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

NOTE 1. See also A.2.

The contour of the weld surface shall be smooth and free from any irregularities that would interfere with the radiographic interpretation. Any change in section shall be gradual.

NOTE 2. 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 3. Where possible, temporary backing rings should be removed prior to radiography since this results in better sensitivity.

NOTE 4. If the above 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 and heat affected zone to identify its position.

10 Identification of radiographs

10.1 Each section of the 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;
- (d) the exposure number;
- (e) the date.

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 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-assemblies prior to shipment to site, other means of positional location shall be used.

NOTE 2. This can be achieved by reference to drawings, sketches or photographs 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, such as dot, vibratory and round Vee, shall be used. Under no consideration shall stamping or centre punching be permitted on material under 10 mm thick.

12 Density of radiographs

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 films (see also clause 18).

NOTE. These values are inclusive of the fog density* which should be no 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 1. The required IQI 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 percentage or this diameter expressed as a percentage of the weld metal thickness being inspected (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.

NOTE 2. For example, for a 6 mm weld metal thickness, using a wire type IQI and a single wall technique, the IQI wire sensitivity to be expected (in accordance with table 7 of BS 3971 : 1980) will be about 1.6 %. If, instead, a double wall, single image technique is used, the penetrated thickness will be about 12 mm and the smallest discernible wire will be larger; the IQI wire sensitivity, expressed as a percentage of the weld metal thickness is likely to be about 3.2 %.

NOTE 3. The type III IQI (see BS 3971) 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 4. 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 5. If the sensitivities obtained are worse 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.

* Density of a processed unexposed film.