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ISO

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO RECOMMENDATION

R 947

RECOMMENDED PRACTICE FOR RADIOGRAPHIC INSPECTION OF CIRCUMFERENTIAL FUSION WELDED BUTT JOINTS IN STEEL PIPES UP TO 50 mm (2 in) WALL THICKNESS

1st EDITION

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BRIEF HISTORY

The ISO Recommendation R 947, *Recommended practice for radiographic inspection of circumferential fusion welded butt joints in steel pipes up to 50 mm (2 in) wall thickness,* was drawn up by Technical Committee ISO/TC 44, *Welding,* the Secretariat of which is held by the Association Française de Normalisation (AFNOR).

Work on this question led to the adoption of a Draft ISO Recommendation.

In April 1967, this Draft ISO Recommendation (No. 1167) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Australia	Ireland	South Africa, Rep. of
Austria	Israel	Spain
Belgium	Japan	Sweden
Canada	Korea, Rep. of	Switzerland
Czechoslovakia	Netherlands	Turkey
Denmark	New Zealand	United Kingdom
Finland	Norway	U.S.A.
France	Poland	U.S.S.R.
Greece	Portugal	Yugoslavia
India	Romania	

One Member Body opposed the approval of the Draft :

Germany

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in January 1969, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 947 January 1969

RECOMMENDED PRACTICE FOR RADIOGRAPHIC INSPECTION OF CIRCUMFERENTIAL FUSION WELDED BUTT JOINTS IN STEEL PIPES UP TO 50 mm (2 in) WALL THICKNESS

INTRODUCTION

The increasing use of X-rays and gamma-rays for the examination of welded joints has made it desirable to issue ISO Recommendations of a general character giving guidance on the application of these methods in order to attain satisfactory sensitivity in the test itself.

In the present state of knowledge of radiographic inspection of welds, it is undesirable to impose strict rules to be followed in order to obtain the best results; the final result depends upon many variables, for example, the characteristics of the equipment and radioactive source, the characteristics of films and screens, and the characteristics and accessibility of welds.

However, it is possible, within certain limits, to assess the radiographic quality by means of such devices as image quality indicators (I.Q.I.), which are specified in ISO Recommendation R 1027, *Radiographic image quality indicators – Principles and identification*.

NOTE. – The shape, size and accessibility of the objects considered here may necessitate differences in the positioning, in relation to the welded joint being examined, of the X-ray equipment (or gamma-ray sources) and of the films. These points are described in section 6.

1. SCOPE

This ISO Recommendation provides general guidance on the techniques of weld radiography with the object of enabling satisfactory results to be obtained and it enunciates some rules which are based on generally accepted practice and the fundamental theory of the subject.

2. FIELD OF APPLICATION

This ISO Recommendation relates to the radiographic examination of circumferential fusion welded butt joints in steel pipes* up to 50 mm (2 in) wall thickness.

It should not be regarded as giving acceptance standards for joints and is concerned only with radiography as such.

3. DEFINITIONS

Definitions of the principal terms concerning radiographic techniques used in this ISO Recommendation are given in an Appendix, separately published under the title *Explanations on the significance of the principal radiographic terms used in ISO Recommendations concerning welding.*

* Besides its conventional meaning, the word "pipe" as used in this ISO Recommendation should be understood to cover other cylindrical bodies, such as tubes, penstocks, boiler drums, pressure vessels, etc.

4. CLASSIFICATION OF RADIOGRAPHIC TECHNIQUES

The examination techniques are divided into the following three classes :

- Class A : general technique for X-ray examination;
- Class B : more sensitive X-ray technique;
- Class C : general technique for gamma-ray examination.

4.1 Class A

Most cases, in particular where mild or low alloy steel is concerned, are covered by the correct use of the technique given for Class A.

4.2 Class B

Class B (high-sensitivity X-ray examination) is intended only for more important and difficult cases or where the Class A technique is unlikely to reveal the imperfections sought. It is a technique in which only fine-grain films and lead screens are used; it therefore requires longer exposure times and, on occasions, the use of equipment capable of giving voltages higher than those required for Class A.

4.3 Class C

With regard to Class C (gamma-ray examination) it is to be noted that the detectability of imperfections obtainable even with the best gamma-ray technique is always inferior to that obtainable with the Class A technique. The use of gamma-rays should, therefore, be limited as far as possible to cases in which the shape, the thickness or the accessibility of the weld renders X-ray inspection impossible. It should be mentioned in the test report that gamma-rays have been used and full details of the source should be given. (See section 7.)

It should also be noted that the known disadvantage of the Class C technique (low contrast) is sometimes offset by the fact that the small size of the radioactive sources allows of their being placed on the axis of the pipe to be examined, thus ensuring the best geometrical conditions while avoiding, in many instances, the disadvantages arising from the double wall techniques.

5. GENERAL

5.1 Protection

Exposure of any part of the human body to X-rays or gamma-rays can be highly injurious to health. It is therefore essential that, wherever X-ray equipment or radioactive sources are in use, adequate precautions should be taken to protect the radiographer and any other person in the vicinity.

Safety precautions to be taken against X-rays and gamma-rays are those in force in each country.*

5.2 Surface preparation

In order to obtain the best flaw sensitivity, it is always advisable to remove surface imperfections before taking radiographs.

In general, surface preparation may not be necessary for radiography, but where surface irregularities might cause difficulty in detecting internal imperfections, the surface should be ground smooth.

5.3 Location of the weld in the radiograph

Markers, usually in the form of lead arrows or other symbols, should be placed alongside the weld on each side of it, so that the position of the weld can be identified on the radiograph. This may not be necessary if the reinforcement is retained.

5.4 Identification of radiographs

Lead letters or symbols should be affixed to each section of the weld being radiographed. The images of these letters should appear in the radiograph to ensure unequivocal identification of the section.

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* In default of such regulations, reference should be made to the latest Recommendations of the International Commission on Radiological Protection.

5.5 Marking

In general, permanent markings on the work piece will provide reference points for the accurate re-location of the position of each radiograph. Where the nature of the material and its service conditions render stamping impossible, other suitable means for re-locating the radiographs should be sought. This may be done by paint marks, or by accurate sketches.

5.6 Overlap of films

In radiographing a continuous length of weld, the separate radiographs should overlap sufficiently to ensure that no portion of this length remains unexamined.

5.7 Image quality indicators

An image quality indicator (I.Q.I.) of mild steel, of a type specified in ISO Recommendation R 1027 and agreed between the contracting parties, should be placed at one or each end of every section to be radiographed. It should be placed on the surface facing the source of radiation, and in such a manner that the thinnest part or smallest diameter of the indicator is placed where the thickness penetrated by the radiation is greatest and, depending upon its type, adjacent to or across the weld. Only where this surface is inaccessible should the I.Q.I. be placed on the film side. If this has to be done, it should be mentioned in the test report, as the I.Q.I. indication has not the same meaning when the I.Q.I. is placed in this position. For details of the recommended types of I.Q.I., see ISO Recommendation R 1027.

The sensitivity values required from I.Q.I. should be agreed between the contracting parties. These values merely provide a guide to the quality of the technique used and do not necessarily bear any direct relation to sensitivity as regards the detection of faults in welds.

6. RECOMMENDED TECHNIQUES FOR MAKING RADIOGRAPHS

6.1 Setting up of the films and of the source of radiation

6.1.1 *Relative position of films and sources, depending on the size and accessibility of the joints*

I FILM INSIDE, SOURCE OF RADIATION OUTSIDE (SEE FIG. 1)

The source of radiation should be placed at a distance from the weld as defined below (see clause 6.6), the axis of the cone of radiation being normal to the surface under examination at its centre.

The cassette should be placed on the corresponding area inside the pipe, in close contact with the weld.

II FILM OUTSIDE, SOURCE OF RADIATION INSIDE (SEE FIG. 2)

The source of radiation should be set up inside the pipe, on the axis of the pipe if possible, though otherwise it may be placed eccentrically in the plane of the weld, the axis of the cone of radiation being normal to the surface under examination at its centre.

The cassette should be placed on the corresponding area outside the pipe, in close contact with the weld.

III FILM AND SOURCE OF RADIATION OUTSIDE – DOUBLE WALL, DOUBLE IMAGE (SEE FIG. 3)

The source of radiation should be placed at a distance as defined below (see clause 6.6) in a position so that the axis of the cone of radiation is inclined to the axis of the pipe, and passes through the centre of the plane of the weld. The cassette containing the film, which should be of sufficient length to contain the two images of the weld, should be placed against the pipe wall further from the source, and disposed in such a manner that the axis of the cone of radiation passes through the centre.

IV FILM AND SOURCE OF RADIATION OUTSIDE – DOUBLE WALL, SINGLE IMAGE (SEE FIG. 4)

The source of radiation should be placed so as to achieve the minimum focus-to-film distance compatible with the source size and wall thickness to be examined. If possible the source should be in contact with the pipe, with the radiation passing through the parent metal adjacent to the weld, but this may not be possible with small diameter pipes. The film should be placed on the side of the pipe further from the source of radiation, in close contact with the weld, the axis of the cone of radiation passing through the centre of the portion of weld under examination.

6.1.2 *General guidance in the selection of the appropriate technique*

I FILM INSIDE, SOURCE OF RADIATION OUTSIDE

This technique should be used for large cylindrical bodies, where the limitation (see clause 6.7) of maximum area to be examined permits the use of long films whilst keeping the focus-to-film distance within reasonable limits.

II FILM OUTSIDE, SOURCE OF RADIATION INSIDE

When applicable, this technique should be considered as the most convenient, because with the source situated at or near the centre, there is no restriction regarding the area examined. For large bodies conventional equipment may be used and for small ones hollow anode X-ray tubes or gamma-ray sources are required.* This technique is particularly recommended for thick pipe of small diameter.

III FILM AND SOURCE OF RADIATION OUTSIDE – DOUBLE WALL, DOUBLE IMAGE

This technique should be used for pipes having diameters not exceeding approximately 100 mm (4 in), the necessary focus-to-film distance being too large with larger diameters; it should be noted, however, that the increase of wall thickness restricts the length of weld which can be properly radiographed.

IV FILM AND SOURCE OF RADIATION OUTSIDE – DOUBLE WALL, SINGLE IMAGE

This technique will give the best results for pipes not accessible from inside, with diameters larger than approximately 100 mm (4 in). It can be used for pipes with diameters up to about 0.90 m (3 ft), beyond which the source-to-film distance becomes too great.

NOTE. – Whenever possible, in particular when a large part of the radiation beam is used for covering the area to be irradiated, it is recommended that operators should set up the equipment in such a way that the axis of the beam (inside the tube) is parallel to the pipe to be radiographed. This ensures the best image definition,even at the extremities of the film, and a more uniform distribution of the intensity of the radiation.

6.2 Films and screens**

The following types of films and screens should be used :

6.2.1 *Class A.* According to circumstances, non-screen films may be used without screens or with lead screens. The thickness of these screens should lie within the range 0.02 to 0.15 mm (0.001 to 0.006 in).

The use of salt screens is not recommended, but if, because of unavoidable circumstances, they are used they should be of the high-definition type, and this should be mentioned in the test report, as this technique causes loss of definition.

6.2.2 *Class B.* Fine-grain, high-contrast films should be used in combination with lead screens. The thickness of these screens should lie within the range 0.02 to 0.15 mm (0.001 to 0.006 in).

6.2.3 *Class C.* Fine-grain, high-contrast films should be used in combination with lead screens. The thickness of the front screens should lie within the range 0.02 to 0.15 mm (0.001 to 0.006 in). The back screens may be of greater thickness.

6.3 Cassettes

Films and screens (if used) should be placed in cassettes, either rigid or flexible. In view of the general difficulty of procuring rigid cassettes with curvatures such as to bring the whole length of the film in close contact with the welded joint, preference should be given to flexible cassettes, provided that adequate precautions are taken to ensure good overall film-to-screen contact.

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* To prevent any misunderstanding, it should be noted that, if the boring of a hole in the pipe wall is necessitated by the application of the method described in order to introduce the source, this method should not be considered preferable to techniques III or IV, owing to the difficulties which may be encountered in repairing the hole.

** The definitions of the type of recommended films (non-screen and screen type, fine-grain, high-contrast, etc.) are related to the conventional descriptions of sensitive material. The same applies to the high-definition and high-speed salt screens. The figures for thickness of lead screens are intended only for guidance.

6.4 Alignment of beam

The beam of radiation should be directed to the middle of the section under examination and should be normal to the pipe surface at that point, except when especially seeking certain imperfections which it is known are best revealed by a different alignment of the beam; such imperfections are those at a fusion face, and the exposure should then be made with the beam directed along the fusion face.

This general rule should be applied with the following two exceptions :

(*a*) When using the double wall, double image technique, the inclination of the beam should be such as to avoid a superimposition of the two images. This inclination will depend on the diameter of the pipe, its wall thickness and the width of the weld.

(*b*) For the double wall, single image technique, the displacement of the source from the plane of the weld should be just sufficient to avoid superimposition of the images of the two portions of the weld and the inclination of the axis of the beam should be such that the axis passes through the middle of the portion of weld under examination.

In order to eliminate possible interference when a backing ring has been used and to provide the best possibility of fine cracks in the root run being revealed, it is suggested that, where the diameter of the pipe permits, the beam should be normal to the weld, not inclined, and centred in the plane of the weld.

6.5 Interception of unwanted and scattered radiation

The film should be shielded from all back scattered radiation by an adequate thickness of lead, say 1.5 mm (0.05 in) or more, placed behind the film-screen combination. On account of the back radiation originated by the lead itself, it is suggested that a tin sheet about 1 mm (0.04 in) thick or, better, a tin and a copper sheet, each 1 mm (0.04 in) thick, should be inserted between the lead plate and the film-screen combination.

Moreover, in order to reduce the effect of internally scattered radiation, adequate masking should be provided so as to limit the area irradiated to the section under examination.

When using the double wall techniques III and IV, in particular on small diameter pipes, adequate masking should be provided to ensure that only direct radiation strikes the film.

6.6 Target (source)-to-film distance

The distance between the film and the adjacent weld surface should be as small as possible.

The minimum target (source)-to-film distance $f_{min.}$ depends on the effective dimension d* of the focal spot or source and on the distance b between the film and the surface of the specimen facing the X-ray tube or radioactive source.

The resulting geometric unsharpness or penumbra, u, can be calculated from the following formula :

$$u = \frac{b\,d}{f_{min.} - b}$$

It should not exceed the following values :

Class A	Class B	Class C
0.4 mm (0.015 in)	0.2 mm (0.008 in)	0.4 mm (0.015 in)

When using techniques I and II, the minimum target (source)-to-film distance should be calculated directly from the conventional formula.

When using technique III it is necessary to introduce into the formula, for b, the external diameter of the pipe instead of its wall thickness.

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* The *effective focal spot dimension* is the maximum dimension of the projected focal spot in a line at right angles to the tube axis which passes through the target. To verify the effective dimensions of the focal spot, see document 183-65 of the International Institute of Welding, *Recommendation for the determination of focal spot size of X-ray tubes.*

In Table 1, below, the approximate minimum target (source)-to-film distances are given as multiples of the external diameter for Classes A and C (penumbra, $u = 0.4$ mm) and for Class B (penumbra, $u = 0.2$ mm) and for different focal spot sizes.

TABLE 1 – **Minimum target (source)-to-film distances ($f_{min.}$)**

Class	d (Focal spot) (mm)	$f_{min.}$ (expressed as a multiple of the pipe diameter)
A and C (penumbra, $u = 0.4$ mm)	2	5
	3	7.5
	4	10
	5	12.5
	6	15
B (penumbra, $u = 0.2$ mm)	2	10
	3	15
	4	20
	5	25
	6	30

When using technique IV, the minimum target (source)-to-film distance should be calculated by introducing into the formula, for b only, the actual wall thickness of the section of circumference under examination. It should be noted that, with technique IV, when the outside diameter of the pipe plus the actual distance between source and radiation outlet port is not less than the minimum target (source)-to-film distance required, there are no objections to putting the X-ray equipment or the radioactive source in close contact with the pipe.

6.7 Size of the area examined

The maximum area to take into consideration at each exposure will be determined by the difference between the thickness of the material penetrated in the centre of the radiation beam and that at the extremities measured in the direction of the beam at those points. The differences in density resulting from this variation of thickness and recorded on the film should not exceed the admissible limits specified in clause 6.8.

It should be noted that this limitation not only ensures the best utilisation of the film characteristics, but also reduces the distortion of the image at each extremity of the film.

6.8 Density of radiograph

Exposure conditions should be such that the density of the radiograph of the sound weld metal in the area under examination, including fog density, lies within the range given in Table 2, below.

TABLE 2 – Density of radiograph

Class A	Class B	Class C
1.7 to 3.0 for non-screen type films 1.3 to 2.3 for screen type films for the exceptional case where this type of film is used	2.0 to 3.0	2.0 to 3.0

Higher densities may be used with advantage where the viewing light is sufficiently bright to permit adequate interpretation. Precautions should be taken to avoid glare.

For Class C, if prior agreement has been given by the inspecting authority, who in some cases will be the purchaser himself and in other cases an authority in whom consulting and inspection rights have been vested by the purchaser, the minimum density may be reduced to 1.5.

In order to avoid unduly high fog densities arising from film ageing, development, or temperature, the fog density should be checked from time to time on a non-exposed sample taken from the films being used, and handled and processed under the same conditions as the actual radiographs. The fog density should not exceed 0.2.

6.9 Tube voltage or type of source

In order to increase the contrast, the tube voltage should be as low as practicable. As a basis, the voltage should be chosen so as to give an appropriate density with an exposure of not less than 8 mA minute for Class A, and not less than 15 mA minute for Class B, for a target-to-film distance of about 760 mm (30 in); the time should in no case be less than 1 minute.

Radioactive sources give the best results above the following thicknesses :

^{192}Ir	10 mm ($\frac{3}{8}$ in)
^{137}Cs	25 mm (1 in)
^{60}Co	38 mm (1 $\frac{1}{2}$ in)

6.10 Processing

Films should be processed in accordance with the recommendations of the film manufacturers. Particular attention should be paid to temperature and developing time. The radiographs should be free from imperfections, due to processing or other causes, which would interfere with interpretation.

6.11 Viewing

The radiographs should be examined in a darkened room on an illuminated diffusing screen and the illuminated area should be masked to the minimum required for viewing the radiographic image. The brightness of the viewing screen should preferably be adjustable so as to allow satisfactory reading of the radiographs.

7. RECORDING OF TECHNICAL DATA

For each radiograph, or set of radiographs, information should be available on the radiographic technique used, and on any other special circumstances which would allow a better understanding of the results.

In particular, the following should be stated :

(*a*) type of X-ray equipment, tube voltage and current ;

(*b*) characteristics of the radioactive source (nature, size, nuclear activity, etc.);

(*c*) time of exposure, type of film and screen, and target (source)-to-film distance;

(*d*) system of marking used.