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Recommended practice for the X-ray inspection of fusion welded butt joints for aluminium and its alloys and magnesium and its alloys 5 to 50 mm thick

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2437 was drawn up by Technical Committee ISO/TC 44, *Welding.*

It was approved in January 1972 by the Member Bodies of the following countries :

Austria	Ireland	Sweden
Belgium	Israel	Switzerland
Canada	Italy	Thailand
Chile	Japan	Turkey
Czechoslovakia	Netherlands	United Kingdom
Egypt, Arab Rep. of	New Zealand	U.S.A.
Finland	Norway	U.S.S.R.
France	Romania	
India	Spain	

The Member Bodies of the following countries expressed disapproval of the document on technical grounds :

Germany
South Africa, Rep. of

Printed in Switzerland

Recommended practice for the X-ray inspection of fusion welded butt joints for aluminium and its alloys and magnesium and its alloys 5 to 50 mm thick

0 INTRODUCTION

In the same way as it appeared desirable to publish recommendations for the radiographic inspection of fusion welded joints for steel, it has been thought worthwhile also to prepare similar recommendations for the inspection of fusion welded butt joints for aluminium and its alloys and for magnesium and its alloys.

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 X-ray equipment, the characteristics of films and screens, 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/R 1027, *Radiographic image quality indicators — Principles and identification,* and ISO 2504, *Radiography of welds and viewing conditions for films — Utilization of recommended patterns of image quality indicators (I.Q.I.).*

It should be noted that the shape, size and accessibility of the objects considered here may necessitate differences in the positioning of the X-ray equipment and of the films in relation to the welded joint being examined.

These points are covered in section 5.

1 SCOPE

This International Standard 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 International Standard relates to the examination of fusion welded butt joints in plates and circumferential fusion welded butt joints in pipes[1] of aluminium and its alloys and of magnesium and its alloys of thicknesses ranging from 5 to 50 mm.

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

3 CLASSIFICATION

The examination techniques are divided into the following two classes :

- Class A, general technique for X-ray examination;
- Class B, more sensitive X-ray technique.

Most cases are covered by the correct use of the specifications given for Class A.

Class B (high-sensitivity X-ray radiography) is intended only for more important and difficult cases when the Class A technique is unlikely to reveal the defects sought. It generally requires longer exposure times.

4 GENERAL

4.1 Protection

Exposure of any part of the human body to X-rays can be highly injurious to health. It is therefore essential that, wherever X-ray equipment is 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 are those in force in each country [2].

4.2 Surface preparation

In general, surface preparation may not be necessary for radiography, but where surface irregularities might cause

1) Besides its conventional meaning, the word "pipe" used in this text should be understood to cover other cylindrical bodies such as tubes, penstocks, pressure vessels, etc.

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

difficulty in detecting internal defects, these irregularities should be removed.

4.3 Location of the weld in the radiograph

Markers designating the weld limits, usually in the form of lead arrows or other symbols, should be placed alongside the weld on each side of it, in such a way that they are visible on the radiograph. This may not be necessary if the reinforcement is retained.

4.4 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.

4.5 Marking

In general, permanent markings on the workpiece 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 undesirable, other suitable means for re-locating the radiographs should be sought. This may be done by paint marks or by accurate sketches.

4.6 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. The overlap of film should not exceed 20 mm.

4.7 Image quality indicators (I.Q.I.)

An I.Q.I., of a type specified in ISO/R 1027 and agreed between the contracting parties, should be placed at one or each end of every section 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 on the side furthest from the film 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 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 use of recommended I.Q.I.s see ISO 2504.

The sensitivity values required from the 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.

5 RECOMMENDED TECHNIQUES FOR TAKING RADIOGRAPHS

5.1 Setting up of the films and source of radiation

5.1.1 *Flat workpieces*

For these pieces there is no difficulty, the underside of the workpiece being always accessible; the method illustrated in Figure 1 can be used.

5.1.2 *Cylindrical workpieces (longitudinal and circumferential welds)*

One of the following techniques should be used, depending on the size and accessibility of the joints.

NOTE – Whenever possible, in particular when a large part of the X-ray beam is used for covering the area to be irradiated, it is recommended to set up the X-ray tube 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.

I Film inside, source of radiation outside (see Figure 2)

The X-ray source is placed outside, the axis of the beam being perpendicular to the tangent of the circumference at the point where the axis strikes the workpiece.

The film is placed inside, against the surface, its centre corresponding with the axis of the beam of radiation.

This technique should be used for large cylindrical bodies, whereas the limitation (see 5.7) of maximum area to be examined permits the use of long films while keeping the focus-to-film distance within reasonable limits.

II Film outside, source of radiation inside (see Figure 3)

The X-ray source is placed inside and, for circumferential welds, with the focus situated in the centre of the hollow body. The film is outside, its centre corresponding with the axis of the X-ray beam.

When applicable, this technique is considered as the most convenient, because the different parts of the film are situated at the same distance from the source, thus enabling uniform density to be obtained and avoiding any restriction as regards the area examined. For larger bodies conventional X-ray equipment may be used but for smaller ones hollow anode X-ray tubes are necessary.

III Film and source of radiation outside. Double wall, double image (see Figure 4)[1)]

The source is placed outside and, for circumferential welds, the axis of the beam is inclined to the surface containing the weld. The source-to-film distance is chosen in such a way, in respect to the dimension of the hollow body, as to obtain two images on the film placed on the surface opposite to that facing the source of radiation.

This technique is used for cylindrical bodies, the interior of which is inaccessible, having diameters not exceeding 100 mm, 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 (see Figure 5)[1)]

The source is placed outside and, for circumferential welds, the axis of the beam is slightly inclined with respect to the surface containing the weld. The distance from source to the wall of the piece facing it is chosen in such a way, in respect to the dimensions of the hollow body, as to obtain only a single image on the film placed on the surface opposite to that facing the source of radiation.

This technique will give the best results for cylindrical bodies, the interior of which is inaccessible, having diameters larger than 100 mm. It can be used for bodies with diameters up to about 900 mm beyond which the source-to-film distance becomes too great.

5.2 Films and screens[2)]

The films used should be of the direct type and should meet the following conditions :

- for Class A, medium speed films;
- for Class B, fine-grain high-contrast films.

In general it is not necessary to use intensifying screens, except where it is desired to reduce the effects of scattered radiation. Lead screens may then be used. These screens should have thicknesses of 0.1 mm for the front screen and 0.16 mm for the back screen.

With voltages above 100 kV the exposure time can be slightly reduced by using only a lead back screen, or by using also a very thin front screen (0.02 mm).

5.3 Cassettes

For small thicknesses, when the absorption of the faces of the cassette is likely to be too great, the film should be used in an envelope of which the radiographic image is uniform and has no pattern.

If cassettes, whether metallic or not, are used, preliminary tests should be carried out to check that the faces do not cause a decrease in sensitivity for the thickness examined.

If lead screens are used, rigid cassettes are preferable to ensure a satisfactory film-to-screen contact. Flexible cassettes may however be used, provided that precautions are taken to ensure good film-to-screen contact.

With curved surfaces, 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, it is preferable to use flexible cassettes, provided that adequate precautions are taken to ensure a good overall film-to-screen contact.

5.4 Alignment of radiation beam

The radiation beam should be directed to the middle of the section under examination, and should be normal to the surface at that point except when specially seeking defects which it is known are best revealed by a different alignment of the beam; such defects 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, (see Figure 4), an inclination of the beam just sufficient to prevent a superimposition of the two images should be adopted. This inclination will depend on the diameter of the cylindrical body, on its wall thickness and on the width of the weld.

b) when using the double wall, single image technique, (see Figure 5) an inclination of the radiation beam should also be adopted. However 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 X-ray beam should be such that this 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

1) This method does not give such good sensitivity.

2) The definitions of the types of recommended films (direct type, fine-grain, high-contrast, etc.) correspond to the conventional descriptions of sensitive material. The figures for thickness of lead screens are intended only for guidance.

fine cracks in the first run being revealed, it is suggested that, where the diameter of the cylindrical body permits it, the beam should be normal to the weld, not inclined, and centred in the plane of the weld.

5.5 Interception of unwanted and scattered radiations

The film should be shielded from all back scattered radiation by an adequate thickness of lead, at least 1.6 mm, placed behind the film-screen combination.

Moreover, in order to reduce the effect of radiation scattered by the workpiece, 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.

5.6 Focus-to-film distance

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

The minimum focus-to-film distance f_{min} depends on the effective dimensions d[1)] of the focal spot and on the distance b between the film and the surface of the specimen facing the X-ray tube.

The resulting geometric unsharpness u should be calculated from the formula

$$u = \frac{b \times d}{f_{min}} \; *$$

It should not exceed the value of 0.12 mm in the cases of both Classes A and B.

For flat workpieces, when using the technique given in 5.1.1, and for cylindrical workpieces when using techniques I and II, the minimum focus-to-film distance should be calculated directly from the conventional formula : if the film is maintained in close contact with the surface, the distance b is practically identical with the thickness of the weld being inspected.

For cylindrical workpieces, when using technique III it is necessary to introduce in the formula for b the external diameter of the pipe instead of its wall thickness.

In the following table approximate minimum focus-to-film distances are given as multiples of the external diameter for different focal spot sizes.

TABLE – **Minimum focus-to-film distances (f_{min})**
(Geometric unsharpness, u, = 0.12 mm for both Classes A and B)

Focal spot, mm	2	3	4
f_{min} (expressed as a multiple of the diameter of the pipe examined)	18	26	34

For cylindrical workpieces when using technique IV, the minimum focus-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 target and X-ray outlet port is not less than the minimum focus-to-film distance required, there are no objections to putting the X-ray equipment in close contact with the pipe.

5.7 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 and that at the extremities of the exposed area, measured in the direction of the beam incident at these points. The difference in density resulting from this variation of thickness and recorded on the film should not exceed the admissible limits specified in 5.8.

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.

5.8 Density of radiographs

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 :

- Class A : 1.7 to 3.0
- Class B : 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.

In order to avoid unduly high fog densities arising from ageing of the film, development time or temperature, the fog density should be checked from time to time on a

1) 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 dimension of the focal spot, see the document prepared by the International Institute of Welding, entitled I.I.S – I.I.W. 183-65, *Recommendation for the determination of focal spot size of X-ray tubes.*

* This is an approximation for the correct formula : $u = \frac{b \times d}{f_{min} - b}$

non-exposed sample taken from the film used and handled and processed under the same conditions as the actual radiographs. The fog density should not exceed 0.3.

5.9 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·min for Class A and not less than 15 mA·min for Class B, for a focus-to-film distance of about 760 mm; the time should in no case be less than 1 min.

Furthermore, to prevent loss of image contrast due to an excessively large inherent filtration of the X-ray beam due to a tube with a thick window, for small thicknesses of specimen, an X-ray tube with a beryllium window should generally be used.

5.10 Processing

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

5.11 Viewing

The radiographs should be examined in a darkened room on an illuminated diffusing screen, the illuminated area of which 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 radiograph.

6 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) the type of X-ray equipment, tube voltage and current;

b) the time of exposure, the type of film and screen, the type of I.Q.I. and the focus-to-film distance;

c) the system of marking used.

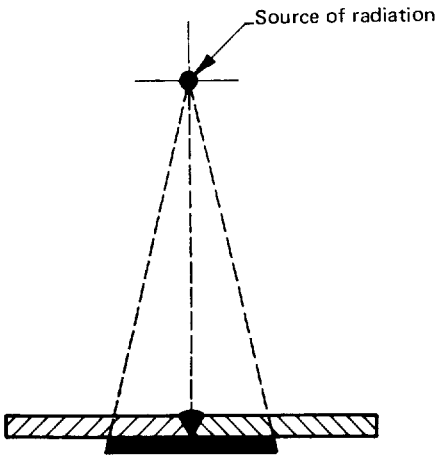

FIGURE 1 — **Arrangement for flat workpiece**

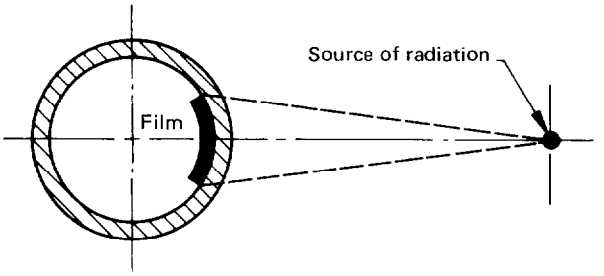

FIGURE 2 — **Film inside, source of radiation outside**

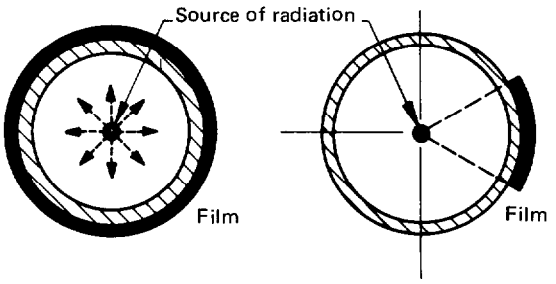

FIGURE 3 — **Film outside, source of radiation inside**

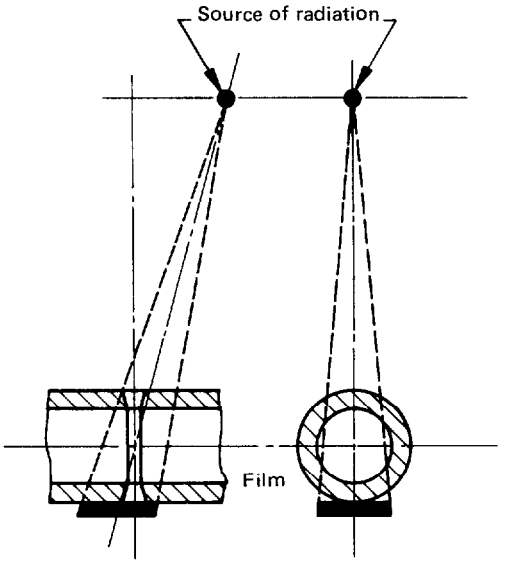

FIGURE 4 — **Film and source of radiation outside — Double wall, double image**

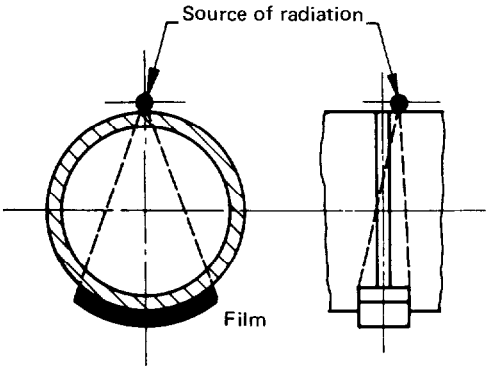

FIGURE 5 — **Film and source of radiation outside — Double wall, single image**