International Standard 1106/2

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Recommended practice for radiographic examination of fusion welded joints — Part 2 : Fusion welded butt joints in steel plates thicker than 50 mm and up to and including 200 mm in thickness

Pratiques recommandées pour l'examen radiographique de joints soudés par fusion — Partie 2 : Joints soudés bout à bout par fusion de tôles d'acier d'épaisseur supérieure à 50 mm *mais inférieure ou égale à* 200 mm

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established 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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1106/2 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, as a replacement for ISO 2405-1972 with editorial amendments of minor importance. A revision of ISO 1106/2 taking into account International Standards prepared by ISO/TC 135, *Non-destructive testing*, (for example, ISO 5579, *Non-destructive testing — Radiographic examination of metallic materials by X- and gamma rays — Basic rules*) will be considered in the future programme of work of ISO/TC 44.

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Recommended practice for radiographic examination of fusion welded joints — Part 2 : Fusion welded butt joints in steel plates thicker than 50 mm and up to and including 200 mm in thickness

0 Introduction

The radiographic techniques suitable for examination of fusion butt welds in steel plates less than or equal to 50 mm thick are described in ISO 1 /1. This part of ISO 1106 is arranged on similar lines to cover welds in plate thicknesses greater than 50 mm and up to and including 200 mm.

This part of ISO 1106 should have the effect of ensuring more unified practice and thus simplify the interpretation of radiographs. It does not lay down standards of acceptance for the welds.

There is only a limited number of types of equipment suitable for this work (for example there are no commercial X-ray sets operating between 400 and 1 000 kV). The available equipment has been arranged into a number of groups and techniques have been detailed which are suitable for the production of satisfactory radiographs from the equipment in each group. Many clauses in the recommended practice are common to all the techniques.

The steel thickness for which each type of equipment is considered to be suitable is given in table 1; it is possible to use betatrons and linear accelerators for greater thicknesses.

The figure indicates the relative performance of the various types of equipment in terms of IQI sensitivity, using the techniques described. These values of sensitivity are not mandatory, but are given as a guide for choosing a technique for a particular weld thickness.

Explanatory notes are included, as necessary.

1 Scope

This part of ISO 1106 specifies general techniques of weld radiography with the object of enabling satisfactory results to be obtained economically. The techniques are based on generally accepted practice and the fundamental theory of the subject.

2 Field of application

This part of ISO 1106 applies to the radiographic examination of fusion welded joints for steel plates thicker than 50 mm and up to and including 200 mm in thickness.

It does not lay down radiographic criteria of acceptance for the joints, but is concerned with the radiographic techniques to be used.

3 References

ISO 1027, *Radiographic image quality indicators for non-destructive testing — Principles and identification.*

ISO 1106/1, *Recommended practice for radiographic examination of fusion welded joints — Part 1 : Fusion welded butt joints in steel plates up to* 50 mm *thick.*

ISO 2504, *Radiography of welds and viewing conditions for films — Utilization of recommended patterns of image quality indicators (IQI).*

ISO 5576, *Industrial radiology — Non-destructive testing — Vocabulary.*[1)]

IRCP Publication 9, *Recommendations of the International Commission on Radiological Protection.*

4 Definitions

For the purpose of this part of ISO 1106, the definitions given in ISO 5576 apply.

5 General

5.1 Protection against ionizing radiations

WARNING — Exposure of any part of the human body to X-rays or γ-rays can be highly injurious to health. Wherever X-ray equipment or radioactive sources are in use, adequate precautions shall be taken to protect the radiographer and any other person in the vicinity.

1) At present at the stage of draft. (Revision of Appendix-1969 to ISO/R 947, ISO/R 1027 and ISO/R 1106.)

Local or national safety precautions at present in force against X- and γ-rays shall be strictly observed.

In default of such regulations, reference shall be made to IRCP Publication 9.

5.2 Equipment

Table 1 shows the types of equipment which are at present known to be commercially available and indicates the steel thicknesses (within the range covered by this part of ISO 1106) for which the equipment is considered to be suitable for butt weld inspection.

Table 1 — Types of equipment and steel thicknesses

Group	Description of equipment	Range of useful thickness e mm
A	X-rays : up to 400 kV	$50 < e \leqslant 85$
B(I)	X-rays : 1 and 2 MV, focus > 6 mm	$50 < e \leqslant 125$[1]
B(II)	X-rays : 1 and 2 MV, focus < 1 mm	$50 < e \leqslant 125$[1]
C	X-rays : linear accelerators 3 to 8 MV	70[2] $\leqslant e \leqslant 200$
D	X-rays : betatrons and linear accelerators, 8 to 35 MV	70[2] $\leqslant e \leqslant 200$
E	γ-rays : cobalt-60	$50 < e \leqslant 150$[3]
F	γ-rays : iridium-192	$50 < e \leqslant 110$[3]

1) For 2 MV equipment, the maximum thickness can be extended to 200 mm.

2) This thickness may be reduced to 60 mm if very fine-grain films are used and a density of 3 is reached.

3) In the case of groups E and F, parts having a thickness close to the upper end of the thickness range can only be radiographed with either very high strength sources or very long exposure times.

5.3 Surface preparation

In order to simplify interpretation of the radiographs, it is advisable to remove surface irregularities before taking radiographs. In general, surface preparation is not necessary for radiography, but where surface irregularities might cause difficulty in detecting internal defects, the surface should be ground smooth.

5.4 Location of the weld in the radiograph

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

5.5 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.

5.6 Marking

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

5.7 Overlap of films

When radiographing a continuous length of weld with separate films, the separate films should overlap by at least 10 mm to ensure that no portion of the weld length remains unexamined. The overlap of the film should not exceed 20 mm.

5.8 Image quality indicator

An image quality indicator (IQI) of mild steel, of a type specified in ISO 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 IQI be placed on the film side. If this has to be done, it should be mentioned in the recording of technical data, as the IQI indication does not have the same meaning when the IQI is placed in this position. For details of use of recommended IQI's, see ISO 2504.

The sensitivity values required from IQI's 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 Films

6.1.1 With equipment in groups A, B, E and F, the film used should be one of the types known as medium-speed, fine-grain or very fine-grain X-ray film. These films are usually described as "direct type", for use with metal intensifying screens, or as "non-screen" film.

6.1.2 With equipment in groups C and D, the film should be of the fine-grain or very fine-grain, direct type. Medium-speed film is not normally necessary.

6.2 Intensifying screens

The film should be used in a type of X-ray cassette which ensures very good contact between the intensifying screens (or screen) and the film emulsion.

NOTE — With thick screens, conventional cassettes are not always satisfactory from this point of view and vacuum-type cassettes can be used with advantage.

The screen thicknesses and materials should be as follows :

Group A :

Lead foil screens : front — 0,02 to 0,1 mm;
: back — 0,02 to 0,1 mm.

Group B :

Lead foil screens : front — 0,2 to 1,0 mm;
: back — 0,5 to 1,6 mm.

Group C :

Copper or lead screens : front — 1,0 to 1,6 mm;
: back — 1,0 to 1,6 mm.

Group D :

Tantalum, tungsten or lead screens : front — 1,0 to 1,6 mm;
: back — none.

NOTE — Screens of tantalum or tungsten give better sensitivity.

Group E :

Copper or lead screens : front — 0,2 to 1,0 mm;
: back — 0,1 to 0,5 mm.

NOTE — In place of copper or copper base alloy screens, it is possible to use screens of other materials of low atomic number and high specific density (Ni, Zn and their alloys).

Group F :

Lead foil screens : front — 0,05 to 0,2 mm;
: back — 0,05 to 0,2 mm.

6.3 Filters

When γ-ray sources are used, i.e. equipment in groups E and F, a filter may be placed between the specimen and cassette. This filter should be of lead 1,0 mm thick with iridium-192 (^{192}Ir) sources and 2,0 mm thick with cobalt-60 (^{60}Co) sources.

6.4 Alignment of beam

The beam of radiation should be directed to the middle of the section of the weld under examination and should be normal to the plate surface at that point, except in special examinations for certain defects, for example, lack of side-wall fusion, when it is known that these can best be detected by a different alignment of the beam.

6.5 Interception of scattered radiation

The film cassette should be shielded as thoroughly as possible from all back-scattered radiation by means of an adequate thickness of lead placed in or behind the cassette.

With equipment in groups A, B, E and F, the minimum desirable thickness of lead is about 2,5 mm.

In order to minimize the unwanted effect of the scattered radiation from the workpiece and from its surroundings, masking should be used whenever possible to limit the area irradiated to the size of the film and edge blocking should also be used if the end of the weld, or any large section-change, is within the radiation field.

6.6 Focus-to-film distance/source-to-film distance (f.f.d./s.f.d.)

Two separate considerations arise. With equipment in groups A, B, E and F, the f.f.d. (or s.f.d.) is determined from the focal spot or source size, in terms of unsharpness and an economical exposure-time.

With equipment in groups C and D, the radiation field is usually restricted in size and the f.f.d. is chosen in terms of a useful field size (length of weld covered per exposure).

Table 2 shows minimum values of f.f.d. and s.f.d. based on these criteria for a number of specimen thicknesses. Intermediate values can be interpolated for other specimen thicknesses but the exact value of f.f.d. is not critical to that extent.

Table 2 — Minimum focus-to-film (source-to-film) distances

Equipment group	Minimum focus-to-film distance (or s.f.d.) in mm					See Notes
	Specimen thickness, mm					
	50	75	100	150	200	
A	1 000	1 250	—	—	—	1
B (I)	1 500	1 800	2 000	3 000	3 800	
B (II)	1 000	1 000	1 000	1 250	1 500	
C	—	1 000	1 500	1 500	1 500	2 and 3
D	—	—	—	—	—	4
E	500	650	750	900	—	5
F	750	900	1 000	—	—	5

NOTES

1 These values are based on a focus size of 5 mm; if the focus is of a different size, the f.f.d. should be adjusted in direct proportion.

2 These values are based on a focus size of 2 mm or less.

3 If a large field coverage is required, these values may have to be increased, irrespective of the focus size, dependent on the amount of beam-flattening which the equipment utilizes.

4 The s.f.d. to be used should be chosen with regard to the length of the weld to be radiographed in one exposure and the beam-flattening of the equipment.

5 These values are based on a source diameter of 4 mm; for other sizes they should be adjusted in direct proportion, with a minimum value of 250 mm s.f.d.

6.7 Specimen-to-film distance

Some equipment in groups B (II) and D can have focus sizes less than 0,5 mm. With such equipment projective magnification techniques are practicable and the cassette may then be placed away from the specimen. This will result in improved

sensitivity, but the length of weld covered on each radiograph will be smaller. Typical values of projective magnification are between 2 : 1 and 3 : 1. Such techniques should only be necessary for special applications.

With all other equipment, the film cassette should be placed near to the specimen. If there are considerable sudden changes of thickness in the weld, a small distance of about 10 mm between film and specimen can be recommended in order to eliminate to a certain extent the disadvantageous inhomogeneities of scattered radiation. If it is necessary for the cassette to be a greater distance from the specimen, the minimum f.f.d. values given in 6.6 should be increased.

6.8 Film density

In the image of the weld under examination, the film density corresponding to sound metal should not be less than 2,0 and not greater than 3,0; these values are inclusive of the fog density which should not be greater than 0,3.

There is no objection to having film densities higher than 3,0 if satisfactory film viewing conditions can be provided[1].

6.9 Processing

Films should be processed in accordance with the manufacturer's instructions. 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.

6.10 Sensitivity and film viewing

The radiographs should be examined and the IQI sensitivity calculated in accordance with ISO 2504. The following should be noted in particular :

The IQI sensitivity required should be mutually agreed between the contracting parties but the figure gives an indication of the values which should be expected. These values are not intended to be mandatory, but if the values obtained are not similar to these values, it is an indication that the technique is not being correctly applied.

The radiograph should be examined on an illuminated diffusing screen (viewing box) in a darkened room and the illuminated area should be masked to the minimum required for viewing the radiographic image. The brightness of the screen should be adjustable so as to allow satisfactory reading of the radiographs[1].

7 Test report

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

The test report shall include at least the following information :

a) type of X-ray equipment, the voltage applied and the anodic current intensity (if applicable);

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

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

d) system of marking used;

e) processing technique;

f) weld geometry, wall thickness and welding process used;

g) the radiograph geometry showing the position of the focus and of the film (sketch);

h) the IQI used and the quality of the image obtained in accordance with ISO 2504;

j) results of interpretation;

k) any deviation, by agreement or otherwise, from the procedures specified;

m) the date of the examination and the endorsement by the inspector.

1) See ISO 2504.