

Australian Standard[®]

**Non-destructive testing—
Radiography of welded butt joints
in metal**

Part 1: Methods of test

This Australian Standard was prepared by Committee MT/7, Non-destructive Testing of Metals and Materials. It was approved on behalf of the Council of Standards Australia on 14 June 1994 and published on 22 August 1994.

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Australian Institute for Non-Destructive Testing
Australian Nuclear Science and Technology Organization
Australian Pipeline Industry Association
AUSTROADS
Bureau of Steel Manufacturers of Australia
Department of Defence
Electricity Supply Association of Australia
Metal Trades Industry Association of Australia
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Non-destructive testing service organizations
Royal Melbourne Institute of Technology

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Part 1: Methods of test

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PREFACE

This Standard was prepared by the Standards Australia Committee on Non-destructive Testing of Metals and Materials to supersede AS 2177.1—1981, *Radiography of welded butt joints in metal, Part 1: Methods of test*.

The second Standard in the series is AS 2177.2—1982, *Radiography of welded butt joints in metal, Part 2: Image quality indicators (IQI) and recommendations for their use*.

In this edition, cognizance was taken of the following International Standard during the revision of the clauses on gamma-ray sources, radiographic density and film coverage:

ISO 1106/3 Recommended practice for radiographic examination of fusion welded joints—Part 3: Fusion welded circumferential joints in steel pipes of up to 50 mm wall thickness.

This edition also contains a new Appendix which gives guidance on the use of the Standard.

This Standard does not cover methods which employ non-film imaging techniques. These techniques will be considered at the next revision of the Standard. The use of non-film imaging techniques for the radiographic examination of welded joints is now permitted by the ASME Boiler and Pressure Vessel Code.

The term ‘informative’ has been used in this Standard to define the application of the appendices. An ‘informative’ appendix is not an integral part of a Standard and is included for information and guidance only.

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FOREWORD

In the methods described in this Standard, the photographic film is generally placed parallel to and in contact with one surface of the weld. The source of ionizing radiation is located on the remote side of the weld and at a calculated distance from it. For hollow products the radiation may be required to penetrate both walls of the product.

Radiographic sensitivity is affected by parameters which include radiation energy (kilovolt or isotope spectrum), the film/screen combination, scattered radiation control, and exposure geometry (source-to-film distance and effective source size). Although the highest radiographic sensitivity is usually achieved using X-rays, their use is limited by the thickness of the workpiece.

For the radiography of hollow components, either single-wall or double-wall methods are used. Although the radiographic sensitivity obtained when using single-wall methods is generally superior to that obtained when using double-wall methods, other factors such as diameter, thickness and accessibility may influence the choice of method.

STANDARDS AUSTRALIA

Australian Standard

Non-destructive testing—Radiography of welded butt joints in metal

Part 1: Methods of test

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out methods and requirements for X-ray and gamma-ray radiographic testing of welded butt joints in metal products. It does not cover neutron radiography and does not specify the permissible defect levels used for the acceptance/rejection criteria of welds. The individual methods of test and the permissible defect levels should be specified in the relevant product or application Standard.

NOTES:

- 1 Advice and recommendations on information to be supplied by the purchaser at the time of enquiry or order are contained in Appendix A.
- 2 Guidance and general information which should assist the users of this Standard is contained in Appendix B.

1.2 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

- 1929 Non-destructive testing—Glossary of terms
2177 Radiography of welded butt joints in metal
2177.2 Part 2: Image quality indicators (IQI) and recommendations for their use
2243 Safety in laboratories
2243.4 Part 4: Ionizing radiations
3669 Non-destructive testing—Qualification and registration of personnel—Aerospace
3998 Non-destructive testing—Qualification and certification of personnel—General engineering
Z5 Glossary of metal welding terms and definitions
Z5.2 Part 2: Terminology of and abbreviations for fusion weld imperfections as revealed by radiography.

BS

- 1384 Photographic density measurements

ASTM

- E 1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging

1.3 DEFINITIONS For the purpose of this Standard, the terms and definitions given in AS 1929 apply.

1.4 TEST METHOD DESIGNATION Radiographic methods are designated in the following manner:

- (a) By prefix letters 'XR' or 'GR' to identify the radiation source, i.e. X-ray or gamma-ray.

- (b) By a number 1, 2 or 3 to indicate the film type, as follows:
 - (i) Type 1: Very fine grain, very high contrast, low speed.
 - (ii) Type 2: Fine grain, high contrast, medium speed.
 - (iii) Type 3: Medium grain, medium contrast, high speed.
- (c) By a solidus (/) followed by one or two letters to indicate whether testing is required through a single plate or wall (S), or through a double wall (DW), and in the latter case, by the addition of another letter to indicate whether a single image of the weld (S) or a double image of the weld (D) is required.

Examples of designation: XR1/S, XR2/DWS, GR3/DWD.

1.5 SAFETY PRECAUTIONS Prolonged exposure of any part of the human body to ionizing radiation can be injurious. Adequate precautions shall be taken to protect testing personnel and any other persons in the vicinity, when X-ray equipment or radioactive sources are being used.

NOTE: The use of radioactive substances and irradiating apparatus is controlled by various statutory regulations. Reference should be made to the 'Code of Practice for the Safe Use of Industrial Radiography Equipment (1989)—Radiation Health Series No 31', issued by the National Health and Medical Research Council.

Reference should also be made to AS 2243.4 for ionizing radiation safety precautions.

1.6 QUALIFICATION OF PERSONNEL Personnel who perform radiographic testing to this Standard should have recognized qualifications in the specific area of test.

NOTE: The Australian Standards for personnel qualification are AS 3669 and AS 3998.

SECTION 2 EQUIPMENT AND ACCESSORIES

2.1 GENERAL The radiographic testing system shall be capable of detecting and delineating the boundaries and contours of discontinuities likely to be present in welds, and of producing radiographs with satisfactory image quality.

2.2 X-RAY EQUIPMENT The X-ray equipment shall be capable of testing the particular metal or alloy concerned. For the testing of steel of thickness up to 75 mm, X-ray equipment capable of operating at voltages up to 400 kV is required. For steel thicknesses above 75 mm, high voltage equipment capable of operating up to the mega-electronvolt (MeV) range is required. The focal spot (source) size should be known for the calculation of geometric unsharpness (see Appendix B).

2.3 GAMMA-RAY SOURCES Gamma-ray sources should not be used for the radiography of steel welds having thicknesses below the limits given in Table 2.1.

NOTE: As a general guide, methods using gamma-rays are usually less sensitive than methods using X-rays and should be limited to applications where the shape, thickness or accessibility of the welds makes X-ray examination impracticable.

TABLE 2.1
RECOMMENDED GAMMA-RAY SOURCES AND
STEEL THICKNESS RANGES

Gamma-ray source		Minimum thickness of steel, mm	
Radioisotope	Symbol	For high sensitivity (Method GR1— see Table 3.1)	For normal sensitivity (Methods GR2 and GR3—see Table 3.1)
Cobalt-60	⁶⁰ Co	60 (40)	40 (30)
Iridium-192	¹⁹² Ir	40 (10)	20 (5)
Ytterbium-169	¹⁶⁹ Yb	8	6

NOTE: In certain cases, it may be permitted to use gamma-ray sources for lesser thicknesses than those given, when X-ray equipment cannot be used on account of unfavourable geometry, e.g. single-wall exposures of tubes of small diameter using the source inside and the film placed outside of the tube, or if the use of gamma-rays makes a more suitable radiation beam direction possible. The lesser thicknesses applicable for these special cases are shown in brackets (see also Paragraph B2 of Appendix B).

2.4 INTENSIFYING SCREENS

2.4.1 General Metal intensifying screens reduce scattered radiation, improve definition and reduce exposure time. Screens shall not contain defects such as dents, creases, scratches and contamination by dirt and grease which may produce spurious images on the radiographic film.

Fluorometallic screen/film combinations may be used where it can be demonstrated that the required image quality indicator (IQI) sensitivity can be achieved.

NOTES:

- 1 When cleaning screens, foreign material such as grease and lint should be removed with care from the surface, to prevent damage.

- 2 The use of fluorescent screens is not recommended because of their inherent unsharpness factor, which may prevent achievement of the required sensitivity.
- 3 Rolls of paper-backed film supplied in commercial packs with integrated metal intensifying screens may be used provided the lead screen thickness complies with Table 2.2.

2.4.2 Thickness of intensifying screens The thickness of metal intensifying screens shall be in accordance with the requirements of Table 2.2. The use of screens of minimum thickness may result in loss of image quality.

TABLE 2.2
REQUIREMENTS FOR USE OF METALLIC
INTENSIFYING SCREENS

Radiation source	X-radiation potential (kV), or isotope type	Screen material	Minimum front screen thickness mm	Minimum back screen thickness mm
X-ray	≤120	Lead	Not required	Not required
	>120 ≤400	Lead	0.02	0.02
Gamma-ray	¹⁶⁹ Yb	Lead	0.02	0.02
	¹⁹² Ir	Lead	0.02	0.02
	⁶⁰ Co	Lead	0.2	0.2
	⁶⁰ Co	Steel or copper	0.2	0.2

2.5 CASSETTES Cassettes shall be light-tight and constructed of a material which will not interfere with the quality or sensitivity of the radiographs. Adequate precautions are required to ensure good film-to-screen contact within the cassette.

2.6 FILTERS Filters are uniform layers of material, usually of higher atomic number than the test piece (test object), used to absorb softer radiation preferentially. Their use is recommended when it can be shown that they produce improvements in radiographic quality. They are used in the following two ways:

- (a) At the source of radiation to absorb the softer components of primary radiation and thus improve image quality.
- (b) Between the test piece and the radiographic film to absorb scattered radiation from the test piece.

2.7 IMAGE QUALITY INDICATORS Image quality indicators (IQI) shall be used as a means of assessing the image quality of the radiograph. The IQI shall have the same or lower attenuation characteristics as the metal under test (see AS 2177.2), and shall be one of the following types:

- (a) *Wire-type (W)* Wire IQIs comprise wires of steel, aluminium, copper or magnesium of different diameters set in a flexible mount.
- (b) *Step-hole type (SH)* Step-hole IQIs are manufactured from various metals and contain steps perforated with holes, the diameters of which are related to step thickness.
- (c) *Plaque-hole type (PH)* Plaque-hole IQIs are manufactured from various metal alloys and consist of a single thickness plaque perforated with holes, the diameters of which are related to the plaque thickness.

The IQI and sensitivity requirements shall be those which are specified in the relevant product or application Standard.

Where a separate indication of contrast is required when using a wire IQI, it is recommended that a step wedge or similar contrast indicator be used. For high-sensitivity radiography using gamma-rays, the contrast should be assessed with a plaque-hole IQI, a step-hole IQI or a contrast meter.

Requirements for IQI are specified in AS 2177.2.

NOTE: The IQI sensitivity is a means of assessing radiographic quality but not a measure of detectable discontinuity size.

2.8 FILMS This Standard categorizes X-ray films into 3 types (see Clause 1.4). All X-ray films shall be free from mechanical, chemical or other blemishes which may mask or be confused with the image of any discontinuities in the test area.

2.9 FILM PROCESSING FACILITIES

2.9.1 General Film processing facilities shall be capable of producing radiographs which meet the quality requirements specified in Clause 3.13.

2.9.2 Automatic processing Where an automatic film processor is used to process exposed X-ray film, it is essential that the processor is installed, maintained and controlled in accordance with the manufacturer's instructions to ensure consistency and quality of processing. It is important that film characteristics be compatible with processing solutions and conditions.

2.9.3 Manual processing Manual film processing requires the use of a properly designed, maintained, controlled and monitored processing facility.

2.10 VIEWING FACILITIES Provision shall be made for the examination of radiographs by diffused light in a darkened room. The illuminated area of the viewing screen shall be equipped with masks to exclude any extraneous light from the eyes of the viewer when viewing radiographs smaller than the screen, or to cover low density areas within a radiograph.

The brightness of an illuminated radiograph shall be not less than 30 cd/m² and shall be preferably greater than 100 cd/m². To achieve the minimum value of 30 cd/m², the minimum brightness of the illuminator for the acceptable viewing of a range of radiographic densities shall be in accordance with Table 2.3.

TABLE 2.3
FILM DENSITY/ILLUMINATOR
BRIGHTNESS RELATIONSHIP

Density of radiograph	Minimum illuminator brightness
	cd/m ²
1.5	1 000
2.0	3 000
2.5	10 000
3.0	30 000
3.5	100 000

SECTION 3 TEST METHOD REQUIREMENTS

3.1 GENERAL Details of the radiographic methods specified in this Standard for welded steel butt joints in metal products and advice on their application are given in Table 3.1.

Table 3.2 lists the wire IQI sensitivities which should be achievable for various weld metal thicknesses in steel, when using the test methods specified in Table 3.1.

The method to be used, the required sensitivity and other parameters to be achieved should be specified in the relevant product or application Standard.

3.2 SURFACE PREPARATION The presence of surface features such as weld ripples can mask the radiographic images of discontinuities and thus interfere with the interpretation of radiographs.

If uncertainties in the interpretation of a radiograph arise, the weld reinforcement should be dressed to remove any surface irregularities. If after dressing, visual inspection and testing by other appropriate non-destructive testing methods, the weld is considered to be satisfactory, no additional radiograph need be taken. If any uncertainties remain, another radiograph shall be taken. In either case, the actions taken shall be recorded.

NOTE: For method XR1 (see Table 3.1), where the highest level of discontinuity detection is required, it may be necessary to dress the weld reinforcement to such a degree that resulting radiographic images due to surface irregularities cannot mask or be confused with the image of any discontinuity.

Backing strips used during the welding process and not forming part of the finished product shall be removed prior to radiographic testing.

3.3 PLACEMENT OF IMAGE QUALITY INDICATORS The following requirements apply for the location of image quality indicators:

- (a) Plaque-hole or step-hole IQIs shall be placed adjacent to the weld at one or both ends of each section to be radiographed.
- (b) Wire IQIs shall be placed transversely across all welds at one or both ends of each section to be radiographed. In certain circumstances it may be necessary to offset the IQI.
- (c) The entire IQI shall be placed in intimate contact with the surface facing the source of radiation, with the thinnest element more remote from the central beam.
- (d) Where the surface facing the source of radiation is inaccessible, the IQI may be placed on the film side of the workpiece in a position specified by the product or application Standard. If not so specified, one of the following methods may be used to determine the required film-side IQI sensitivity:
 - (i) *Method A* Make an exposure on a representative sample with the required source-side IQI in place, and a thinner IQI element in place on the film side. Provided that the required sensitivity is achieved by the IQI on the source side, the first discernible IQI element on the film side shall be used as the sensitivity requirement.
 - (ii) *Method B* For double-wall, double-image exposures of pipe with an outside diameter equal to or less than 90 mm, choose the IQI for single-wall thickness and place it on the source side.
- (e) If the IQI is placed on the film side (see Item (d)), a lead marker in the form of the letter 'F' shall be positioned beside the film side IQI; this shall be stated in the report.