

Australian Standard™

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



This Australian Standard was prepared by Committee MT-007, Non-destructive Testing of Metals and Materials. It was approved on behalf of the Council of Standards Australia on 10 March 2006.
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Australian Railway Association
Australian Aerospace Non-Destructive Testing Committee
Australian Industry Group
Australian Institute for Non-Destructive Testing
Australian Nuclear Science & Technology Organisation
Australian Pipeline Industry Association
Bureau of Steel Manufacturers of Australia
Engineers Australia
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STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 2177—2006

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

RECONFIRMATION NOTICE

Technical Committee MT-007 has reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

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National Association of Testing Authorities Australia
New Zealand Non-Destructive Testing Association
TestSafe Australia
Welding Technology Institute of Australia
WorkSafe Victoria

NOTES

Australian Standard™

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

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PREFACE

This Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee MT-007, to supersede AS 2177.1—1994, *Non-destructive testing—Radiography of welded butt joints in metal, Part 1: Methods of test*. After consultation with shareholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this revision is to revise the methods, equipment and film types in this Standard.

During the drafting of this Standard the Committee decided that AS 2177.2—1982, *Radiography of welded butt joints in metal, Part 2: Image quality indicators (IQI) and recommendations for their use* should be revised so that it was applicable to metallic materials and not exclusively to welds. AS 2177.2 was redesignated as AS 2314.

During the public review process in the drafting of this Standard comments were received from Australian Industry about the need for an Australian Standard on computerized radiography which the Committee decided should be addressed in AS 2168.1 and AS 2168.2.

This Standard is one of a series of Standards covering the range of radiography. The series comprises the following:

AS

- | | |
|--------|--|
| 2168 | Non-destructive testing—Computerized radiography |
| 2168.1 | Part 1: Systems |
| 2168.2 | Part 2: Testing of metallic materials using X-rays and gamma rays |
| 2177 | Non-destructive testing—Radiography of welded butt joints in metal |
| 2314 | Radiography of metals—Image quality indicators (IQI) and recommendations for their use |

The term ‘informative’ has been used in this Standard to define the application of the appendix to which it applies. An ‘informative’ appendix is only for information and guidance.

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FOREWORD

In the methods described in this Standard, the radiographic 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

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies 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 are 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 |
| 2243 | Safety in laboratories |
| 2243.4 | Part 4: Ionizing radiations |
| 2314 | Radiography of metals—Image quality indicators (IQI) and recommendations for their use |
| 3669 | Non-destructive testing—Qualification and approval of personnel—Aerospace |
| 3998 | Non-destructive testing—Qualification and certification of personnel |
| 4749 | Non-destructive testing—Terminology of and abbreviations for fusion weld imperfections as revealed by radiography |

ISO

- | | |
|---------|---|
| 11699 | Non-destructive testing—Industrial radiographic films |
| 11699-1 | Part 1: Classification of film systems for industrial radiography |

ASTM

- | | |
|-------|--|
| E1165 | Standard test method for measurement of focal spots of industrial X-ray tubes by pinhole imaging |
| E1815 | Standard test method for classification of film systems for industrial radiography |

BS

- | | |
|------|-----------------------------------|
| 1384 | Photographic density measurements |
|------|-----------------------------------|

BS EN

- | | |
|-------|--|
| 584-1 | Non-destructive testing—Industrial radiographic film—Classification of film systems for industrial radiography |
|-------|--|

JIS

7627 Non-destructive testing—Industrial radiographic films, Part 1: Classification of film systems

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:

NOTE: Refer to Appendix D for image quality and film systems classes.

- (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—T2 or better as specified in ISO 11669-1.
 - (ii) Type 2
Fine grain, high contrast, medium speed—T3 or better as specified in ISO 11699-1.
 - (iii) Type 3
Medium grain, medium contrast, high speed—T4 or better as specified in ISO 11699-1.
- (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 are: XR1/S, XR2/DWS, GR3/DWD.

1.5 SAFETY PRECAUTIONS

Prolonged exposure of any part of the human body to ionizing radiation is hazardous to your health. 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 irradiation apparatus is controlled by various statutory regulations. Reference should be made to the Radiation Health Series No. 31 Code of Practice for the safe use of industrial radiographic equipment.

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

1.6 QUALIFICATIONS OF NON-DESTRUCTIVE EXAMINATION PERSONNEL

Radiographic examination, interpretation, evaluation for compliance, and reporting shall be made by personnel having qualifications and experience for their job function acceptable to the testing body, the manufacturer and where required by the purchaser.

Operators shall have the qualifications detailed below or shall carry out their duties under the supervision of persons responsible for the examination.

Qualifications acceptable for the examination of components include the following:

- (a) Certification by the Australian Institute for Non-Destructive Testing (AINDT) in accordance with AS 3998 or approval in accordance with AS 3669 in radiographic testing.
- (b) Equivalent qualifications.

1.7 VISION REQUIREMENTS

The personnel shall provide documented evidence of satisfactory vision in accordance with AS 3998 or AS 3669.

Subsequent to certification, the tests of visual acuity shall be carried out annually and be verified by the employer or the responsible agency.

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.

NOTE: See Figure B1.

2.3 GAMMA-RAY SOURCES

Gamma-ray sources shall 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-ray.

TABLE 2.1
ACHIEVABLE SENSITIVITY LEVELS FOR STEEL THICKNESS
USING GAMMA RAYS

Gamma-ray source		Thickness of steel, mm	
Radioisotope	Symbol	For high sensitivity	For normal sensitivity
Cobalt-60	⁶⁰ Co	60 to 150	40 to 200
Iridium-192	¹⁹² Ir	10 to 70	5 to 100
Selenium-75	⁷⁵ Se	14 to 40	10 to 40
Ytterbium-169	¹⁶⁹ Yb	2 to 12	1 to 15

NOTES:

- Where it can be proven by test exposure that either high or normal sensitivities can be achieved on steel thickness outside the thickness ranges indicated above the process may be used if in agreement by the principal. Likewise it may be possible that in some circumstances sensitivities indicated above may not be achieved in some circumstances.
- Figure B7 sensitivity chart should be used to ensure that the correct sensitivity levels are achieved and takes precedence over Table 2.1.

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, area of interest.

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	Not required	Not required	Not required
	$> 120 \leq 400$	Lead	0.02	0.02
Gamma-ray	^{169}Yb	Lead	0.02	0.02
	^{192}Ir	Lead	0.02	0.02
	^{75}Se	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 shall be applied 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 shall be used in the following ways:

- (a) At the source of radiation to absorb the softer components of primary radiation and thus improve image quality.
- (b) Behind and in intimate contact with the radiographic film to absorb side and back scatter radiation.

NOTE: Refer to Figure B3 for scatter reduction techniques.

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 2314), 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.

2.8 FILMS

This Standard categorizes radiographic films into 3 types (see Clause 1.4). All radiographic 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.

NOTE: Refer to Appendix D.

2.9 FILM PROCESSING FACILITIES

2.9.1 General

Film processing facilities shall be capable of producing radiographs (PMC strips) which meet the quality requirements specified in Clause 3.12.

NOTE: It is good practice to process PMC strips weekly and especially in hot climates. In very hot climates this frequency should be increased when temperatures exceed 35°C.

2.9.2 Automatic processing

Where an automatic film processor is used to process exposed radiographic film, the processor shall be installed, maintained and controlled in accordance with the manufacturer's instructions to ensure consistency and quality of processing.

NOTE: It is important that film characteristics be compatible with processing solutions and conditions, see Appendix D.

2.9.3 Manual processing

Manual film processing shall follow the film manufacturer's processing instructions, with the equipment being properly designed, maintained, controlled and monitored so that it will comply with these requirements.

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.

NOTE: 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 should be in accordance with Appendix E.

SECTION 3 TEST METHOD REQUIREMENTS

3.1 GENERAL

Details of the radiographic methods specified in this Standard for welded metal 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.

For the method to be used, the required sensitivity and other parameters to be achieved refer to the relevant product or application Standard.

3.2 SURFACE PREPARATION

The presence of surface features such as weld ripples and excess weld penetration 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 shall 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 or complimentary NDT method used to cross reference. 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 IMAGE QUALITY INDICATORS

3.3.1 Placement of IQI

The following requirements and options 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, as shown in Figure 3.4 and specified in AS 2314.
- (b) Wire IQIs shall be placed transversely across all welds at one or both ends of each section to be radiographed with the thinnest at the edge of the diagnostic film length see Figure 3.4. In certain circumstances it may be necessary to offset the IQI.
- (c) 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 so specified the following method may be used to determine the required film-side IQI sensitivity:

Method

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.

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.

- (d) 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.
Sensitivity shall be determined in accordance with Clause 3.3.2 based on a single wall thickness.
- (e) When radiographing a circumferential joint by means of a central source, using complete encirclement film, a minimum of three IQIs placed at equal intervals around the circumference shall be used, unless otherwise specified in the relevant product or application Standard.
- (f) If the weld reinforcement or backing strip has not been removed prior to radiography, a shim of material with absorbance equal to or greater than that of the material under test shall be placed under the IQI so that the total thickness under the IQI is approximately the same as the total thickness through the weld, including reinforcement or backing strip. To ensure that its image is readily identifiable in the radiograph, the shim shall be of larger area than the IQI and the sensitivity may be determined through the shim.
- (g) Wherever possible the IQI shall be apparent on the film. Where this is not possible it shall be reported in the record of test and test reports.
- (h) The entire IQI image shall be viewed without a mask concealing any part of the image, but the use of a mask to shade other areas is permitted.

3.3.2 Wire Type (W) Assessments

For a wire IQI laid across a metallic surface, the assessment is based on that part of the image of the IQI which is across the weld region. The diameter of the smallest element which can be seen shall be used to determine the sensitivity which shall be calculated from the following formula:

$$\text{Sensitivity, percent} = \frac{\text{Diameter of smallest wire visible on a radiograph}}{\text{Thickness of weld metal}} \times 100$$

The graph given in Figure 3.1 may also be used for the direct reading of wire IQI sensitivity, as defined above for numbers 1/7, 6/12 and 10/16, as appropriate, depending upon the number of elements discernible on the radiograph.

3.3.3 Step Hole (SH) Assessments

For step/hole IQI, the assessment is based on the image of the smallest hole which can be seen. Where there are two holes of the same diameter, images of both are to be discernible in order that the step can be considered discernible. The sensitivity is calculated from the following formula:

$$\text{Sensitivity, percent} = \frac{\text{Diameter of smallest hole visible on a radiograph}}{\text{Thickness of weld metal}} \times 100$$

Figure 3.2 may also be used for the direct reading of step/hole IQI sensitivity as defined above for numbers A, B or C, as appropriate, depending upon the number of elements discernible on the radiograph.

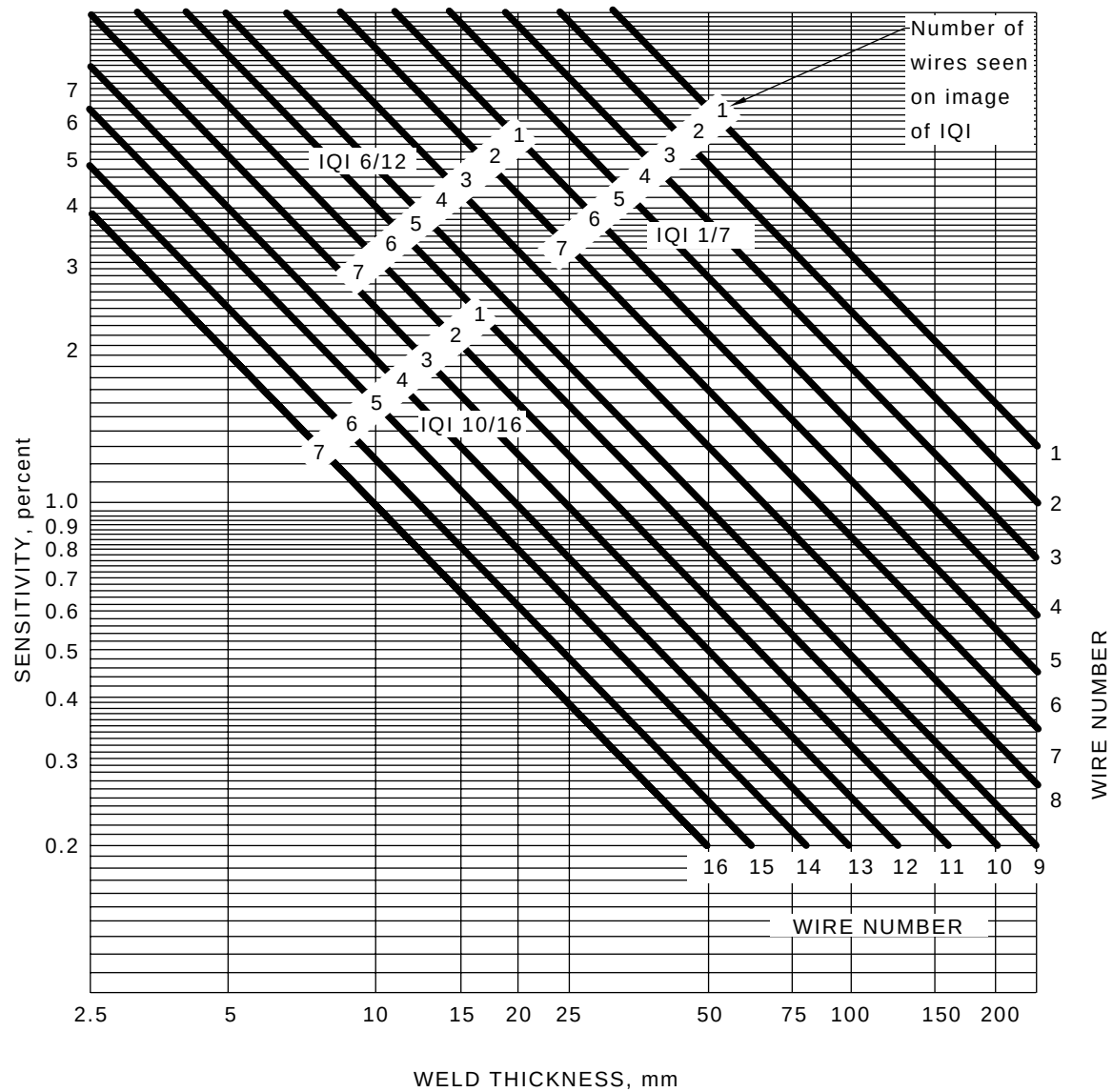


FIGURE 3.1 GRAPH FOR DERIVING WIRE IQI SENSITIVITY

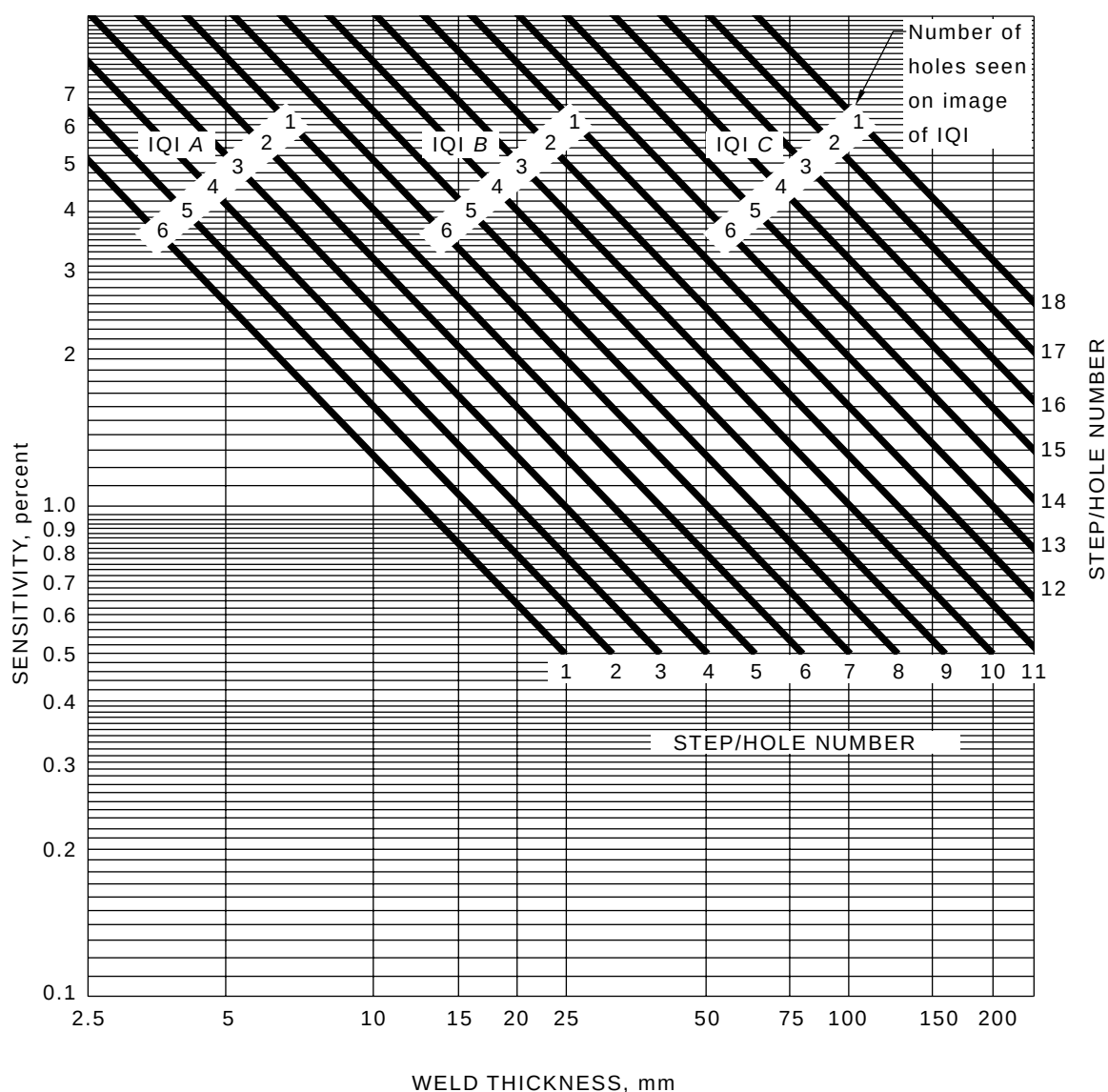


FIGURE 3.2 GRAPH FOR DERIVING STEP/HOLE IQI SENSITIVITY

3.3.4 Plaque/Hole (PH) Assessments

For plaque/hole IQI, the assessment shall be based on the assumption that the required image of a 4 percent hole in a 2 percent plaque is equivalent to 2 percent sensitivity. The required image is considered to have been achieved when the image of the plaque, and the image of the required hole are both discernible.

The sensitivity is based on the smallest hole diameter visible and the thickness of the plaque and shall be calculated from the following simplified formula:

$$\text{Sensitivity, percent} = \sqrt{\frac{AB}{2}}$$

where

- A = the thickness of the smallest plaque image visible, expressed as a percentage of the weld thickness
- B = the diameter of the smallest hole image visible, expressed as a percentage of the weld thickness.