

Australian Standard™

Non-destructive testing

Part 1: Guide to radiography for ferrous castings



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 15 August 2003 and published on 16 September 2003.

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Australian Industry Group
Australian Institute for Non-Destructive Testing
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Part 1: Guide to radiography for ferrous castings

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee MT-007, Non-Destructive Testing of Metals and Materials, at the request of industry. This Standard supersedes, in part, AS 3507—1987, *Non-destructive testing—Radiography of steel castings and classification of quality*.

This Standard was prepared by the Australian members of the joint Standards Australia/Standards New Zealand Committee MT-007. 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 Standard is to specify methods for film radiography of ferrous castings for the determination of quality.

In preparation of this Standard, cognizance was taken of the BS 4080, *Methods for non-destructive testing of steel castings*.

This Standard is Part 1 of a series of Standards covering the radiography of ferrous castings.

The series comprises the following Parts:

AS

3507 Non-destructive testing

3507.1 Part 1: Guide to radiography for ferrous castings (this Part)

3507.2 Part 2: Radiography determination of quality for ferrous castings

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

Diagnosis of the nature of discontinuities located by radiography can only be made by consideration of both metallurgical and radiographic factors. Consideration should therefore be given to the method of manufacture of the casting under test, and the type, position and probable distribution of any discontinuities likely to be present.

Radiographic sensitivity, in addition to consideration of surface conditions or preparation prior to radiography, depends upon scattered radiation energy (kilovolt or isotope spectrum), film/screen combination, scatter radiation control, exposure geometry (source to film distance and effective source size) and several less important parameters; usually, the highest sensitivity methods necessitate the use of X-rays. However, thickness limitations and accessibility may preclude the use of X-rays.

For hollow components it may be possible to use single-wall or double-wall methods. Although radiographic sensitivity obtained with single-wall methods is generally superior to that obtained with double-wall methods, other factors such as diameter, thickness and accessibility may have a pronounced influence on the choice of a method.

Where alternatives exist, the exact method should be agreed on between customer and contractor if not covered by the product or application Standard.

Non-destructive testing methods are mutually complementary; it is emphasized that the results of one test should be considered in relation to those obtained by another method. Accordingly differing interpretations may be required to be reassessed by alternative methods.

STANDARDS AUSTRALIA

Australian Standard Non-destructive testing

Part 1: Guide to radiography for ferrous castings

1 SCOPE

This Standard specifies the methods for film radiography of whole or specified areas of ferrous castings.

NOTES:

- 1 Information to be supplied with the enquiry and order is given in Appendix A.
- 2 Any repair welding carried out is deemed to be part of the casting.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- | | |
|--------|--|
| 1929 | Non-destructive testing—Glossary of terms |
| 2177 | Non-destructive testing—Radiography of welded butts 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 radiation |
| 3507 | Non-destructive testing |
| 3507.2 | Part 2: Radiographic determination of quality of ferrous castings |
| 3998 | Non-destructive testing—Qualifications and certification of personnel (ISO 9712) |
| 4738 | Metal casting—Ferrous sand moulded |

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 |
|-------|--|

3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 1929 apply.

4 DESIGNATION

4.1 Principle

Radiographic methods shall be designated in accordance with the following scheme (see Table 1):

- (a) By a prefix letter 'C' to signify testing of a casting.
- (b) By a second letter to indicate source of ionizing radiation, as follows:

G—Gamma-ray source.

M—Mega electron-volt source.

X—X-ray source.

- (c) By the numeral 0, 1, 2, 3 or 4 to indicate film type (see Appendix D).

NOTE: Examples of designations: CM, CX1 and CG2.

5 SAFETY PRECAUTIONS

Exposure of any part of the human body to ionizing radiation can be injurious. It is therefore essential that when X-ray equipment or radioactive sources are being used, adequate precautions shall be taken to protect testing personnel and any other persons in the vicinity.

NOTE: The use of radioactive substances and irradiating apparatus is controlled by various statutory regulations. Reference should also be made to the 'Code of Practice for the Control and Safe Handling of Sealed Radioactive Sources used in Industrial Radiography', see AS 2243.4.

6 EQUIPMENT AND FACILITIES

6.1 General

The radiographic testing system shall be capable of detecting discontinuities likely to be present in castings, of delineating their boundaries and contours, and of producing satisfactory image quality in a radiograph. See Table 2.

6.2 X-ray equipment

X-ray equipment up to 450 kV shall be used. The exposure should be carried out at the lowest voltage consistent with a reasonable time.

NOTES:

- 1 Figure 1 shows recommended tube voltage versus casting thickness.
- 2 The X-ray technique may be employed where either of the following is established:
 - (a) The casting will be welded in position and the weld X-rayed.
 - (b) Where high sensitivity requirements are needed due to the casting being used in a critical environment, e.g. nuclear, creep, hydrogen, high temperature and/or high pressure.
- 3 Due to the physical aspects of castings, isotopes are commonly used for radiographic testing.

6.3 Gamma-ray sources

Gamma-ray sources given in Table 1 may be used for penetrating the approximate thickness of steel specifications.

NOTE: As a general guide, methods using gamma-rays are usually less sensitive than methods using X-rays.

TABLE 1
GAMMA-RAY SOURCE FOR THE TESTING OF STEEL

Gamma-ray source	Approximate thickness of steel*	
	min.	max.
Cobalt 60 (^{60}Co)	50	200
Iridium 192 (^{192}Ir)	10	90
Ytterbium 169 (^{169}Yb)	6	20

* Values of thickness are for general guidance only and are generally regarded as those values above which exposure times will be unreasonably long and below which the required quality may not be readily achieved.

TABLE 2
HIGH ENERGY MEGA ELECTRON-VOLT (MeV) EQUIPMENT

Equipment type	Typical energy level MeV	Maximum steel thickness*
Van de Graaff	2.5	150
Betatron	18	300
Betatron	31	400
Linear accelerator	8	350
Linear accelerator	15	500

* Maximum practical thickness assuming an exposure time less than 20 min.

6.4 Intensifying screens

6.4.1 General

Metal intensifying screens emit electrons under irradiation and the action of these electrons on the film contributes to producing a chosen density of radiograph with a shorter exposure time. Screens are used to minimize scattered radiation. The following recommendations apply to screens:

- Screens should be handled carefully to avoid dents, creases, scratches and contamination by dirt and grease.
- Any damaged screens which may produce a spurious image in the section under test on the radiographic film should not be used.
- Foreign material such as grease or lint should be removed with care from the surface of the screen.
- Fluorescent screens are not recommended because their inherent 'unsharpness' factor may prevent achievement of the required sensitivity.
- Fluorometallic screen/film combinations may be used where it can be demonstrated that required parameters can be achieved.

NOTE: Use of fluorometallic screen/film combinations is subject to agreement between contracting parties.

Where fluorometallic screens are used, this shall be stated on the test report in AS 3507.2, Clause 7.

6.4.2 *Thickness of intensifying screen*

Recommendations for intensifying screens are set out in Table 3.

NOTE: Selection of screen material and thickness will depend on the sample shape and whether optimum contrast or optimum definition is the more important criterion. Generally contrast will be obtained with screen thicknesses around the maximum value quoted. Alternatively optimum definition would require appreciably thinner screens.

6.5 Cassettes

Irrespective of the type of cassette used, adequate precautions shall be taken to ensure good film-to-screen contact and cassette-to-test object contact. Rigid cassettes may be necessary to maintain a fixed position in relation to the beam, especially where it is difficult to obtain film/screen contact.

6.6 Filters

Filters are uniform layers of material, usually of higher atomic number than the casting. They are used to preferentially absorb softer radiation in X-rays up to 400 kV in the following two ways:

- (a) At the source of radiation to absorb the softer components of primary radiation and thus act to reduce radiographic contrast.
- (b) Between the casting and the radiographic film to absorb scattered radiation from the casting.

Filters in either location reduce intensity of unattenuated primary radiation which can strike radiographic film around the borders of irregular shaped casting, and thus can reduce the undercut of the image by scattered radiation. Hence, filters placed at the radiation source, or between test piece and film, often improve radiographic quality, and their use is recommended.

NOTE: Maximum useful filtration may be as much as one half-value layer of the filtering material (see also Appendix B).

6.7 Image quality indicators

Image quality indicators (IQI) are used as a means of assessing image quality of the radiographic. The IQI should have the same or lower attenuation characteristics as the metal under test (see AS 2177.2, Appendix A) and be one of the following:

- (a) Wire-type (W) made of wire of different diameters in a flexible mount, e.g. 1.6 percent W.
- (b) Step-hole type (SH), perforated with holes related to step thickness, e.g. 3 percent SH.
- (c) Plaque-hole type (PH), a single thickness plaque perforated with holes related to the plaque thickness, e.g. 2.1 percent PH.

6.8 Radiographs

All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they cannot mask or be confused with the image of any discontinuities in the test area.

TABLE 3
INTENSIFYING SCREENS

Source	Radiation	Screen material	Recommended front screen thickness mm	Recommended back screen thickness mm
X-rays	<100 kV	Lead	Not required	0.12 min
	100 to 200 kV	Lead	0.02 to 0.12	0.12 min
	200 to 300 kV	Lead	0.05 to 0.12	0.12 min
	300 to 400 kV	Lead	0.05 to 0.12	0.12 min
Gamma-rays	¹⁶⁹ Yb	Lead	0.05 to 0.12	0.12 min
	¹⁹² Ir	Lead	0.05 to 0.25	0.12 min
	⁶⁰ Co	Lead	0.15 min	0.15 min
	⁶⁰ Co	Steel or	0.5 to 2.0	0.25 to 1.0
	⁶⁰ Co	Copper		
X-rays	2 MeV	Lead	0.25 to 1.6	to 1.6
	3 to 8 MeV	Lead or copper	0.25 to 1.6	to 1.6
	>8 MeV	Tantalum Tungsten Lead	0.25 to 1.6	None

6.9 Viewing conditions

6.9.1 General

Provision should be made for the viewing of radiographs by diffused light in a darkened room. Illuminated areas of the viewing screen shall be masked to the minimum required for viewing of the radiograph.

The edges of a radiograph shall always be masked. Where the radiograph contains regions which are considerably less dense than the section under test, these also shall be masked off when viewing.

The luminance of the illuminated area should be such that it can be satisfactorily interpreted. It should not be less than 30 cd/m² and preferably greater than 100 cd/m². To achieve the minimum value of 30 cd/m², the luminance or brightness of the illuminator should be as shown in Table 4.

TABLE 4
BRIGHTNESS OF ILLUMINATORS

Density of radiography	Screen brightness cd/m ²
1.5	1000
2.0	3000
2.5	10 000
3.0	30 000
3.5	100 000
4.0	300 000

6.9.2 Eye adaptation

As eye adaptation depends largely on the lighting to which the observer is subject before viewing, mandatory requirements cannot be specified. By way of guidance, a film interpreter coming from full sunlight should allow at least 10 min in subdued lighting before commencing viewing: from ordinary artificial room lighting about 30 s adaptation is necessary. Adaptation time shall be one continuous period of time.

If eyes are subject to the full brightness of the illuminator during changes of radiographs, a re-adaptation time of at least 30 s is necessary.

NOTES:

- 1 The candidate should provide documented evidence of satisfactory vision in accordance with the following:
 - (a) Near-vision acuity should permit reading a minimum of Jaeger number 1 or Times Roman N4.5 or equivalent letters at not less than 30 cm with one or both eyes, either corrected or uncorrected.
 - (b) Colour vision should be such that the candidate can distinguish and differentiate contrast between the colours used in the NDT method concerned as specified by the employer.Subsequent to certification, the test of visual should be carried out annually and be verified by the employer or the responsible agency.
- 2 Continual viewing of radiographs may lead to fatigue; prolonged viewing therefore should be avoided.
- 3 The use of lower power magnifying glasses is desirable for study of fine details.

7 METHODS OF TEST

7.1 General

Radiographic sensitivity, in addition to consideration of surface condition or preparation prior to radiography, depends upon radiation energy (kilovolt or isotope spectrum), film/screen combination, scattered radiation control, exposure geometry (source-to-film distance and effective source size) and several less important parameters: usually, the highest sensitivity methods necessitate the use of X-rays. However, thickness limitations and accessibility may preclude the use of X-rays.

For hollow components it may be possible to use either single-wall or double-wall methods. Although radiographic sensitivity obtained with single-wall methods is generally superior to that obtained with doubled-wall methods, other factors such as diameter, thickness and accessibility may have a pronounced influence on the choice of a method.

NOTE: Where alternatives exist, the exact method should be agreed between customer and contractor if not specified by the product or application Standard.

The method of test to be used, shall be specified for the casting or an application code, however the above factors have to be considered when choosing the appropriate test method and sensitivity, and are reviewed in this Clause (7).

Radiographic methods described in this Clause (7) are set out in Table 5 which also includes the recommended field of application for each method.

NOTE: Typical values of sensitivity quoted for each of the test methods in Table 5 are not to be taken as mandatory unless specified or agreed between customer and contractor if not specified by the product or application Standard.

TABLE 5
TEST METHOD DESIGNATION NUMBERS

Radiographic method designation number	Radiation source	Film type	Sensitivity level
CM	X-rays, mega	T2	Where high sensitivity is required
CX1	X-rays	T2	Where high sensitivity is required
CX2	X-rays	T3	High sensitivity, general use.
CG1	Gamma-rays	T2	—
CG2	Gamma-rays	T3	—

NOTE: See ISO 11699-1 for film type classifications.

7.2 Surface preparation

Castings shall be fettled before radiography. All loose scale and excessive roughness shall be removed to produce a relatively smooth surface so that the interpretation of radiographs is not impaired and possible discontinuities are not masked.

Methods used to prepare test surfaces shall not be detrimental to the casting.

NOTES:

- 1 A good 'as-cast' surface is considered to be satisfactory.
- 2 Where runners and risers are cut-off, it is necessary to grind the surface reasonably flush.

7.3 Image quality indicators (IQI)

IQI used and sensitivity selected for radiographic testing should be as specified in the product or application standard. Alternatively IQI selected shall be such that the 'equivalent sensitivity' complies with requirements specified in the relevant product or application Standard.

NOTES:

- 1 Other types of IQI may be used where specified in the relevant product specification or application Standard or as agreed on between contracting parties.
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. Requirements for IQI are specified in AS 2177.2.
- 2 With identical radiographic methods, the numerical value of IQI sensitivity will generally be for different types of IQI and their positioning (see AS 2177.2).
- 3 IQI sensitivity is a means of assessing results of the radiographic method used and is not a measure of detectable discontinuity size.

7.4 Geometric unsharpness

Two levels of geometric unsharpness to be used in radiography of castings are specified, viz. $U_g = 0.2$ mm max. and $U_g = 0.4$ mm max. These maximum values of geometric unsharpness are restricted to the following test methods:

- (a) $U_g = 0.2$ mm max., for methods CX1 and CX2.
- (b) $U_g = 0.4$ mm max., for methods CG1 and CG2.

Where accessibility or limitations of equipment prevent the achievement of $U_g = 0.2$ mm for methods CX1 and CX2, a geometric unsharpness in excess of 0.2 mm may be specified in the casting Standard. However, in no case should $U_g = 0.4$ mm be exceeded.

NOTE: Actual geometric unsharpness value may be calculated by use of either Equation B1 or B2 in Appendix B.

For high voltage equipment the U_g values will depend on type of equipment, sample thickness and source-to-film distance.

Typical values for the various types of equipment are as follows:

- (a) 2 MeV Van de Graaff 0.05 to 0.15 mm
- (b) 5 MeV Linear accelerator 0.2 to 0.7 mm
- (c) 15 MeV Linear accelerator 0.2 to 0.7 mm
- (d) 18 to 31 MeV Betatron 0.05 to 0.5 mm

With method CM different criteria will generally apply in specifying minimum source-to-film distances and geometric unsharpness values. The inherently narrow radiation beam associated with high energy X-ray equipment will generally require relatively long source-to-film distance in order to ensure adequate sample coverage.

7.5 Radiographic density

Radiographic density corresponding to the area under examination shall be not less than 1.7, inclusive of fog density of 0.3 maximum.

Density above 4.0 may be used by agreement or when permitted in the casting Standard (see Note 1).

Densities below 1.7 may be used when permitted in the casting product Standard.

NOTES:

- 1 Radiographs in excess of density 4.0 may be used with advantage but such densities require a sufficiently bright light for adequate interpretation (see Table 4).
- 2 Density may be checked with a calibrated densitometer or assessed by the use of a calibrated film strip.
- 3 In general, film contrast and hence radiographic sensitivity increases with density (see Appendix B).

7.6 Factors influencing diagnostic film area

At times it may be necessary, e.g. where casting section thickness varies, to position the source of radiation in such a manner that the density of the radiograph varies over its area from excessively dark to excessively light. The diagnostic area shall then be taken as that area of film on which positive interpretation of discontinuities can be made, i.e. between points where recommended density limits are met.

In such circumstances it may be necessary to expose, in one shot, more than one type of film having different speeds so as to obtain maximum coverage of the area under test.

7.7 Back-scatter protection

Effects of back-scattered radiation can be reduced by confining the radiation beam to the smallest practical cross-section and by placing lead behind the film. In some cases either or both the back lead screen and the lead contained in the back of a cassette, or film holder, will provide adequate protection against back-scattered radiation. Where back-scatter is likely to adversely affect the quality of a radiograph, a piece of lead not less than 1.5 mm thick should be placed behind the film/screen combination in close contact.

NOTES:

- 1 If there is any doubt about adequacy of protection against back-scattered radiation, a characteristic symbol (frequently a 3 mm thick letter B) should be attached to the back of the cassette or film holder and a radiograph should be made in the normal manner. If the image of this symbol appears on the radiograph, it is an indication that the protection against back-scattered radiation is insufficient and that additional precautions need be taken.
- 2 Additional information on precautions against back-scatter is given in Appendix B.