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Indian Standard

CODE OF PRACTICE FOR NON-DESTRUCTIVE TESTING OF STEEL CASTINGS

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Indian Standard

CODE OF PRACTICE FOR NON-DESTRUCTIVE TESTING OF STEEL CASTINGS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 10 April 1978, after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 The purpose of this standard is to assist the manufacturers to control the quality of the castings they produce and also to help the purchaser and inspecting authority of the castings to select the appropriate testing method to ensure the desired quality level. As non-destructive testing methods are complimentary to each other, selection of test method and acceptance standard should always be made keeping in mind the ultimate application of the casting and the advantages and limitations of each non-destructive testing method. Non-destructive testing has tremendous potential to reveal hidden defects. Hence, the acceptance standard should be made very clear. Ambiguous acceptance limit or over classification will be quite dangerous. When applying non-destructive testing methods, it is quite essential that the operator be fully conversant with the physical principles of test methods, characteristics of the equipments used, have fair knowledge of the method of manufacture of the castings to be tested; nature, position and probable distribution of defects likely to be present. It is emphasized here that the diagnosis of the nature of defects revealed in radiography and ultrasonic flaw detection may only be made by considering both the metallurgical condition and the respective test principles. It should also be noted that the various techniques described in this standard may be limited in their applications subject to the shape and the size of the castings.

0.3 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard describes the five commonly used non-destructive testing methods, namely, visual examination, magnetic particle testing, penetrant testing, ultrasonic flaw detection and radiography for examination of steel castings.

2. METHODS OF NON-DESTRUCTIVE TESTING

2.1 Visual Examination — All castings should be subjected to visual examination at various stages of manufacture to detect any surface defect.

2.2 Magnetic Particle Flaw Detection — This is a surface/sub-surface flaw detection method which may be used for ferritic steel castings.

2.3 Penetrant Flaw Detection — This is a method for detection of flaws open to surface, and may be applied on all types of castings.

2.4 Radiographic Flaw Detection — This method may be applied to steel castings for detection of surface and internal defects and has the advantage of being able to provide a permanent record on films.

2.5 Ultrasonic Flaw Detection — This method may be applied to ferritic steel castings of suitable shapes and sizes for the detection of surface and internal defects and has the advantage that it may be applied to large thickness of material.

3. VISUAL EXAMINATION

3.1 Introduction — This section deals with the visual examination of all types of cast steel components. The surface examination should be carried out at specified stages during the processing of the casting.

3.2 Equipment — In all cases, visual examination should be carried out under adequate lighting. Artificial lighting may be used to supplement it whenever necessary. Optical aids may be used for examination of areas of castings otherwise difficult to examine.

3.3 Stage of Examination

3.3.1 *Examination of the Cast Component* — Initial examination should be carried out after the casting has been fettled/cleaned.

3.3.2 *Examination After Defect Removal and Weld Repair* — Visual examination should be carried out after defect removal to make sure that previously revealed defect is removed completely. The final examination should be carried out after complete welding and preferably after heattreatment.

4. MAGNETIC PARTICLE FLAW DETECTION

4.1 Introduction — This section deals with the magnetic particle examination method of surface/sub-surface flaw detection of ferritic steel castings.

4.2 Method of Magnetisation — Basically, there are two methods of magnetisation, current flow method and magnetic flow method which may be again subdivided as detailed in **4.2.1.1** and **4.2.1.2** and **4.2.2.1** to **4.2.2.4.**

4.2.1 *Current Flow Method*

4.2.1.1 *Prod method* — In this method, magnetisation is accomplished by flow of current from point to point in the casting. The current used may be alternating, half wave rectified or direct.

4.2.1.2 *End contact method* — Magnetisation is accomplished by passing current from one end of the casting to the other end. The current used may be alternating, half-wave rectified or direct.

4.2.2 *Magnetic Flow Method*

4.2.2.1 *Threading bar method* — Magnetisation is accomplished by passing current through a central conductor placed in the hole of the casting.

4.2.2.2 *Threading coil method* — Magnetisation is accomplished by passing current through a flexible cable formed into a threading coil by threading or wrapping it through a hollow casting.

4.2.2.3 *Coil method* — In this method magnetisation is accomplished by encircling the casting by a current carrying conductor.

4.2.2.4 *Magnetic pole method* — In this method magnetisation is accomplished by bringing the casting or part of the casting between poles of an electro-magnet or permanent magnet.

4.3 Testing Equipment

4.3.1 *Current Flow Method* — The equipment consists of a source of high amperage current for producing strong magnetic fields adequate for the size of the casting to be inspected. The equipment is provided with the current control for adjusting the magnetic field to meet the varying requirements. An indicating ammeter is used to make sure that proper magnetising current is applied to the casting.

4.3.2 *Magnetic Flow Method* — Magnetic flow type magnetic particle test equipment is essentially the same as described above, with the addition of electro-magnetic poles and heavy-duty conductors for encircling or threading through the casting.

4.4 Examination Medium — Examination medium should be:

a) Dry magnetic particles,

b) Wet magnetic particles (magnetic particles suspended in carrier liquid), or

c) Fluorescent magnetic particles (magnetic particles treated with fluorescent material used in conjunction with ultraviolet light).

The examination medium used should conform to IS : 6410-1971*.

4.4.1 *Illumination* — For non-fluorescent magnetic particle inspection, adequate illumination by visible light should be provided. For fluorescent magnetic particle inspection, a source of ultraviolet light should be used.

4.5 Surface Preparation

4.5.1 In general, satisfactory results may be obtained when the surface is in as cast condition, free from sand and dirt. However, in some cases, surface preparation by grinding or machining may be necessary when surface irregularities would otherwise mask the indication of un-acceptable discontinuities. All re-entrant radii should be ground to present smooth curved surface.

4.5.2 If magnetic particles do not give good contrast with the casting surface, titanium or magnesium based paint should be applied in a thin coating to the surface under test.

4.6 Testing Procedure

4.6.1 The entire casting or specific area on the casting to be tested should be magnetised and separately examined in two mutually perpendicular directions by any of the following methods.

4.6.1.1 *Current flow method*

a) *Prod method* — When using prod method of magnetisation, prod-spacing and amperage for various section thickness should be as given below:

Prod-Spacing (mm)	*Amperage for Section Thickness*	
	Under 20 mm	Above 20 mm
50 to 100	200 to 300 A	300 to 400 A
100 to 150	300 to 400 A	400 to 600 A
150 to 200	400 to 600 A	600 to 800 A

Prod-spacing of less than 50 mm is not recommended.

*Specification for magnetic flaw detection inks and powders.

b) *End contact method* — Current required depends on the diameter or maximum dimension of the part at right angles to the direction of the current flow and not upon the cross-sectional area. In general, 100 to 400 A per 25 mm of diameter are used.

4.6.1.2 *Magnetic flow method*

a) *Threading bar method* — In this method the current requirement is 100 to 400 A per 25 mm of diameter.

b) *Threading coil method* — When using this method, the minimum peak current may be estimated from the formula, minimum Peak Current = 16 R/N, where R is the radius in mm, and N is the number of coil turns.

c) *Coil method* — When using the coil method of magnetisation, the current used usually vary between $\frac{10\,000}{L/D}$ and $\frac{30\,000}{L/D}$ ampere-turns, where L/D is the length-to-diameter ratio of the coil.

d) *Magnetic pole method* — Alternating current electro-magnetic yokes may be used provided that the sensitivity to detect surface cracks is at least equivalent to that of prod method when a direct current of 25 to 30 A per 25 mm of prod spacing is used and the lifting power of the yoke is at least 5 kg with a pole spacing of 75 to 150 mm. When permanent magnet is used, the lifting power of the magnet should be 20 kg with a pole spacing of 75 to 150 mm.

4.6.2 *Application of Magnetic Particles* — The surface to be examined should be adequately and uniformly coated with magnetic particles. The coating may be applied by immersion, brushing, spraying or dusting either immediately prior to, during or after magnetisation subject to agreement.

NOTE — Casting which exhibit significant residual magnetism should be demagnetised or completion of test when specified by the purchaser.

5. PENETRANT FLAW DETECTION

5.1 Introduction — This section deals with the penetrant examination method of surface flaw detection of all types of steel castings.

5.2 Testing Materials

5.2.1 *Penetrants* — For the purpose of this standard, penetrants are classified into two basic types, dye penetrants and flourescent penetrants, which fall into three main groups:

a) *Spirit/soluble* — The penetrant is removed by organic solvents,
b) *Pre-emulsified* — The penetrant contains an emulsifying agent, which makes it water-washable, and
c) *Post emulsified* — After application of the penetrant an emulsifying agent is applied to the penetrant which makes it water-washable.

5.2.2 *Solvents/Cleaner* — These are used to remove excess penetrant from the coating and may be either organic liquids or water.

5.2.3 *Developers* — These consist either of dry white absorbent powders or a powder suspended in a volatile spirit or water.

NOTE — For testing austenitic steel castings, it is recommended that the materials described in **5.2.1**, **5.2.2** and **5.2.3** should be chloride-free or have a very low chloride content.

5.3 Illumination — For dye penetrant method, adequate illumination by visible light should be provided. For fluorescent penetrant method, a source of ultraviolet light should be used.

5.4 Surface Preparation — In general, satisfactory results may be obtained when the surface is in as-cast condition. In some cases, however, surface preparation by grinding or machining may be necessary when surface irregularities would otherwise mask the indications of unacceptable discontinuities.

5.4.1 The surface to be examined and any adjacent area should be dry and free from any dirt, grease, lint, scale, oil or any extraneous matter that would obscure surface opening or otherwise interfere with the examination.

5.4.2 Typical cleaning agents which may be used are detergents, organic solvents, descaling solutions and paint removers.

5.5 Testing Procedure

5.5.1 *Application of Penetrant* — The whole casting or specified surface which has been prepared for testing shall be thoroughly and uniformly coated with penetrant by immersion, flooding, brushing or spraying. At temperatures between 15°C and 50°C, the penetration time shall be at least 10 minutes.

5.5.2 *Removal of Penetrant* — The penetrant should be removed by the appropriate procedure recommended by the penetrant manufacturer. Excessive cleaning shall be avoided because of the possibility of removing penetrant from defects. After this, the surface shall be allowed to dry either by normal evaporation or by use of forced air circulation at a temperature not exceeding 50°C.

5.5.3 *Application of Developer* — A liquid developer should be applied uniformly in a thin coating to the test surface, either by spraying or brushing. Before use, the developer should be agitated to ensure uniform dispersal of solid particles in the carrier fluid. Developer in the form of dry powder should be thinly and uniformly applied immediately after drying the test surface.

5.6 Examination — It is a good practice to observe the surface during the application of the developer in order to detect the nature of certain indications which might tend to bleed out profusely. Final interpretation, however, shall be made after allowing the penetrant to bleed out for a period not less than 10 minutes nor more than 30 minutes.

6. RADIOGRAPHIC FLAW DETECTION

6.1 Introduction — This section deals with the radiographic flaw detection and classification of radiograph by X-ray or γ-ray for carbon and alloy steel castings. When employing radiographic techniques, appropriate safety precautions should be observed in conformity with relevant statutory regulations. The operator performing radiography should have knowledge of defects in castings as well as adequate technique, and experience in radiography, including radiation equipment, film processing and interpretation of radiograph.

6.2 Surface Preparation — Castings should be fettled and loose scale and excessive roughness should be removed. Where local grinding is necessary, care should be taken to preserve the natural profile of the casting. A good as-cast surface is adequate.

6.3 Identification — Each section of the casting radiographed should have suitable symbols affixed to identify the casting and the area of the casting under examination. The lead letters or numerals should in general be placed on the surface facing the source of radiation. Where this is not possible, they may be placed on the film side of the casting.

6.4 Image Quality Indicators — An image quality indicator conforming to any one of the three types, as specified in IS : 3657-1978* should be placed on the surface of the casting facing the source of radiation. The steel image quality indicator should be positioned on the thickest section of the specimen which is being examined. If a thickness variation greater than 30 percent is to be examined on one radiograph image quality indicator should be placed on both the thickest and the thinnest sections. Wherever, it is not possible to place the penetrameter on source side, the same may be placed on film side. When the image quality indicator is kept on the film side a lead letter 'F' of size 12·5 mm should be kept by the side of image quality indicator.

6.5 Radiographic Sensitivity — As a measure of image quality, sensitivity is usually expressed as a percentage, for example:

$$S\,(\text{Wire}) = \frac{\text{Diameter of smallest visible wire}}{\text{Specimen thickness}} \times 100$$

or

$$S\,(\text{Step}) = \frac{\textit{Min.}\ \text{thickness of the step in which the hole is visible}}{\text{Specimen thickness}} \times 100$$

*Specification for image quality indicators (*first revision*).

Thus, smaller numerical figure of sensitivity indicates better sensitivity. As a guide to good practice, Table 1 gives an indication of the values which should be expected but is not mandatory.

TABLE 1 IMAGE QUALITY INDICATOR SENSITIVITY

(*Clause* 6.5)

Specimen Thickness (mm)		12·5	25	50	75	100	150	200	250	300
I. Q. I. sensitivity, percent	Wire type	2·4	1·7	1·3	1·1	1·00	0·9	0·8	0·8	0·8
	Step type	4·6	3·0	2·2	2·0	1·8	1·8	1·7	1·7	1·6

6.6 Film — The radiograph should be made in non-screen type, medium speed or fine grain high contrast X-ray film.

6.7 Screen — Lead intensifying screens should be used in pairs pressed together in good contact with the front and back sides of the film. Table 2 shows the thicknesses of the screens recommended in IS : 2595-1963*.

TABLE 2 RECOMMENDED THICKNESS OF INTENSIFYING SCREENS

Sl No.	Radiation Energy	Thickness of Lead Screens (mm)	
		Front	Back, *Min*
(1)	(2)	(3)	(4)
i)	X-ray generated below 120 kV	0·025-0·050	0·127
ii)	X-ray generated from 120 to 250 kV	0·025-0·127	0·127
iii)	X-ray generated from 250 kV to 6 MeV	0·100-0·152	0·127
iv)	Gamma-Rays	0·100-0·254	0·127

6.8 Interception of Scattered Radiation — The film cassette should be shielded as thoroughly as possible from all back scattered radiation by an adequate thickness of lead in or behind the cassette. With lower energies below 400 kV X-rays, if the edge of the casting is within the radiation field edge blocking or filtration of the primary beam may be used for reducing objectionable undercut scatter. It is desirable that masking is used to limit the irradiated area to the size of the film.

*Code of practice for radiographic testing.

6.9 Radiation Energy — There is a wide choice of satisfactory radiation energy although there is optimum radiation energy for a given thickness. Optimum radiation energy depends on a number of factors, such as the type and make of film used and on the thickness range covered on each radiograph. In choosing the best conditions from the equipment available, all these factors should be taken into consideration. Table 3 indicates the section thickness at which radiographic examination may be carried out with appropriate techniques.

TABLE 3 THICKNESS FOR DIFFERENT RADIATION SOURCES

Sl No.	Radiation Source	Steel Thickness, mm
(1)	(3)	(3)
i)	Cobalt-60	40 to 200
ii)	Iridium-192	12·5 to 75
iii)	Caesium-137	20 to 100
iv)	X-rays generated from 100 kV	Up to 12·5
v)	X-rays generated from 200 kV	12·5 to 40
vi)	X-rays generated from 400 kV	40 to 90
vii)	X-rays generated from 1 000 kV	50 to 150
viii)	X-rays generated from 2 000 kV	60 to 250
ix)	X-rays generated from 5 to 31 kV	75 to 400

6.10 Focus/Source to Film Distance — The radiograph should have a sharply defined image. Un-sharpness depends upon the film or film screen combinations, the focal spot size, job thickness and source to film distance. Radiography is to be performed with a geometrical un-sharpness maximum of:

a) 0·5 mm for material thickness up to 50 mm,

b) 0·75 mm for material thickness up to 51 to 100 mm, and

c) 1·25 mm for material thickness up to over 100 mm.

The minimum source to object distance d may be calculated from the following equation:

$$d = \frac{Ft}{Ug}$$

where

F = effective source/focal spot size as viewed from the film location,

t = the thickness of object assuming that the film is in close contact with the object, and

Ug = the geometric un-sharpness.

6.11 Density of Radiograph — The film density throughout the sound metal area of interest of the radiographic image should be not less than 1·7 and normally should not exceed 3. Film density higher than 3 is acceptable if adequate film viewing conditions may be provided.

6.12 Processing — The film should be processed according to the manufacturer's recommendations. The radiograph should be free from mechanical, chemical or other processing defects that could interfere with proper interpretation.

6.13 Viewing — The radiograph should be examined by diffused light that does not cause troublesome reflections on the radiographic film. The equipment used to view films for radiographic interpretation should provide a variable high intensity light source sufficient for the essential penetrameter detail to be visible for specific density range. The illuminated area should be masked to the minimum required for viewing the radiograph.

7. ULTRASONIC FLAW DETECTION

7.1 Introduction — This section deals with the ultrasonic flaw detection of defects of ferritic steel castings of different grades. Ultrasonic testing may also be used as a thickness measuring method for castings.

7.2 Testing Procedure — Ultrasonic testing of ferritic steel castings should be carried out in accordance with IS : 7666-1975*.

7.2.1 *Selection of Testing Technique* — Selection of the testing technique depends upon the following factors:

a) Type, orientation, position and incidence of defects likely to be encountered in the casting under consideration;

b) Thickness and profile of the section; and

c) Metallurgical condition.

7.2.2 *Test Frequency* — For all ultrasonic examinations, the highest frequency compatible with the size, metallurgical condition and thickness of the casting should be used.

7.2.3 *Procedure* — All parts of the casting surface where a contact probe may be used, should be tested, irrespective of casting geometry or whether a back wall signal is obtained for use as a reference. A longitudinal wave probe of a frequency of 2 MHz should normally be used, but should be augmented as necessary by shear wave probes. When examining areas which have to be machined, a double crystal probe should be used to minimize dead zone problems. This type of probe

*Recommended procedure for ultrasonic examination of ferritic castings of carbon and low alloy steel.

should also be used for the examination of thin sections. Where large areas have to be covered, a probe giving a beam of larger diameter should be used for an initial search for defects. If suspect areas are found, a more critical examination should be made. It should be noted that crystals of each twin-crystal probe have their angle of incidence and so its own range of testing depth and dead-zone. A shear wave probe is useful when assessing defect size and type, for examination under difficult geometric conditions and for the detection of un-favourably oriented defects.

7.3 Defect Size Determination — When a large defect is detected, its extent may be determined by movement of the probe. It is advisable to re-locate and assess the defect by passing the ultrasonic beam into the casting from different directions for example by placing the probe on the opposite surface, or on an adjoining surface normal to that initially tested, or by using another type of probe. Variations of these techniques enable a more detailed appraisal of both the size and location of the defect to be made. When a defect smaller than probe diameter is detected its size may be determined by comparison with flat bottomed holes or by using DGS diagram.

7.4 Wall-Thickness Measurement — Using the pulse-echo-technique, longitudinal wave probes may be used for thickness measurement of castings by directly calibrating the time base scale against parallel surfaces of the same casting having a known thickness. For this application, the highest frequency compatible with the material under examination should be used. Using this procedure, the accuracy of the measurement shall be about 2 percent to 5 percent of the section thickness, but shall depend upon two main factors, that is the surface roughness and whether or not the surfaces are parallel.

AMENDMENT NO. 1 FEBRUARY 1982

TO

IS:8780-1978 CODE OF PRACTICE FOR NON-DESTRUCTIVE TESTING OF STEEL CASTINGS

Alteration

(*Page 9, clause 6.1, line 2*) - Delete the words 'and classification of radiograph'.

(SMDC 25)

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