IS 5530 (2005): Recommendations for production rectification and repair of steel castings by metal arc welding process [MTD 12: Welding Applications]

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भारतीय मानक

धातु आर्क वैल्डिंग द्वारा इस्पात ढलाई सामग्रियों का उत्पादन, परिशोधन तथा मरम्मत की अनुशंसाएँ

(दूसरा पुनरीक्षण)

Indian Standard

RECOMMENDATIONS FOR PRODUCTION, RECTIFICATION AND REPAIR OF STEEL CASTINGS BY METAL ARC WELDING PROCESS

(Second Revision)

ICS 25.160.01

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Price Group 8

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Welding Applications Sectional Committee had been approved by the Metallurgical Engineering Division Council.

The standard was first published in 1969 and subsequently revised in 1987. While reviewing the standard in the light of experience gained during these years, Committee decided to revise it. In this revision following modifications have been effected:

a) Post heating operation has been incorporated under **6**, and
b) Figure 1C Section AA has been modified.

Steel castings may require welding to make them satisfactory for their intended service and this has long been accepted as part of normal production process. This standard has been prepared so that satisfactory procedures can be specified to ensure good welding practice both on new castings and those which need repair in service. However, good, workmanship is essential and the welding operation has to be properly executed.

This standard prescribes details of tests for approval of welder's qualifications and recommendations for electrodes, weld preparation and pre and post-weld heat-treatment temperature. Although the recommendations apply specifically to steels conforming to the grades mentioned in col 3 of Table 1, they are generally applicable to other cast steels also.

Unlike fabrication welding, there are no standard types of weld and each location, where welding is required, has to be considered in respect of its particular characteristics. It is for this reason that in some clauses of this standard only guidance has been given to assist in determining the action required. Similarly, no acceptance levels for completed welds are specified and these should be the subject of mutual agreement.

This standard keeps in view the manufacturing and trade practices followed in the country into this field. Assistance has also been derived from BS 4570 : Part 1 : 1970 (metric units) 'Specification for fusion welding of steel castings, Part 1, Production, rectification and repair', issued by the British Standards Institution, London.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

RECOMMENDATIONS FOR PRODUCTION, RECTIFICATION AND REPAIR OF STEEL CASTINGS BY METAL ARC WELDING PROCESS

(Second Revision)

1 SCOPE

1.1 This standard specifies requirements for metal arc welding of steel castings, when it is used:

a) as a part of normal production process,
b) to rectify a casting before it is put into service, and
c) to repair a casting that has been in service.

1.2 It does not cover the welding of complete castings into a fabrication, nor the surface deposition of weld metal for applications, such as corrosion resistance or hard facing.

1.3 This standard primarily covers the manual metal arc welding of steel castings given in Table 1, but guidance for use of other processes has been given in some clauses. Other fusion welding processes may be used with suitable modification and/or additions to the requirements specified.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards.

3 TERMINOLOGY

3.1 For the purpose of this standard, the definitions given in IS 812 shall apply in addition to the following.

3.1.1 *Minor Repair* — Weld repair involving a depth not exceeding 20 percent of the wall thickness or 25 mm, whichever is lower.

3.1.2 *Major Repair* — Any weld repair exceeding the depth specified in 3.1.1 shall be considered as major repair. Also any single repair having an arc exceeding 250 mm^2 for every mm of wall thickness shall also be deemed to be a major repair regardless of the considerations mentioned in 3.1.1.

4 CASTINGS

This standard relates to steel castings of the types shown in Table 1.

5 WELDING CONSUMABLES

5.1 Electrodes and Filler Wires

Electrodes and filler wires shall be selected in such a way that the weld metal is compatible with the parent metal in regard to service requirements of casting. Recommendations for type of electrodes for each of the cast steels referred to are given in Table 1.

5.2 For information regarding storage and handling of electrodes, reference should be made to the relevant electrode specifications and manufacturer's recommendations.

5.3 Shielding Gases

When a gas or gas mixture is used, it shall be of the following quality as appropriate:

a) *Argon* — The gas shall comply with the requirements of IS 5760.
b) *Carbon dioxide* — The gas shall comply with the requirements of IS 307.
c) *Gas mixtures* — The use of gas mixtures is permissible, provided that they have proved to be satisfactory as a result of procedure qualification test.

When a gas mixture is used which has specified additions, the variation of small additions shall not exceed ± 10 percent of stated value.

Moisture content shall correspond to a dew point of −30°C or lower.

5.4 Submerged Arc Welding Consumable

Submerged arc welding wires shall conform to IS 7280 and the wire-flux combination shall conform to IS 3613. Wire flux combination shall be such that the weld metal chemical composition and physical properties are similar to that of the parent metal, unless otherwise agreed between the purchaser and the supplier.

6 PREPARATION FOR WELDING

6.1 Fusion faces shall be free from notches or other irregularities, which may be the cause of defects or may interfere with the deposition of weld. Fusion faces and the surfaces adjacent to the joint having a width of atleast 25 mm on either side shall be free from scale, moisture, oil, paint or any other foreign substance which may affect the quality of weld or impedes the progress of welding. In certain cases, filamentary shrinkage may be sealed-off by suitable means subject to agreement between the purchaser and the supplier. When the service conditions demand, it may be necessary to apply suitable non-destructive examination to prove that the grooves or excavation is free from defects. The groove may then require further preparation and cleaning to make it suitable for welding.

6.2 When the defects require further preparation to make it suitable for welding, the fusion faces shall slope to the bottom and contour changes should be gradual. Deep and narrow grooves shall be avoided as they make it difficult to achieve complete root penetration and promote under cutting. They may also lead to slag inclusions and cavities at roots and sides of the weld.

6.3 Grooves for welding shall preferably be of 'U' or 'V' form. If any other preparation is used, proper fusion shall be ensured. Where the defect extends through the section of the casting, the choice between single and double preparation will be governed by:

a) Thickness of the section,
b) Location of the preparation, and
c) Access and environment for the welder.

6.4 In double 'U' or 'V' preparation, the root gap should be adequate to ensure complete penetration. The root run should be chipped off before commencing the weld from the other side.

6.5 In single 'U' or 'V' preparation, a suitable backing strip may be used. Wherever possible, the backing strip should be removed after the completion of weld.

The preparation of fusion faces, angle of bevel, root radius and root face shall be such that the limits of accuracy are within the tolerances recommended in Fig. 1.

6.6 The preparation of fusion face may be done by the following methods:

a) Mechanical methods including machining,
b) Oxy-acetylene flame gouging,
c) Carbon arc or metal arc gouging in combination with air or oxygen,
d) Powder washing, and
e) Plasma cutting.

The suitability of these methods for specific steels is indicated in Table 1. In order to minimize the size of cracking, it may be necessary in the case of certain complicated castings and those which are likely to contain high residual stresses produced during manufacture to subject the casting to a suitable form of heat treatment before weld preparation.

6.7 Backing Strips and Backing Bars

6.7.1 *Permanent Backing Strips*

In certain circumstances of access, to ensure full penetration with a single 'U' and 'V' preparation, a permanent backing strip may be used, in which case, it shall be compatible with the service requirements of the casting. Backing strips shall not be attached by welding all round to their perimeter in order to minimize the risk of basal cracking.

6.7.2 *Temporary Metal Backing Strips*

When a temporary metal backing strip is used, it shall be of similar chemical composition to that of the casting or it shall be a carbon steel up to 0.26 percent carbon, provided that the sulphur and phosphorus contents do not exceed 0.04 percent each. Backing strip shall not be welded all round to their perimeter in order to minimize the risk of basal cracking.

6.7.3 *Copper Backing Strips*

Removable copper backing strips shall only be used by agreement between the manufacturer and the purchaser since there is a danger of copper pick-up in the weld metal.

6.7.4 *Temporary Non-metal Backing Strips*

Temporary non-metal backing strips shall be of combustible materials and shall be completely removed after completion of welding.

6.8 Precautions Associated with Welding

6.8.1 *Arc Strikes*

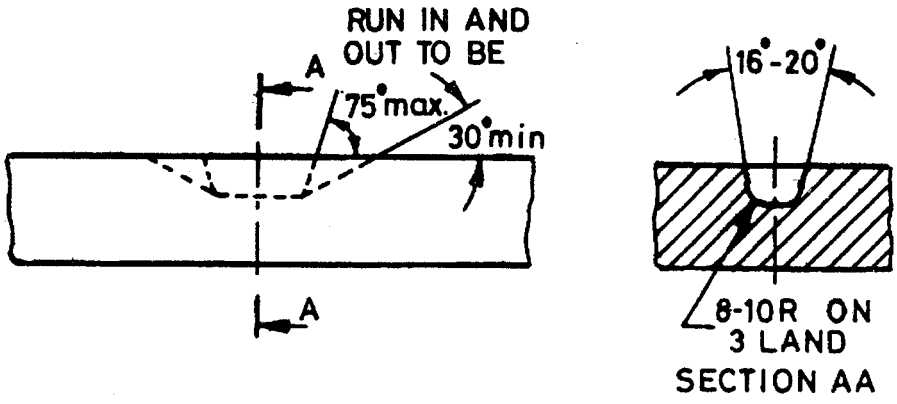
Contact of the electrode or the non-insulated parts of electrode holders with the casting shall be avoided. A piece of scrap plate clamped to the casting near the weld shall be used for striking the arc.

NOTE — Electrode holders shall be of the fully insulated type.

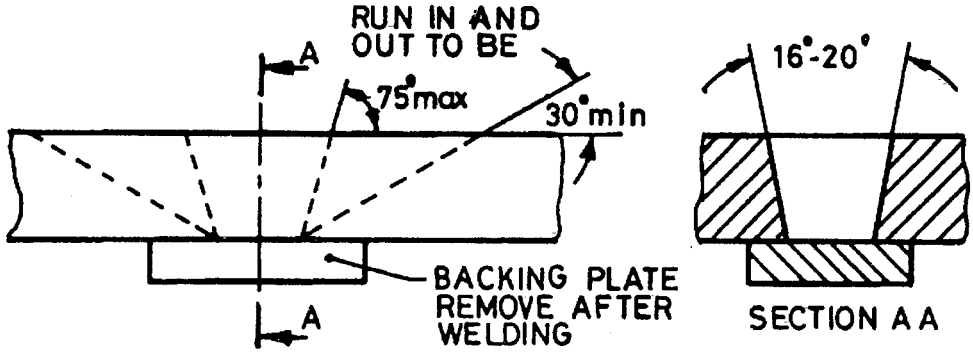
6.8.2 Welding return leads shall be connected to the work by some means that prevents damage by sparking.

6.8.3 *Inter-run Cleaning*

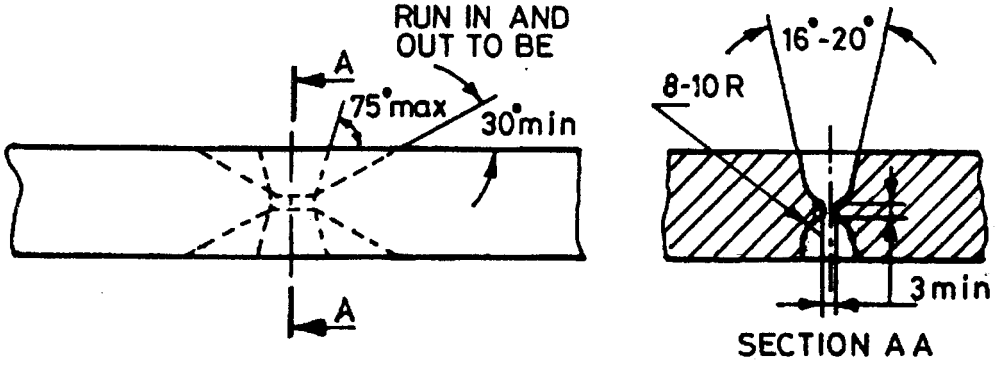
Each run of weld metal shall be cleaned before a further run is applied, particular attention being paid to the junctions between the weld metal and the fusion faces. Visible defects, such as cracks, cavities, etc, shall be removed before deposition of further weld metal.



1A Preparation not Extending Through Wall



1B Preparation Extending Through Wall



1C Preparation Extending Through Wall (Double-U Preparation)

All dimensions in millimetres.

NOTE — If weld in Fig. 1B accessible from both sides, back chip and for thick sections, a double U preparation as in Fig. 1C, may be preferred for which back chipping is also recommended.

FIG. 1 RECOMMENDED CONTOURS FOR WELD CAVITY PREPARATION

6.8.4 *Distortion*

The welding procedure and sequence shall be so chosen that distortion is minimized; this is particularly important when machined castings are being welded.

6.8.5 *Cooling After Welding*

In general, low carbon steel (below 0.2 percent) castings may be cooled in still air without precautions. In the case of other castings care shall be taken to ensure slow and even cooling.

6.8.6 *Peening*

For austenitic manganese steel castings or other hardenable castings, peening shall be considered necessary immediately after welding (*see also* IS 9595).

7 PRE-HEATING AND INTERPASS TEMPERATURES

7.1 Pre-heating

No thermal gouging or welding shall be carried out where the temperature of the casting is below 15°C. Pre-heating shall be as specified in Table 1, and during welding the temperature of the parent metal in the region of the weld shall not fall below the pre-heating temperature.

7.1.1 The castings shall preferably be pre-heated in a furnace. If it is not possible to pre-heat the entire casting either because of the size of the casting or because the extent of welding required is such that the temperature of the casting will fall below the appropriate value specified in Table 1 before the completion of welding, then local pre-heating shall be used over an area on each side of the weld having a width of at least three times the thickness of the material with a minimum of 75 mm. It is preferable to pre-heat the casting to a slightly higher temperature than that given in Table 1 so that the weld is completed before the temperature falls below the value specified. This will also keep the number of pre-heating is required to a minimum.

7.2 Interpass Temperature

Interpass temperature shall be measured on the surface of the parent metal on the side from which the welding will be performed, within 25 mm of the edge of the weld preparation and along the joint for a length equal to the proposed continuous deposit. If at any time the temperature, as measured 75 mm in front of arc, exceeds the pre-heating temperature by more than 10 percent, then welding shall be discontinued until the temperature has dropped to below that limit.

7.3 Post-heating

In order to minimize the risk of hydrogen cracking post-heating shall be carried out for Cr-Mo castings. The castings shall be post-heated immediately after welding before cooling down to room temperature from the pre-heat temperature. Suitable temperature and time for post-heating may be selected based on parent material composition.

8 POST-WELD HEAT TREATMENT

8.1 Post-weld heat treatment may be necessary to reduce the stresses due to welding; or to prevent hardening or to soften weld-hardened zones. Recommended post-weld heat treatment temperatures for specific steels are given in Table 1.

8.2 For many steels, post-weld heat treatment may be integral with the final heat treatment of the casting. But in any case, it should be considered in relation to any general heat treatment to be applied to the casting to provide specific properties. Where such general heat treatment has been applied before welding is done, it may be necessary to repeat the treatment after welding.

8.3 The heat treatment may be done by one of the following methods:

a) An immediate stress-relief, when the casting is stress-relieved, before its temperature falls below the minimum pre-heating temperature;

b) A final heat treatment of the casting, as specified, carried out before its temperature falls below the minimum pre-heating temperature; and

c) A stress-relieving, annealing, normalizing or quenching and tempering heat treatment carried out some time after the casting has cooled from the welding temperature.

8.4 Post-weld heat treatment shall be carried out by heating the casting in a furnace, unless any other method is agreed to between the manufacturer and the purchaser. The temperature of the furnaces shall not be above 300°C at the time of inserting the casting, after which the temperature of the furnace shall be raised at a rate appropriate to the geometry and thickness.

8.5 Alternative Methods of Stress-Relief

Only where castings cannot be post-weld heat-treated for stress-relief as, for example, in the case of castings that have been in service and are repaired *in-situ*, an alternative method of stress-relief may be used only by agreement between the manufacturer and the purchaser.

9 TEMPERATURE MEASUREMENT

9.1 General

Pre-heat, interpass and post-weld heat treatment temperatures, where applicable, shall be checked and recorded.

9.2 Pre-heat, Interpass and Post-heat Temperatures

Pre-heating, interpass and post-heat temperatures shall be checked and recorded wherever applicable using thermometers, thermo-couples, pyrometers. Temperature indicating crayons may be used when they are compatible with casting material.

9.2.1 Thermo-couples when used shall be located in positions that give a true measure of the joint temperature.

9.3 Post-weld Heat Treatment Temperature

Thermo-couples shall be used for recording post-weld heat treatment temperatures in a furnace or for local treatment and they shall be disposed so as to give a true measure of the joint temperature. Where local post-weld heat treatment is used, thermo-couples shall be located so as to indicate the temperature at significant point on the weld.

9.4 Thermo-Couple Attachment and Junctions

Thermo-couples shall be in metallic contact with the parts being heated and attached by an approved mechanical method, for example, temporary localized weld deposits to an approved procedure, with drilled thermo-couple pockets in the deposits which are subsequently removed. Other means of thermo-couple attachment shall be used only by agreement between the manufacturer and the purchaser.

9.4.1 Thermo-couple junctions and wires shall be protected from flame impingement. To prevent direct radiation from the heating elements on the hot junction when electrical resistance heating is used, thermo-couples shall be covered with a protective wrapping.

10 DRESSING

10.1 Dressing of the weld area may be necessary for any of the following reasons:

a) To facilitate non-destructive testing;
b) To remove notches, etc, that would impair fatigue properties;
c) For service in corrosive environments; and
d) To minimize the risk of stress-relief cracking in the case of Cr-Mo-V steel and stabilized austenitic steels.

10.2 The method of dressing shall be one of those given in **6.6** (a), (b) or (c). When a thermal process is used, the requirements and precautions in **7**, **8** and **9** shall apply. In such cases, mechanical dressing by grinding shall follow the thermal process and shall cover a sufficient arc round the weld to remove any surface cracking or fine cracking in both filler metal and parent metal. Any post-weld heat treatment shall follow this grinding. Grinding wheels for use on austenitic stainless steels shall be the iron free type and shall have been used only on such steels.

11 INSPECTION OF COMPLETED WELDS

In general, the inspection of weld zones shall be to the same extent as that applied to the unwelded casting. Depending on the availability of manufacturing records and on service conditions, this inspection may be extended to include any of the following tests, as agreed to between the manufacturer and the purchaser;

a) Visual examination,
b) Magnetic particle testing,
c) Liquid penetrant testing,
d) Radiographic examination,
e) Ultrasonic examination,
f) Leak testing,
g) Dimensional check
h) Hardness check,
j) Macro-etching, and
k) Sulphur printing.

12 RECORD OF LOCATION OF WELDS

If required, the manufacturer shall make available to the purchaser, sketches or photographs of casting showing the location of all welds.

13 PROCEDURE QUALIFICATION

13.1 General

A manufacturer shall be exempt from making procedure tests in accordance with this clause when he can show that, for the previous three years, he has successfully undertaken welding in the production, rectification or repair of steel castings in compliance with satisfactory welding procedures in respect of welding process, type of steel, filler metal and approximate thickness. A manufacturer shall also be exempt when he can show that he has previously made successful procedure tests of the type required.

In other cases, when required by the application standard or by agreement between the manufacturer and the purchaser, welding procedure tests shall be carried out before a manufacturer can be permitted to weld castings in accordance with this standard. For each of the steels in Table 1 for which approval is required, the welding procedures shall specify the details given in **13.2**, including the operational ranges for each relevant feature. These welding procedures, if requested, shall be submitted to the purchaser for approval.

Separate procedure tests are not necessarily required for each type of steel where proof of satisfactory

performance does not exist. Where welding procedures are similar with respect to welding process, welding position, pre-heating, post-weld heat treatment, electrodes, filler material, flux or shielding gas, then one welding procedure qualification shall be sufficient.

It is recommended that welding procedure qualification test carried out in accordance with this standard and witnessed by an independent inspecting authority should be accepted by other inspecting authorities provided that all the provisions have been fulfilled.

13.2 Procedure Test Records

The records of the procedure qualification tests shall specifically include the following details:

a) Type of steel;
b) Welding process;
c) Preparation;
d) Method of preparation;
e) Welding position;
f) Pre-heating;
g) Welding technique and sequence;
h) Electrodes, filler materials, flux and shielding gas;
j) Electrodes or filler material size, or interpass temperature, or both;
k) Electrical characteristics and welding speed;
m) Post-weld heat treatment; and
n) Test results.

13.3 Re-qualification of Procedure

A new procedure qualification test shall be required consequent upon a change in any of the following items;

a) Welding process;
b) A major change in geometry of preparation;
c) Welding position, subject to the extent of qualification given in **13.3.1**;
d) Pre-heating or post-weld heat treatment, except when other than a full stress-relief is applied; and
e) Type of electrode, filler material, flux or shielding gas.

In the absence of a change in any of the above items, the qualification of a procedure shall remain in force indefinitely. If any of the additional tests mentioned in **13.4** were not made for the original procedure qualification but are required at a later date, then a new procedure qualification test shall be made.

13.3.1 *Welding Position*

A procedure qualification test should done in a position that simulates the actual repair; normally this would be the flat position. Qualification in the flat position shall not qualifying procedure for use in other positions.

Qualification in the vertical position shall also qualify the procedure for use in the flat position, while qualification in the overhead position shall qualify the procedure for use in all positions.

13.4 Tests

The cast parent metal used for welding procedure test pieces shall be of the same type of steel as that for the casting on which production welding might be used. The steel for the test piece shall be examined by suitable non-destructive means and the location of the weld preparation then chosen so that any parent metal imperfections will not influence the test results.

The welded test piece shall be tested in the condition in which the casting complied with the steel specification. Visual examination of the test piece shall be followed by magnetic particle or liquid penetrant testing for the detection of surface cracks and then by radiographic or ultrasonic examination for sub-surface flaws.

Acceptable test pieces shall then be subjected to hardness survey and macro examination. In case of major repairs (*see* **3.1.2**) carried out at the steel foundry, additional mechanical test like tensile and bend test, etc, shall be conducted. The result of such tests shall not be less than those specified for the parent casting material, unless agreed otherwise.

Acceptance levels for each method of examination and testing shall be those agreed to between the manufacturer and the purchaser.

14 ELDER QUALIFICATION

14.1 General

Welders employed on welding castings in accordance with this standard shall have been successfully tested by the manufacturer to the satisfaction of an inspecting authority which shall be given the opportunity of witnessing the tests. In all cases, complete records of such tests shall be available for inspection.

The welder who satisfactorily completes the procedure qualification tests is thereby exempt from undergoing separate welder qualification tests involving the same range of procedures.

A welder's qualification to weld to a particular procedure shall remain valid provided that it can be shown that the welder has, subsequent to the test been employed with reasonable continuity on that procedure and has continued to produce satisfactory welds as verified by non-destructive examination. Re-qualification shall be required. If:

a) during the preceding six months or more, the welder has not been engaged in welding to this procedure; or

b) there is some specific reason to question the welder's ability; or

c) it is necessary to re-qualify the welding procedure, unless the change concerns only the pre-heating temperature or post-weld heat treatment.

It is recommended that welder qualification tests witnessed and accepted by one inspecting authority should be accepted by other inspecting authorities so long as the welder remains in the employment of the same manufacturer.

14.2 Test Pieces

The test piece shown in Fig. 2 shall be used for the approval of welders but additional test may be specified by agreement between the manufacturer and the purchaser.

The parent metal for the test piece shall be cast carbon steel corresponding to IS 1030 Grade 26-52 (or an equivalent wrought steel).

If desired, the surfaces and edges of the plates may be machined, but the groove in the base plate shall be prepared by one of the methods given in Table 1 for the appropriate type of steel, except machining.

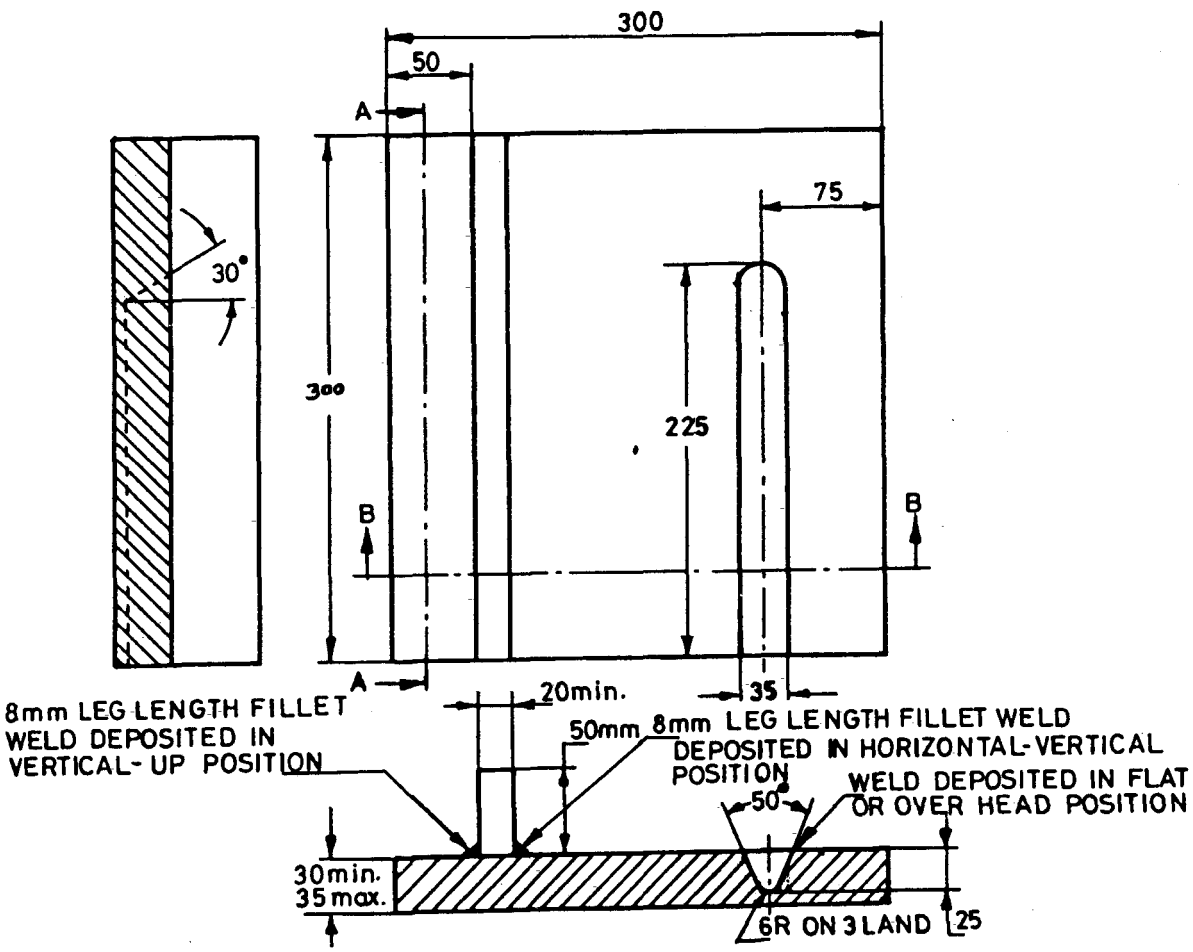
The test piece shall be welded using the type of electrode or filler wire given in Table 1 for the type of steel specified in the welding procedure, but electrode of IS 814 classification E5xx shall not be used.

The groove shall be welded in flat, vertical up or overhead position with qualification in the overhead position covering qualification for welding in all positions. One of the fillet welds shall be welded vertically upwards. Each run shall contain a stop and re-start.

14.3 Tests

14.3.1 *Visual Examination*

Welds shall be free from cracks, porosity cavities, trapped slag and all but slight intermittent occurrences



All dimensions in millimetres.

FIG. 2 TEST PIECE FOR THE APPROVAL OF WELDERS

of under-cut. The stop and start position shall show no pronounced hump or crater in the weld surface.

14.3.2 *Radiographic Examination*

The groove weld shall be dressed smooth prior to radiography by one of the techniques given in IS 1182. A radiographic sensitivity of 2 percent or better as shown by an image quality indicator complying with IS 3657 shall be obtained on all radiographs.

Groove welds, for which the radiographs show any type of crack, shall be unacceptable. Welds for which the radiographs show lack of fusion, slag inclusions or cavities shall be unacceptable, if the length of any such flaws is greater than 6 mm or if the total length of all such flaws, which exist in a line exceeds 12 mm.

14.3.3 *Macro-Examination*

The groove weld shall be sectioned for macro-examination at those locations where acceptable imperfections have been shown to exist as a result of radiographic examination but if no imperfections have been revealed by such examination, at least one section shall be taken at a top and start position. If radiographic equipment is not available at least four sections of the groove weld shall be taken for macro-examination. The fillet welds shall be sectioned at three places for macro-examination.

All sections shall be prepared for macro-etching and etched [*see* IS 3600 (Part 9)] to give a clear indication of the weld structure.

Welds, which on visual examination show any cracks, lack of fusion or incomplete penetration shall be unacceptable.

14.3.4 *Retests*

If any of the above tests show that the welds do not meet the required standard, two further test pieces shall be made and the tests repeated. If either of these additional test pieces does not meet the required standard, the welder shall not be regarded as capable of welding steel castings to the requirements of this standard without further training.

Table 1 Steel, Weld Preparation, Electrodes and Filler Wires, Pre-heating and Post-weld Heat Treatment

(NOTE — Where alternatives are given, no order of preference is implied.)

(*Clauses* 1.3, 4, 5.1, 6.6, 7.1, 7.1.1, 8.1, 13.1 *and* 14.2)

Sl No.	Type of Steel for Castings	Indian Standards and Grade	Method of Weld Preparation	Recommended for				
				Electrodes and Filler Wires (*see* 5.1)			Minimum Pre-heat Temperature (*see* 7.1) °C	Post-weld Heat Treatment Temperature Range (*see* 8) °C
				Manual metal-arc welding	Gas shielded processes	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Low Carbon	IS 1030 Grades 20-40 and 23-45 IS 2986 Grades 1, 2 and 3 IS 4491 Grades 1 and 2	a, b, c, d, or e	IS 814 Exxx-41x	IS 6419 S-1, S-3 and S-4	IS 3613 Sections 1, 2 or 5	None	580-650 (*see* Note 1)
ii)	0.25 to 0.35C	IS 1030 Grades 26-52 and 27-54 IS 2856 Grades 1 and 2 IS 10343 Grades 1A, 1B and 3A	do	IS 814 Exxx-51x	IS 6419 S-2	IS 3613 Sections 1 and 3 or 6	(*see* Note 2)	600-650 (*see* Note 3)
		IS 7899 Grades 1N and 1Q	do	IS 1395 E638 D1	—	—	do	do
iii)	0.35 to 0.45C	IS 1030 Grade 30-57 IS 2707 Grade 1 IS 10343 Grade 1C	do	IS 814 Exxx-51x (*see* Note 4)	IS 6419 S-2	IS 3613 Sections 1 and 4 or 7	150	do
iv)	C-Mo	IS 3038 Grade 2 IS 2986 Grade 4	do	IS 1395 E49x-A1	IS 6560 SLA-1 and SLA-2	(*see* Note 5)	do	630-680 (*see* Note 8)
		IS 7899 Grades 2N, 2Q, 3N, 3Q	do	IS 1395 Exx BDI	do	do	do	do
v)	1.5 Mn	IS 3038 Grade1 IS 2708 Grades 1 and 2 IS 2985	a, b, c, d or, e (*see* Note 6)	IS 814 Exxx-51x (*see* Note 4)	IS 6419 S-2	IS 3613 Sections 1 and 4 or 7	150 (*see* Note 7)	600-650 (*see* Note 8)

Table 1 (*Continued*)

Sl No.	Type of Steel for Castings	Indian Standards and Grade	Method of Weld Preparation	Recommended for				
				Electrodes and Filler Wires (*see* 5.1)			Minimum Pre-heat Temperature (*see* 7.1) °C	Post-weld Heat Treatment Temperature Range (*see* 8) °C
				Manual metal-arc welding	Gas shielded processes	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
vi)	0.4 to 0.6	IS 10343 Grades 2A and 2B	a, b, c, d or e	IS 1395 E63 BD1	—	—	200-250	600-650 (*see* Note 3)
vii)	1.6 Mn	IS 2708 Grades 3A and 3B	a, b, c, d or e (*see* Note 6)	IS 814 Exxx-51x (*see* Note 4)	IS 6419 S-2	IS 3613 Sections 1 and 4 or 7	200	600-650 (*see* Note 8)
viii)	Austenitic manganese	IS 276	a, c, d or e	IS 5206 E 19.9 or any suitable austenitic electrode with or without a facing of austenitic manganese steel	IS 5856 S-BO1 S-BO1L S-BO1Nb	(*see* Note 5)	(*see* Note 9)	None
ix)	High tensile	IS 2644 Grades 1 to 5 (*see* Note 10)	a, b, c, d or e (*see* Note 10)	(*see* Note 5)	(*see* Note 5)	do	200 (*see* Note 11)	600-650 (*see* Notes 8 and 12)
x)	1.25 Cr-Mo	IS 3038 Grade 4 IS 2986 Grade 5 IS 10343 Grade 5A	do	IS 1395 E55x-B2	IS 6560 SLA-3	do	250	630-680
		IS 7899 Grade 9A, 9Q	do	IS 1395 ExxxB2				
xi)	2.25 Cr-Mo	IS 3038 Grade 5 IS 2986 Grade 6 IS 7899 Grade BN or 8Q	do	IS 1395 E63x-B3	IS 6560 SLA-4	do	do	680-710 (*see* Note 12)
xii)	5 Cr-Mo	IS 3038 Grade 6	a, c, d or e (*see* Note 10)	IS 1395 E41x-B6	IS 6560 SLA-5	do	300	650-720 (*see* Note 13)
xiii)	9 Cr-Mo	IS 3038 Grade 7	do	IS 1395 E41x-B8	IS 5856 S-BO2Mo S-BO2MoL (*see* Note 14)	do	do	620-720 (*see* Note 13)
xiv)	Cr-Mo-V	IS 3038 Grade 3	a, c or e (*see* Note 10)	IS 1395 E55x-B1	IS 6560 SLA-4	(*see* Notes 5 and 15)	250	680-710 (*see* Note 16)
xv)	3% Ni	IS 10343 Grade 3B	a, b, c, d or e	IS 1395 ExxB-C2	(*see* Note 5)	(*see* Note 5)	150	600-650

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xvi)	Cr-Ni-Mo	IS 7899 Grades 4N, 4Q, 4QA, 5N, 5Q, 6N, 6Q, 10N and 10Q IS 10343 Grades 3C, 3D and 3E	a, c or e (*see* Note 10)	IS 1395 ExxB-Mx	(*see* Note 5)	(*see* Notes 5 and 15)	250	680-710 (*see* Note 8)
xvii)	Cr-Ni-Mo-V	IS 7899 Grade 7Q	do	(*see* Note 5)	do	do	do	do
xviii)	13 Cr	IS 3444 Grades 10 and 14 IS 7806 Grade 1 IS 9541 Grade 2	do	IS 5206 E19.9 E19.12.3 E25.20 (*see* Notes 14 and 17) IS 5206 E13	IS 5856 S-BO1-Nb S-BO5 S-BO5-Nb and S-BO2 Mo (*see* Notes 14 and 17)	(*see* Note 5)	300	680-750 (*see* Note 18)
xix)	13 Cr-Mo	IS 3444 Grade11 IS 7806 Grade 1A IS 10774 Grades 7 and 9	do	IS 5206 E19.9 E19.12.3 E25.20 (*see* Notes 14 and 17) E 13	IS 5856 S-BO1 Nb S-BO5 S-BO5 Nb And S-BO2Mo (*see* Notes 14 and 17)	do	do	do
xx)	13 Cr-4Ni-Mo	IS 3444 Grade 24 IS 10774 Grade 8	do	IS 5206 E 19.12.2 E 19.12.3 E 13.4 (*see* Notes 14 and 17)	IS 5856 S-BO1 Nb S-BO5 S-BO5 Nb S-BO2 Mo (*see* Notes 14 and 17)	do	do	do
xxi)	18 Cr-2Ni	IS 3444 Grade 12	do	IS 5206 E 19.12.2 E 19.12.3 and E 13.4 (*see* Notes 14 and 17)	IS 5856 S-BO1 Nb S-BO5, S-BO5 Nb and S-BO2 Mo (*see* Notes 14 and 17)	do	do	do

Table 1 (*Continued*)

Sl No.	Type of Steel for Castings	Indian Standards and Grade	Method of Weld Preparation	Recommended for				
				Electrodes and Filler Wires (*see* 5.1)			Minimum Pre-heat Temperature (*see* 7.1) °C	Post-weld Heat Treatment Temperature Range (*see* 8) °C
				Manual metal-arc welding	Gas shielded processes	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxii)	18 Cr-8 Ni	IS 3444 Grades 1, 3 and 15 IS 5522 Grade 5 IS 7806 Grades 2, 2A, 3 and 3A IS 9541 Grade 1 IS 10774 Grades 1 and 4	a, c or e (*see* Note 6)	IS 5206 E 19.9 E 19.9 L (*see* Note 19)	IS 5856 S-BO1, S-BO1 Nb and S-BO1 L (*see* Note 19)	(*see* Notes 5 and 19)	None	1 000-1 100 (*see* Note 20)
xxiii)	18 Cr-8Ni-cb	IS 3444 Grade 5 IS 7806 Grade 5A IS 10774 Grade 3	do	IS 5206 E 19.9 Nb	IS 5856 S-BO1 Nb	(*see* Note 5)	do	None (*see* Note 16)
xxiv)	18 Cr-10Ni-Mo	IS 3444 Grade 6	do	IS 5206 E19.12.3 E 19.12.3L E 19.12.3 Nb	IS 5856 S-BO2 Mo S-BO2 Mo	do	do	do
xxv)	18 Cr-10 Ni-2½ Mo	IS 3444 Grades 4, 4A and 16 IS 7806 Grades 4, 4A and 5 IS 11286 Grade 1 IS 10774 Grades 2, 10						
xxvi)	18 Cr-14 Ni-2 Mo	IS 7806 Grade 13						
xxvii)	18 Cr-10 Ni-3½ Mo	IS 3444 Grade 17 IS 10774 Grade 11	do	IS 5206 E 19.12.3 E 19.12.3L E 19.12.3 Nb	IS 5856 S-BO3 Mo S-BOMo Nb	do	do	1 000-1 150 (rapid cool)
xxviii)	20 Cr-10 Ni	IS 3444 Grade 2	do	IS 5206 E 19.9 E 19.9L E 19.9 Nb	IS 5856 S-BO1 S BO1L S BO1 Nb	do	do	None

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxix)	20 Cr-14 Ni	IS 4522 Grade 8						
xxx)	25 Cr-12 Ni	IS 3444 Grade 7 IS 7806 Grades 6, 7 and 8 IS 10774 Grade 5	a, c or e (*see* Note 6)	IS 5206 E 23.12 E 23.12 L E 23.12.2 E 23.12 Nb	IS 5856 S-BO4 S-BO6 (*see* Note 23)	(*see* Note 5)	None	None
xxxi)	25 Cr-20 Ni	IS 3444 Grade 8 IS 4522 Grade 9 IS 7806 Grades 9, 10 and 11 IS 10774 Grade 6	do	IS 5206 E 25.20 E 25.20 Nb E 25.20 C (*see* Notes 14 and 23)	IS 5856 S-BO5 Nb S-BO6 (*see* Notes 14 and 23)	do	do	do
xxxii)	28 Cr	IS 4522 Grades 2 and 3	a or e	IS 5206 E 25.4	(*see* Note 5)	do	300	650-700 (*see* Note 13)
xxxiii)	28 Cr 4 Ni	IS 3444 Grade 13 IS 4522 Grade 4						
xxxiv)	28 Cr 8 Ni	IS 3444 Grade 9 IS 4522 Grade 6 IS 11286 Grades 6 and 7	a, c or e (*see* Note 6)	IS 5206 E 25.4, E29.9	do	do	None	None
xxxv)	28 Cr 20 Ni	IS 4522 Grade 10	a, c, d or e (*see* Note 6)	IS 5206 E 25.20 E 25.20 L E 25.20 Nb E 25.20 C (*see* Notes 14 and 23)	IS 5856 S-BO5, S-BO5 Nb, S-BO6	do	do	do
xxxvi)	25 Ni 20 Cr	IS 4522 Grade11						
xxxvii)	28 Ni-20 Cr-Mo-Cu	IS 3444 Grade 18 IS 7806 Grade 14 IS 11286 Grade 2	do	IS 5206 E 20.25.5 LCu, E 23.27.3 LCuNb	(*see* Note 5)	do	do	do

Table 1 (*Continued*)

Sl No.	Type of Steel for Castings	Indian Standards and Grade	Method of Weld Preparation	Recommended for				
				Electrodes and Filler Wires (*see* 5.1)			Minimum Pre-heat Temperature (*see* 7.1) °C	Post-weld Heat Treatment Temperature Range (*see* 8) °C
				Manual metal-arc welding	Gas shielded processes	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxxviii)	35 Ni 15 Cr	IS 4522 Grade12 IS 7806 Grade12	a, c, d or e (*see* Note 6)	IS 5206 E 18.36	(*see* Note 5)	(*see* Note 5)	None	None
xxxix)	40 Ni 20 Cr	IS 4522 Grade 13						
xl)	66 Ni 17 Cr	IS 4522 Grade 14	do	(*see* Note 5)	do	do	do	do
xli)	Ni-18 Cr-18 Mo	IS 3444 Grade 19 IS 10774 Grade 13	do	IS 8736 ENiCrMo4 ENiCrMo5	do	do	do	do
xlii)	Ni-15 Cr-11 Fe	IS 3444 Grade 20 IS 10774 Grade 12	do	IS 8736 ENiCrFe-1 ENiCrFe-2 ENiCrFe-3 ENiCrFe-4	do	do	do	do
xliii)	Ni-3Fe-1 Cu	IS 3444 Grade 21 IS 11286 Grade 3	do	IS 8736 ENi-1	do	do	do	do
xliv)	Ni-30Cu-3 Fe	IS 3444 Grade 22 IS 11286 Grade 4B	do	IS 8736 ENiCu-7	do	do	do	do
xlv)	Ni-30 Mo-6 Fe	IS 3444 Grade 23 IS 10774 Grade 14 IS 11286 Grade 5	do	IS 8736 ENiMo-1	do	do	do	do
xlvi)	C-1%Cr	IS 4896 Grade 1	a, c or e (*see* Note 10)	IS 814 Exxx-51X (*see* Note 21)	IS 6419 S-2 (*see* Note 21)	IS 3613 Sections 1 and 3 or 5 (*see* Note 21)	250	600-650 (*see* Note 12)
xlvii)	C-1% Cr-Mo	IS 4896 Grade 2	do	do	do	do	300	do
xlviii)	Low carbon (case carburizing)	IS 4898 Grade 1	a, b, c, d or e	(*see* Note 5)	(*see* Note 5)	(*see* Note 5)	None	580-620 (*see* Note 8)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xlix)	3 Ni (case carburizing)	IS 4898 Grade 2	a, b, c, d or e (*see* Note 5)	(*see* Note 5)	(*see* Note 5)	(*see* Note 5)	250	580-620 (*see* Note 8)
l)	3½ Ni-Cr-Mo (case carburizing)	IS 4898 Grade 3	do	do	do	do	do	600-650
li)	0.30 *Max* carbon (low temperature)	IS 4899 Grades 1, 2 and 3	a, b, c, d or e	IS 814 Exxx-41X, Ex-xx-51 x (*see* Note 22)	do	IS 3613 Sections 1 and 2 or 5 (*see* Note 22)	None	600-650 (*see* Note 8)
lii)	C-Mo (low temperature)	IS 4899 Grade 4	do	IS 1395 E 55 B-C1 (*see* Note 22)	do	(*see* Note 5)	150	630-680
liii)	2½ Ni (low temperature)	IS 4899 Grade 5	a, b, c, d or e (*see* Note 10)	IS 1395 E 55 x-C2	do	do	do	580-620
liv)	3½ Ni (low temperature)	IS 4899 Grade 7	do	(*see* Note 5)	do	do	250	do
lv)	4½ Ni (low temperature)	IS 4899 Grade 8	do	do	do	do	do	do
lvi)	3 Ni-1½ Cr-½Mo (low temperature)	IS 4899 Grade 6						

(a — Mechanical methods including machining; b — flame gauging; c — carbon arc or metal arc gauging in combination with air or oxygen or other suitable gases; d — powder washing; e — plasma cutting)

NOTES

1 Due to the excellent weld ability of these steels, while stress relieving at 580-650°C after welding is desirable, it is not always essential. For some applications, a range of 580-620°C is specified.

2 If the section thickness or configuration is such that pre-heating is necessary, the pre-heating temperature shall be 100°C minimum.

3 In special cases, for example, if the carbon exceeds 0.35 percent or with castings having rapid changes in section and subject to a high degree of internal stress, it is recommended that an immediate post-heating of 600-650°C, followed by air cooling, be applied.

4 The tensile strength of these filler material is rather low compared with that of the cast steel specification but the yield stress is satisfactory.

5 No suitable electrode or filler wire complying with an Indian Standard is available, although suitable types may be manufactured and marketed under various trade names.

6 If any method except (a) is used, it shall be followed by grinding.

7 The actual pre-heat temperature will depend on the chemical composition. The value quoted is for analysis which is towards the upper end of the composition range. The application of a carbon equivalent formula may be helpful in determining pre-heating temperature for this grade of steel.

8 A lower post-weld heat treatment may be necessary for certain hardened and tempered castings in order to maintain the specified tensile strength, but if this is done, the time at the heat treatment temperature may have to be extended to ensure adequate stress-relief.

9 This steel shall not be pre-heated and the interpass temperature shall not be allowed to exceed 200°C.

10 If any method except (a) is used, the casting shall be pre-heated and the preparation shall be followed by grinding.

11 Depends on composition of steel; higher temperature may be necessary.

12 For heavy sections and steels of certain compositions, Note 13 may apply.

13 Extreme care is needed when welding these steels which require immediate post-weld heat treatment to minimize the risk of cracking.

14 These filler materials have non-matching compositions and/or properties to the parent casting.

15 Welds made using vanadium bearing electrodes are susceptible to carbide embrittlerment.

Table 1 (*Concluded*)

Sl No.	Type of Steel for Castings	Indian Standards and Grade	Method of Weld Preparation	Recommended for				
				Electrodes and Filler Wires (*see* 5.1)			Minimum Pre-heat Temperature (*see* 7.1) °C	Post-weld Heat Treatment Temperature Range (*see* 8) °C
				Manual metal-arc welding	Gas shielded processes	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

16 Welds in this material shall be ground at the toes, before post-weld heat treatment, if any.

17 In the cases of these steel castings, the filler wires specified are not suitable for those parts of castings subject to abrasion. In the case of these, the following consideration also apply:

a) In all cases, particularly when it is intended to use austenitic filler wires to minimize the risk of cracking, reference should first be made to the service requirements of the casting for hardness, corrosion and abrasion resistance, fatigue and tensile properties and appearance.

b) A 13 percent chromium filler wire may be used provided a satisfactory weld can be made.

18 Extreme care is needed when welding this steel which requires immediate post-weld heat treatment to avoid cracking. When certain austenitic steel electrodes or filler metals have been used it may not be essential to apply any post-weld heat treatment.

19 Weld before final heat treatment.

20 In the case of high Cr and CrNi steel castings during post-weld treatment the temper brittleness range (540-650°C) is to be avoided. Hold the casting within the prescribed range for not less than one hour per 25 mm of thickness. Quench all parts of the casting uniformly and as rapidly as possible. Material not stabilized with columbium or titanium should be cooled through the range of (920-540°C) is not more than three minutes. The rapid cooling should be continued to below 425°C. Slower cooling rates may be just as satisfactory for some composition of the material and conditions of service.

21 Should not be used for surfaces subject to abrasion.

22 Care should be taken to ensure that the low temperature weld metal properties are appropriate for service conditions.

23 For steel castings of 25 Cr 20Ni, 28Cr 20Ni and 25Ni 20Cr needing to undergo high temperature service, the use of an electrode having similar composition may not always be appropriate. In such cases, high nickel alloy electrodes (Ni-Cr-Fe type) may be the recommended choice.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
276 : 1978	Specification for austenitic manganese steel castings (*third revision*)
307 : 1966	Carbon dioxide (*second revision*)
812 : 1957	Glossary of terms relating to welding and cutting of metals
814 : 2004	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel (*fifth revision*)
1030 : 1998	Specification for carbon steel castings for general engineering purposes (*fifth revision*)
1182 : 1983	Recommended practice for radiographic examination of fusion welded butt joints in steel plates (*second revision*)
1395 : 1982	Specification for low and medium alloy steel covered electrodes for manual metal arc welding (*third revision*)
2644 : 1994	Specification for high tensile steel castings (*fourth revision*)
2707 : 1996	Specification for carbon steel castings for surface hardening (*fourth revision*)
2708 : 1993	Specification for 1.5 percent manganese steel castings (*third revision*)
2856 : 1999	Specification for carbon steel castings for pressure containing parts suitable for fusion welding (*fourth revision*)
2985 : 1990	Specification for steel castings for ships structure (*third revision*)
2986 : 1990	Specification for steel castings for marine engines and boilers (*third revision*)
3038 : 1992	Specification for alloy steel castings for pressure containing parts suitable for high temperature service (*third revision*)
3444 : 1999	Specification for corrosion resistant alloy steel and nickel based castings for general applications (*third revision*)
3600 (Part 9) : 1985	Method of testing fusion welded joints and weld metal in steel: Part 9 Macro and micro examination (*second revision*)
3613 : 1974	Specification for acceptance tests for wire-flux combinations for submerged arc welding of structural steels (*first revision*)
3657 : 1978	Radiographic image quality indicators (*first revision*)
4491 : 1994	Specification for steel castings of high magnetic permeability (*third revision*)
4522 : 1986	Specification for heat resistant alloy steel and nickel base castings (*second revision*)
4896 : 1992	Specification for one-percent chromium steel castings for resistance to abrasion (*second revision*)
4898 : 1989	Specification for steel castings for case conforming (*second revision*)
4899 : 1999	Specification for ferritic steel castings for use at low temperature
5206 : 1983	Covered electrodes for manual metal arc welding of stainless steel and other similar high alloy steels (*first revision*)
5522 : 1992	Stainless steel sheets and strips for utensils (*second revision*)
5760 : 1998	Argon, compressed and liquid — specification (*second revision*)
5856 : 1991	Specification for corrosion and heat-resisting chromium nickel steel solid welding rods and bare electrodes (*first revision*)
6419 : 1996	Welding rods and bare electrodes for gas shielded arc welding of structural steel (*first revision*)
6560 : 1996	Specification for molybdenum and chromium molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding (*first revision*)
7280 : 1974	Specification for bare wire electrodes for submerged arc welding of structural steel
7806 : 1993	Specification for ferritic and austenitic steel castings for high temperature service (*second revision*)
7899 : 1992	Specification for low alloy steel castings suitable for pressure Service (*second revision*)
8736 : 1977	Nickel and nickel alloy covered electrodes for metal arc welding

IS No.	*Title*
9541 : 1987	Specification for cast CTC segments (*first revision*)
9595 : 1996	Metal arc welding of carbon and carbon manganese steels — Recommendations (*first revision*) (superseding IS 6227)
10343 : 1999	Specification for carbon and low alloy steel investment castings for general applications (*second revision*)
10774 : 1993	Specification for corrosion resistant high alloy steel and nickel base investment castings for general applications (*first revision*)
11286 : 1995	Specification for corrosion resistant high alloy steel nickel base and cobalt base investment castings for severe applications (*first revision*)

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Review of Indian Standards

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