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November 2023

भारतीय मानक ब्यूरो

DRAFT FOR WIDE CIRCULATION

भारतीय मानक मसौदा

ऑक्सी-एसिटिलीन और हस्त धातु आर्क वेल्डिंग द्वारा ढलवाँ लोहे की ढलाइयों की मरम्मत — सिफारिशें

(*आईएस 5139 का दूसरा पुनरीक्षण*)

Draft Indian Standard

Repair of Cast Iron Castings by Oxy-Acetylene and Manual Metal Arc Welding – Recommendations

(*Second Revision of IS 5139*)

ICS 25.160.10 ; 77.080.10

Welding General and its Applications Sectional Committee, MTD 11

Last date of comment: 30/12/2023

FOREWORD

(*Formal clauses will be added later*)

This standard was originally published in 1969 and subsequently revised in 1995.While reviewing the standard in the light of experiences gained during these years, the committee decided to revise it to bring it in line with the present practices being followed by the Indian industry.

In this revision, the following changes have been made:

a) references clause has been updated;
b) clause 7.1 on order of weldability of cast iron has been added;
c) clause 22.1.1 has been added regarding the length of arc;
d) clause 23 has been modified;
e) clause 24.1.1 has been added;

The great majority of welding operations of cast iron castings come under the category of repair work, which covers such activities as salvage of defective castings, the building up of worn operations and the repair of cracks and fractures. A successful weld may be the means of saving the heavy expense or delay which might be involved by the replacement of a broken or worn casting. This standard has been prepared with a view to recommending well-established procedure for repair of cast iron casting by welding.

Unlike fabrication welding, there are no standard types of weld and each location, where welding is required, has to be considered in respect of particular characteristics. Similarly, no acceptance levels for completed welds are specified. Therefore, these parameters should be mutually agreed to between the purchaser and the supplier.

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 : 2022 'Rules for rounding off numerical-values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Draft *Indian Standard*

REPAIR OF CAST IRON CASTINGS BY OXY-ACETYLENE AND MANUAL METAL ARC WELDING — RECOMMENDATIONS

(*Second Revision*)

1 SCOPE

1.1 This standard covers recommended procedures for repair of cast iron castings by welding.

1.2 Iron castings, referred in this standard, cover the following categories of cast iron castings:

i) Grey cast iron,
ii) Low alloyed cast iron,
iii) Pearlitic cast iron,
iv) Malleable cast iron, and
v) Nodular or ductile cast irons.

1.3 Section 1 of this standard describes general guidance on classification of defects, decision making for repairs, preparation of repairs, inspection before and after removal of defects and also after repair, etc. Section 2 describes the procedures for repair welding by gas welding process and Section 3 describes the procedures for repair welding by manual metal arc welding process.

2 REFERENCES

The following standards 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 agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
IS 1278 : 1972	Filler rods and wires for gas welding (*second revision*)
IS 2595 : 2008	Industrial radiographic testing — Code of practice (*second revision*)
IS 2953 : 1985	Glossary of terms used for interpretation of welds and castings radiograph (*first-revision*)
IS 3658 : 1999	Code of practice for liquid penetrant flaw detection (*second revision*)
IS 5334 : 2014	Magnetic particle flaw detection of welds — Code of practice (*third revision*)
MTD/11/23176	Welding consumables — Covered electrodes wires rods and tubular cored electrodes for fusion welding of cast iron — Classification (*second revision*)

IS 8780 : 2004 Non - Destructive testing of steel castings — Code of practice (*first revision*)

SECTION 1 REPAIRABLE DEFECTS, THEIR CLASSIFICATION, DECISION MAKING FOR REPAIRS, PREPARATION FOR WELDING AND INSPECTION

3 REPAIRABLE DEFECTS

Defects, such as porosities, sand holes, washouts, cracks, broken off portions, error in machining may be considered for repair by welding ascertaining that the repair to be conducted on the casting does not adversely affect any of the following conditions:

i) Serviceability of the casting,

ii) Machinability of the casting if required to be machined after repair welding, and

iii) Colour mismatch if happens due to a certain welding process will be of no consequence.

4 MINOR AND MAJOR DEFECTS

4.1 The defects may be considered as minor defects which fall into the following categories;

i) The defect must be located at an unstressed and non-critical area of the casting,

ii) The repair welding is confined to correction of defects that may affect only the appearance of the casting,

iii) Reduction in mechanical properties and machinability due to repair welding are of no significance,

iv) The cavity after removal of defect is confined within 10 percent of section thickness at the location of defect or the maximum depth of the cavity being 10 mm whichever is less, and

v) Distortion effected due to welding heat is minimum.

4.2 All defects, their extent, locations, effect on casting after repair welding not covered by **4.1** shall be considered as major defects.

5 TECHNICAL CONSIDERATIONS TO REPAIR A CASTING BY WELDING

5.1 The decision to repair a new casting to be supplied to a customer shall be taken on the basis of mutual agreement on the extent of repair and process to be followed.

5.2 The decision to repair a used or old casting will depend on the user’s discretion for reconditioning the casting for further use depending on the serviceability and/or machinability of the repaired casting.

5.3 Availability of facilities and skill to do the welding of required quality shall be taken into consideration before undertaking repair of casting by welding.

6 INSPECTION OF CASTING BEFORE REPAIR

6.1 The casting shall be inspected by visual method under adequate lighting. The rough casting shall be shot blasted before inspection.

6.2 Used casting smeared with grease or oil shall be degreased by suitable method before visual inspection.

6.3 Non-destructive testing method, such as magnetic particle inspection or dye penetrant test, shall be used to detect surface defects if necessary.

6.4 Leakage test shall be conducted on casting required to be leak proof to detect leakage locations.

6.5 The defective areas shall be clearly marked before repair by welding.

7 PREPARATION FOR WELDING

7.1 The order of weldability of cast iron (from good to poor) is as follows:

a) Spheroidal Graphite (SG) iron and malleable iron.
b) Ferritic and pearlitic Grey Iron
c) Alloy cast iron and white cast iron

7.2 The casting shall be properly cleaned to be made free from dirt, rust, sand, etc.

7.3 All traces of cutting oil shall be removed by solvent cleaning.

7.4 Impregnated oil, grease or other volatile matters if present on used casting shall be burnt out completely by heating with a neutral flame of oxyacetylene torch to approximately 450 to 500°C. Sealed internal passages if any must be vented to prevent explosion during heating.

7.5 Suitable method, for example, electrolytic process, for removal of graphites before braze welding may be adopted wherever possible.

7.6 Casting skin shall be removed from surfaces to be welded and from adjacent areas by grinding, chipping, filing or any other equivalent means.

7.7 Sharp corners and edges shall be rounded off. Bottom of the cavity shall be made shallow in case of removal of porosities, sands, inclusions, cold shuts, etc.

7.8 In case of cracks not extending from end to end of a casting, holes should be drilled at both crack tips to prevent them from extending during edge preparation and welding.

7.9 In case of defect extending throughout the section of a completely broken section, the edges shall be bevelled to make single, double *V* or *U* groove depending on the thickness of the section to be joined 1.5 to 3 mm of material to be left at the root face to align the parts. For double *V* groove joint, the face should be near the center of the section to permit alignment. *V* groove shall

have an inclined angle of 60 to 90° to permit proper manipulation of torch and welding rod. For very thick section, *U* groove may be done with a smaller groove angle of 30°.

7.10 General guidance for making *V* grooves depending on section thickness is as given below:

i) Single *V* groove for casting thickness of 3 mm and under 12 mm,

ii) Double *V* groove for casting thickness of 12 mm and above, and

iii) If the casting is very thick it is advisable to leave a portion of the original fracture at the ends to assist alignment.

7.11 Standards for bevelling the edges are given in Fig. 1A to 1E.

7.12 Thin casting below 3 mm thickness may be joined without making any *V* groove as illustrated in Fig. 1F.

8 INSPECTION OF CASTING AFTER PREPARATION FOR WELDING

8.1 The casting ready for repair by welding shall be inspected by the following methods either single or in combination depending on the merit of the case:

i) Visual inspection under adequate lighting,

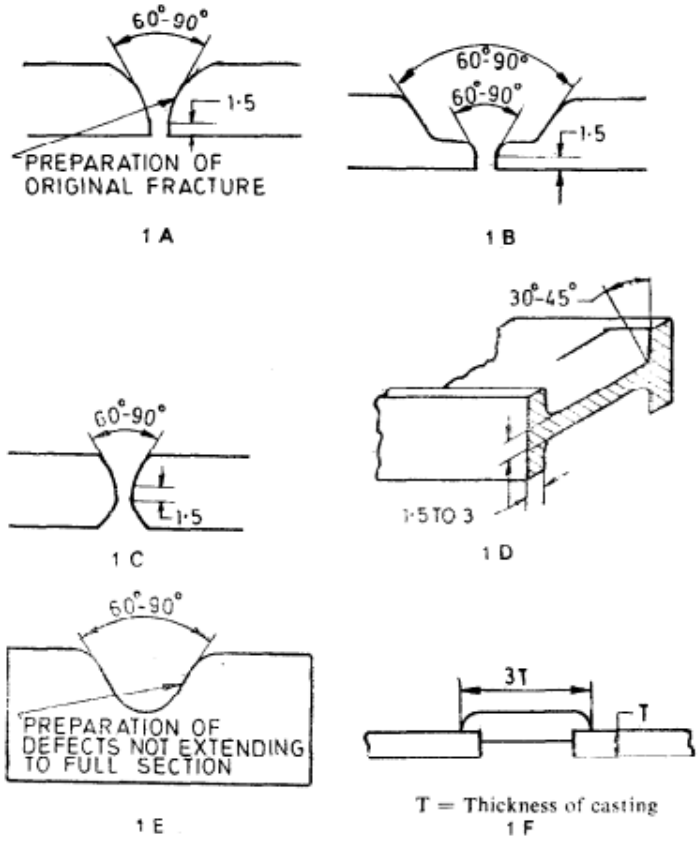
ii) Magnetic particle inspection (*see* IS 5334),

iii) Dye penetrant test (*see* IS 3658), and

iv) Radiography (*see* IS 2595 and IS 2953).

NOTE – Reference may also be made to IS 8780.

8.2 A defect map should be prepared and documented indicating the locations, size, depth and extent of cavities prepared for repair of major defects in case of critical component especially safety items.



All dimensions in millimetres.

FIG. 1 PREPARATION OF CAST IRON EDGES FOR WELDING

9 INSPECTION OF CASTING AFTER REPAIR BY WELDING

9.1 The casting after repair by welding shall be inspected for weld defects such as pinholes, blow holes, craters, undercut, HAZ cracks, etc by methods as per **8.1**.

9.2 Casting shall be tested for leaks in case of leak proof casting by suitable means. The test medium must not adversely affect the adherence of any paint that may be subsequently applied.

SECTION 2 PROCEDURES FOR REPAIR OF IRON CASTINGS BY GAS WELDING

10 METHOD OF WELDING

Two gas welding methods may be employed for repair of cast iron castings:

i) Fusion welding, and
ii) Braze welding.

11 FUSION WELDING OF CAST IRON CASTINGS

11.1 Preparation for Welding

Preparation of the casting for repair by gas welding and inspection before and after preparation shall be as described in Section 1.

11.2 Pre-heating

11.2.1 *Local Pre-heating*

The casting shall be pre-heated locally to a temperature between 500 to 670°C immediately before start of welding.

11.2.1.1 Small castings and castings without restraints in their design, for example, free to expand and contract during the welding cycle may be pre-heated locally by means of oxy-fuel gas flame. Pre-heating temperature should be checked with contact pyrometer or thermal crayons.

11.2.2 *Total Pre-heating*

Small castings may be pre-heated totally by means of oxy-fuel gas flame. Larger castings should be pre-heated in oil fired, gas fired or electric furnace. Total pre-heating may also be performed by induction heating method.

12 CONSUMABLES

12.1 Filler Rod

12.1.1 Cast iron welding rod conforming to IS 1278 should be chosen depending on the composition of the cast iron castings to be repaired.

12.1.2 Cast iron welding rods of same composition of casting prepared inhouse by the manufacturer of casting may also be used.

12.2 Size/Diameter of Rod

As a general guidance 3.15 to 5 mm diameter rods should be used for material thickness up to 6 mm. Above this thickness the welding rod size should be approximately half the material thickness to a maximum of 12 mm.

12.3 Fluxes

12.3.1 Suitable grade of flux as recommended by the manufacturers of filler rod should be used.

12.3.2 Borax of Boric acid powder mixed with calcium silicide as inoculant, which is 5 percent by weight of borax or boric acid powder, may also be used as flux.

12.4 Gases

Oxygen and acetylene shall be used.

13 WELDING TECHNIQUE

13.1 Sequence of Welding

13.1.1 Wherever possible, the weld should be completed for its full depth in one run. Intermittent welding of short runs and layer welding should be attempted in case of material of higher thickness. Interpass temperature should be maintained at the preheating temperature.

13.2 Welding Position

Welding of grey iron castings should be done in flat position. Leftward or forward method should be adopted while welding cast iron. The blow pipe should be kept at quite a steep angle.

13.3 Welding Speed

In repair of grey iron castings, it is rarely necessary to weld over a considerable length. Table 1 gives an approximate idea of the time necessary for welding cast iron plates of various thicknesses.

Table 1 Time for Welding Cast Iron, Plates

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Sl No.	**Plate Thickness** *mm*	**Welding Time per 100 mm of Weld** *Min*
(1)	(2)	(3)
i)	6	3
ii)	12	5
iii)	18	10
iv)	25	16
v)	32	20
vi)	36	26

13.4 Flame Adjustment

The flame should be strictly neutral.

13.4.1 The face of the flame should be used to keep the molten metal in place.

13.4.2 The inner core of the flame should be directed against the tip of the welding rod, melting it off at the rate indicated by the fusion of the filler and parent metals.

13.5 Medium or high velocity torch tips should be in preference to low velocity torch tips. As a general guidance torch tip sizes for different thickness of cast iron to be welded and a corresponding regulator pressure for acetylene is given in Table 2.

Table 2 Torch Tip Size, Material Thickness and Acetylene Regulator Pressure for Gas Welding of Cast Iron

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Sl No.	**Torch Tip**		**Material Thickness** mm	**Acetylene Regulator Pressure** MPa
	Number	Size mm		
(1)	(2)	(3)	(4)	(5)
i)	0	0.64	0.8	0.014 to 0.069
ii)	1	0.79	1.6	
iii)	2	0.96	2.4	
iv)	3	1.19	3.2	0.017 to 0.069
v)	4	1.40	4.8	
vi)	5	1.70	6.4	
vii)	6	1.93	8.0	0.021 to 0.069
viii)	7	2.18	9.5	
ix)	8	2.49	12.5	
x)	9	2.79	15.9	
xi)	10	3.25	19.0 and higher	

14 FINISHING THE WELD

14.1 Slags on the weld surface shall be removed by brushing while the weld is still hot.

14.1.1 Adequate peening on hot weld metal should be done.

14.2 Casting shall not be hammered after welding.

14.3 After completion of welding, the repaired casting shall be allowed to cool down as slowly and evenly as possible. Depending on the size and shape, the casting after welding shall be covered with heat insulating material like lime. If necessary, the casting should be put into a furnace and allowed to cool slowly at a rate of not more than 50°C per hour.

15 POST-HEAT TREATMENT

15.1 Stress relieving of repaired casting at 650 to 680°C depending on section thickness is to be conducted to satisfy the following conditions:

a) Severe service conditions;
b) Trouble free machining; and
c) Maintenance of close tolerance after machining.

16 INSPECTION AFTER FINISHING OF WELD

16.1 Inspection of casting after finishing of weld shall be conducted as per **8.**

16.2 In case casting is subjected to post-weld heat treatment inspection shall be also conducted after post-weld heat treatment as per **8.**

17 BRAZE WELDING OF CAST IRONS

17.1 Preparation for Braze Welding

Preparation for braze welding should be done in accordance with the guidance given in **6**.

17.2 Pre-heating

Pre-heating temperature should be at around 480°C. The casting should be heated uniformly.

17.3 Welding Technique

17.3.1 *Brazing Welding Rod*

17.3.1.1 For general use, the braze welding rod should conform to IS 1278.

NOTE – Braze welding rod other than those specified in **17.3.1 .l**, may be used after mutual agreement with the customer.

17.4 Blow Pipe Nozzle

Blow pipe nozzle sizes are governed by the degree of pre-heating. Smaller should be the nozzle size higher the pre-heating temperature. Blow pipe nozzle should be about two sizes smaller than for butt welds of steel of the same thickness.

17.5 Flame Adjustment

The flame should be first adjusted to neutral after setting the pressures as recommended for the size of the nozzle chosen. The acetylene value is then chosen to give a very slight excess of oxygen.

17.6 Flux

Flux as recommended by the manufacturer of rod should be used.

17.7 Braze Welding

Position Braze welding should be done by the left ward or upward vertical method according to position of the joint, the welding blow pipe being given steadily semi-circular movement. The braze should not be allowed to run forward and wet the heated surface. The end of the rod should be kept between the core of the flame and the edges of the metal, to prevent them from overheating. It is of assistance if the casting may be supported so that welding is carried out uphill at from 30° to 70° from the horizontal. Figures 2 and 3 show relative angles of the rod, blow pipe and position of the weld, and movement of rod respectively. Single or double operator vertical technique may be employed in bronze welding depending on the accessibility to the joint for welding. In case of difficulty to control large pool of molten metal while braze welding heavy section from one side

heat method may be used. The metal is deposited into series of cups formed by steel cleats placed across the *V*. These control the metal so that a large blow pipe may be used increasing the speed of working on sections of thickness 25 mm and over, where otherwise it is hard to avoid spilling the molten braze metal as illustrated in Fig.4.

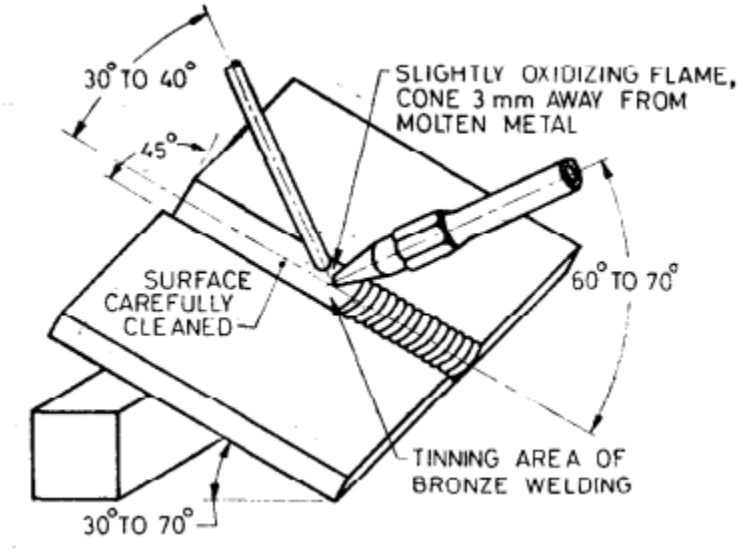

FIG. 2 ANGLES OF RODS AND BLOWPIPE FOR BRONZE WELDING

17.8 Inspection After Braze Welding

Braze welded casting shall be inspected in accordance with guidance given in **8.**

SECTION 3 WELDING OF CAST IRON BY MANUAL METAL ARC PROCESS

18 GENERAL ELECTRODES FOR WELDING

In the repair of cast iron castings by manual metal arc welding process, the choice of electrode is governed by various factors, such as the strength of the weld required, post-weld finishing method to be employed, service conditions and cost of welding. Generally, the following four types of electrodes are used:

i) Cast iron electrodes,
ii) Steel base electrodes,
iii) Ni and Fe-Ni base electrodes, and
iv) Copper base electrodes.

The electrodes, their applications and general properties of the weld metal are covered by MTD/11/23176. Any other electrodes falling under the above general types may also be used after mutual agreement with the customer.

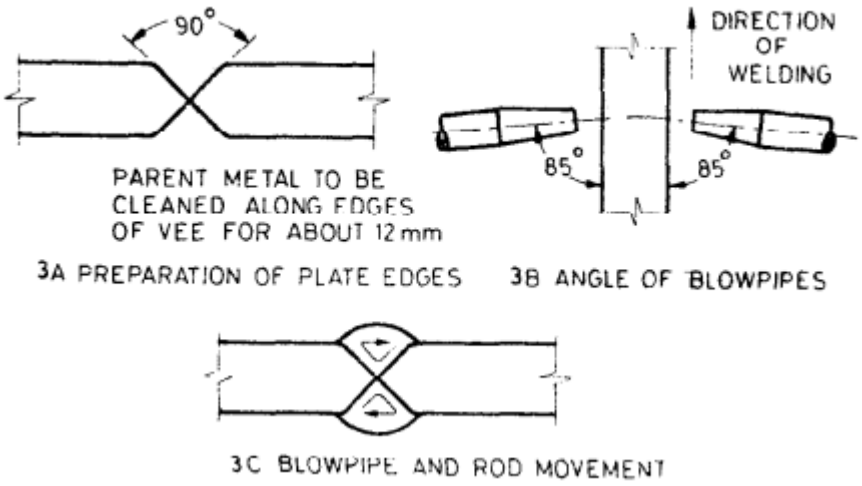

FIG. 3 PREPARATION AND TECHNIQUE FOR TWO-OPERATOR VERTICAL BRONZE WELDING OF CAST IRON

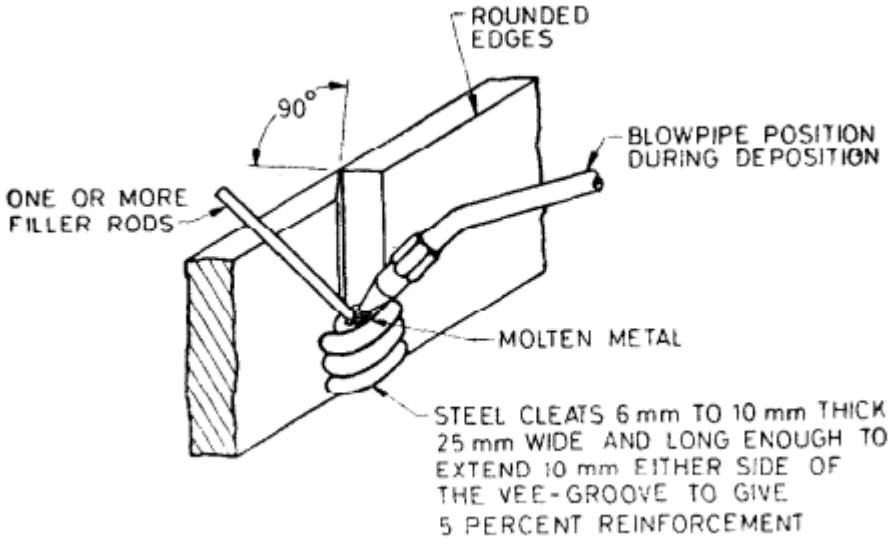

FIG. 4 CLEAT METHOD OF BRONZE WELDING

19 PREPARATION FOR WELDING

The casting shall be prepared for welding in accordance with guidance given in **6**.

20 PRE-HEATING

Pre-heating is recommended from 150 to 760°C while using cast iron electrodes which depends on the size of the work piece and the machinability desired. Subsequent run should be deposited without delay to prevent cooling. While using steel base electrodes, pre-heating within the range of 500 to 650°C may be followed depending on the size of the work piece and its complexity. Pre-heating gives better results as regards machinability, residual stresses etc.

For Ni and Fe-Ni base electrodes normally pre-heating is not required. Joints should be preheated to a temperature between 150 to 200°C while using copper bases electrodes.

21 WELDING CURRENT

Welding current conditions and the amperage shall be as recommended by the electrodes manufacturers.

22 WELD RUN SEQUENCE AND BEADS

22.1 Generally short runs of maximum length of 25 to 40 mm should be deposited, by preference using the back step welding technique. In the usual sequence a new run shall be started at the end of the preceding one. In back step welding, however, the direction of welding is towards the start point of the preceding run, instead of following the usual welding sequence as illustrated in Fig. 5 and 6.

22.1.1 The arc should be struck in the weld groove and not on the casting. The arc length should be kept as short as possible.

22.2 Stringer bead of short lengths are to be deposited up from the weld bead.

23 PEENING

Light hot peening should be done while removing slag for every pass of weld metal deposited.

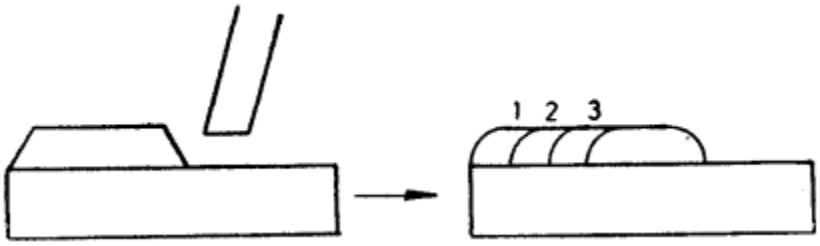

FIG. 5 USUAL SEQUENCE OF WELDING

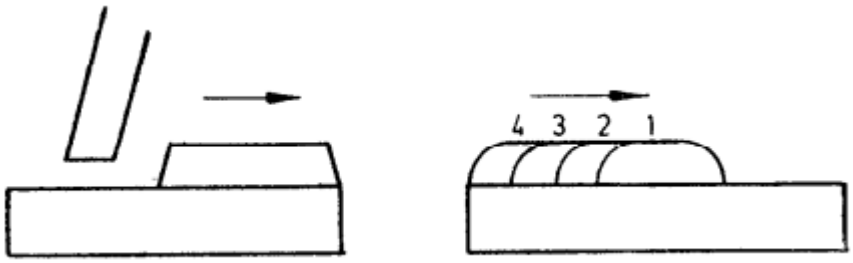

FIG. 6 SEQUENCE OF BACK STEP WELDING

24 POST-WELD HEAT TREATMENT

24.1 Post-weld heat treatment after welding should be decided on the following factors:

i) Type of welding done either hot or cold,
ii) Trouble free machining,
iii) Service condition, and
iv) Final mechanical properties.

24.1.1 Normally stress relief is performed immediately after welding by increasing the temperature of the entire casting into 590-620°C range. The casting is held in the temperature range of 590-620°C about 1 hour / inch of the thickness. The cooling rate should not exceed (shall not be more than) 30°C/ hour, until the casting has cooled down to a temperature of about 370°C.

24.2 Casting welded with cast iron, steel base, Nickel and ferro nickel base electrodes may be stress relieved or given an annealing or normalizing cycle depending on the requirements as per **24.1.**

25 INSPECTION AFTER COMPLETION OF WELDING

Inspection of casting after completion of weld shall be conducted as per **8**.

26 SPECIAL REPAIR WELDING TECHNIQUE

26.1 On highly stressed work pieces and components of high thickness, the application of stud bolts studding might be considered. In some cases it may be practicable and more desirable to shape out grooves in the casting with a round nosed tool, instead of studding. Figures 7 and 8 show the usual procedure of studding and grooved edges respectively.

26.2 In repairing a cast iron part which has cracked right through as shown in Fig. 9 and which is accessible only from one side, bevelling may be dispensed with end studs screwed in a straight line on either side of the crack. A mild steel weld deposit is then made corresponding to a butt strap in a riveted splice. The transverse strength of such a joint when properly executed equals the sheer value of the studs. Joints made by the studding process are seldom reliable for tightness against fluids and gases as the weld metal pad often breaks away from the casting during cooling.

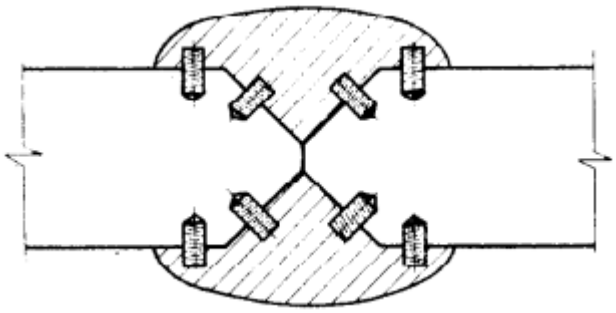

FIG. 7 USUAL PROCEDURE OF STUDDING FOR CAST IRON WELDING

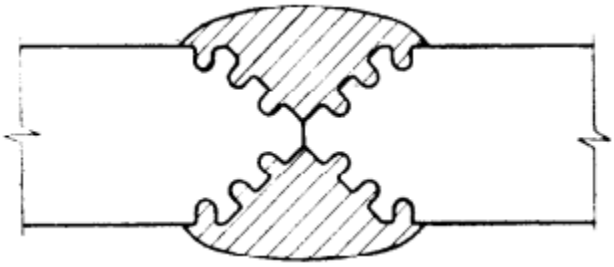

FIG. 8 GROOVES INSTEAD OF STUDS IN WELDING CAST IRON

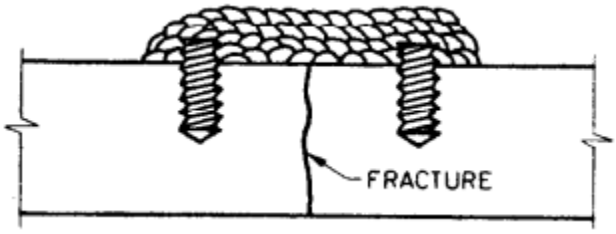

FIG. 9 REPAIR OF CASTING BY STUDDING