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(पहला पुनरीक्षण)

Indian Standard

METAL-ARC WELDING OF CARBON AND CARBON MANGANESE STEELS — RECOMMENDATIONS

(First Revision)

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BUREAU OF INDIAN STANDARDS
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Welding Applications Sectional Committee, MTD 12

FOREWORD

This Indian Standard (First 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.

This standard was first published in 1980. 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.

This standard relates to the welding of particular types of steel regardless of the form in which the steel is used, for example, plates, sections or tubes. It has been used extensively over a wide field of fabrication and has been recognized as a comprehensive welding standard.

Annexures are included to give guidance on factors that should be considered in establishing welding requirements and procedures for a particular fabrication. Permissible stresses in welds, methods of testing and acceptance levels are not specified. These requirements should be obtained from the relevant application standard or by agreement between the purchaser and the fabricator.

This standard keeps in view the practices being followed in the country in this field. Assistance has also been derived from BS 5135 : 1984 'Specification for process of arc welding of carbon and carbon Manganese steels', issued by the British Standards Institution.

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, 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

METAL-ARC WELDING OF CARBON AND CARBON MANGANESE STEELS — RECOMMENDATIONS

(*First Revision*)

1 SCOPE

1.1 This standard recommends general requirements for the manual, semi-automatic and automatic metal arc welding of carbon and carbon manganese steel in all product forms including tubes and hollow sections, complying with the requirements of **5**.

1.2 The annexures are intended to assist users of this Standard by giving guidance on various topics.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
307 : 1966	Carbon dioxide (*second revision*)
812 : 1957	Glossary of terms relating to welding and cutting of metals
813 : 1986	Scheme of symbols for welding
814 : 1991	Covered electrodes for metal arc welding of structural steel
816 : 1969	Code of practice for use of metal arc welding for general construction in mild steel (*first revision*)
822 : 1970	Code of procedure for inspection of welds
1024 : 1979	Code of practice for use of welding on bridges and structures subject to dynamic loading (*first revision*)
2062 : 1992	Steel for general structural purposes — Specification (*fourth revision*)
8500 : 1991	Structural steel-microalloyed (medium and high strength qualities) — Specification (*first revision*)
3613 : 1974	Acceptance tests for wire-flux combinations for submerged arc welding of structural steels (*first revision*)
4353 : 1967	Recommendations for submerged arc welding of mild steel and low alloy steels
5760 : 1983	Compressed argon (*first revision*)
6419 : 1971	Welding rods and bare electrodes for gas shielded arc welding of structural steel
7280 : 1974	Base wire electrodes for submerged arc welding of structural steels
7307 (Part 1) : 1974	Approval tests of welding procedures: Part 1 Fusion welding of steel
7310 (Part 1) : 1974	Approval tests for welders working to approved welding procedures: Part 1 Fusion welding of steel
7318 (Part 1) : 1974	Approval tests for welders when welding procedure approval is not required : Part 1 Fusion welding of steel
10178 : 1982	Recommended procedure for CO_2 gas shielded metal-arc welding of structural steels
13851 : 1993	Storage and redrying of covered electrodes before use — Recommendations

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 812 : 1957 and the following shall apply.

3.1 Auto-Contact Welding

An automatic metal-arc welding process using covered electrode the covering of which is kept in contact with the parent metal during welding.

3.2 Gravity Welding

Metal-arc welding using a contact electrode supported by a mechanism which allows the electrodes to descend and move along the joint under gravity.

4 INFORMATION TO BE SUPPLIED

The information either supplied by the purchaser or decided between the purchaser or his representative and the fabricator as appropriate shall include the following:

a) Specification of the parent metal and of the required weld metal and weld joint properties,

b) The application standard or code to be applied together with any supplementary requirements;

c) Locations, dimensions and details, that is, form of joint, angle between fusion faces, gaps between parts, of all welds. Symbols conforming to IS 813 : 1986 should be used for standard weld forms, but details shall be given for any non-standard welds;

d) Whether the welds are to be made in the shop or elsewhere;

e) Surface finish of weld profile;

f) Pre-and post-weld heat treatment;

g) Whether written welding procedures and/or tests are required;

h) Quality control arrangements and testing and inspection requirements;

j) Weld acceptance levels; and

k) Whether means of identification on welds to trace back to the welders is required and if so means to be used.

5 PARENT METAL

5.1 The requirements of this standard apply to carbon and carbon manganese steels both semi-killed and killed having chemical analysis determined by ladle analysis and refer to steels up to a maximum carbon equivalent of 0.53 when calculated using the following formula:

Carbon Equivalent

$$= C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

NOTE — This carbon equivalent formula may not apply to carbon manganese steels of low carbon content (less than 0·10 percent) or boron containing steels and therefore the guidance given in F-3.1 should be followed.

5.2 The requirements of this standard may be applied to steels whose carbon equivalent exceeds 0·53, but it should be borne in mind that fabrication experience above this level is limited, particularly with respect to the effects of higher strength levels and higher alloy contents (as in quenched and tempered weather-resistance grades of steel). In this respect, users should consult the steel maker, the welding consumable supplier or other appropriate authoritative sources with regard to the welding procedures (*see* **23**).

5.3 Requirements of these standards may be applied to the steels in as rolled and normalized conditions.

6 DISSIMILAR STEELS

While welding joints between dissimilar carbon or carbon manganese steels covered by this standard, the welding procedure shall be that relating to the steel having the higher carbon equivalent unless otherwise required by the designer.

7 WELDING CONSUMABLES

7.1 Manual Metal-Arc Welding

The electrodes used for manual metal-arc welding shall comply with the requirements of IS 814 : 1991 or other appropriate standard. Electrodes should be selected having regard to the application, that is, joint design, welding position, current conditions and the properties required to meet the service conditions.

7.2 Semi-Automatic and Automatic Metal-Arc Welding (Covered Electrodes)

This group of processes embraces 'gravity' and 'autocontact' welding with long straight lengths of covered electrode and open-arc welding with a continuous covered electrode. The weld metal produced from electrodes used with these processes shall have mechanical properties not less than the minimum specified for the weld metal produced by electrodes complying with IS 814 : 1991, except otherwise specified in the standard for the particular application.

7.3 Submerged Arc Welding

Electrode wire shall conform to IS 7280 : 1974. The electrode wire and flux combination shall satisfy the requirements dictated by factors such as the welding procedure and position and shall comply with the appropriate sections of IS 3613 : 1974. The combination should be selected having regard to particular application.

7.4 Gas-Shielded Processes

7.4.1 *Filler Rods and Wires*

When a solid metal filler rod or wire is used with a gas shielded process, it shall comply with the requirements of IS 6419 : 1971 and should be selected having regard to the particular application.

7.4.1.1 Cored electrodes, when used with the appropriate shielding gas or gas mixture, shall give weld metal properties not less than the minimum specified for grade of material being welded.

7.4.2 *Shielding Gases*

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

a) *Argon* — The gas shall conform to IS 5760 : 1983.

b) *Carbon Dioxide* — The gas shall conform to IS 307 : 1966. Sound welds can be made consistently if the electrode designed for use with carbon dioxide contains the appropriate balance of de-oxidizers.

c) *Gas Mixtures* — The use of gas mixtures is permissible provided they have been proved to be satisfactory. This may be as a result of procedure approval tests where in sufficient previous experience exists. When a gas mixture is used which has specified additions, the variation of such additions shall not exceed ±10 percent of the stated.

The following are some typical gas mixtures:

a) Gas shielded tungsten arc process
   1) Argon
   2) Argon + Helium

b) Gas shield metal arc welding
   1) Argon + 3 to 5 percent oxygen
   2) Argon + 1 to 2 percent oxygen
   3) Carbon dioxide using de-oxidizing electrodes
   4) Argon + 20 to 50 percent carbon dioxide
   5) Argon + 10 percent carbon dioxide + 5 percent oxygen using de-oxidizing electrodes
   6) Carbon dioxide + 20 percent oxygen
   7) 75 percent argon + 25 percent carbon dioxide

7.5 Unshielded Semi-Automatic Arc Welding

Electrodes for this process are generally of the cored type and shall deposit weld metal with mechanical properties not less than those specified as satisfactory for the particular grade of steel being welded. Exceptions may be allowed if specified in the particular application standard being used.

7.6 Hydrogen Levels

When hydrogen controlled welding consumables are to be used the contractor shall be able to demonstrate that he has used the consumables in the manner recommended by the consumables manufacturer and that the cosumables have been dried or baked to the appropriate temperature levels and times.

7.7 Storage and Handling

7.7.1 *General*

All consumables shall be stored and handled with care and in accordance with the manufacturer's recommendations. Electrodes, filler wires and rods and fluxes that show signs of damage or deterioration shall not be used. Examples of damage or deterioration include cracked or flaked coatings on covered electrodes, rusty or dirty electrode wires and wires with flaked or damaged copper coatings.

7.7.2 *Covered Electrodes*

Electrodes shall be stored in their original packets or cartons in a dry and well ventilated, preferably under heated conditions where relative humidity (RH) shall be less than the external conditions (preferred RH is approximately less than 50 percent). Use of racks, pallets or other suitable means to store electrodes off the floor is recommended. The ideal storage temperature is about 10-15°C above the ambient temperature. When special protection or other treatment during storage or immediately prior to use is recommended by the manufacturers of the electrodes, they shall be treated in accordance with the recommendations of the mauufacturers (*see* **3.1** of IS 13851 : 1993).

7.7.2.1 In order to ensure that the weld metal deposited by hydrogen controlled electrodes falls within the limits of the appropriate carbon equivalent scale besides the weld metal soundness, these electrodes shall be redried at 360°C for an hour or as recommended by the manufacturers (*see* **6** of IS 13851 : 1993).

7.7.2.2 After removal from the drying oven, the electrodes shall be protected from exposure to conditions conductive to moisture absorption, preferably by being kept in a heated secondary oven, if the lowest hydrogen levels are desired. All unused electrodes shall be returned to the storage so that they are not exposed to unheated and possible damp working area where they can regain moisture (*see* **6** of IS 13851 : 1993).

7.7.3 *Automatic and Semi-Automatic Welding*

Wire or cored electrodes shall be suitably packed to guard against damage, including that during transportation. When stored, the wire or electrode should be kept in its original bundle or package in a dry store room.

7.7.3.1 The performance of copper coated wires depends on the continuity and regularity of the copper coating. Such considerations should be the subject of agreement between the fabricator and the supplier of copper coated wires.

7.7.3.2 Flux shall be packed in moisture, resistant containers and shall be protected from damage, including that during transportation. When stored,· the flux should be kept in its original container in a dry store room.

7.7.3.3 If the composition of the flux is such that special protection during storage or special treatment before use is desirable details of such special protection or treatment shall be furnished by the manufacturer of flux and implemented by the fabricator. Regrinding of welding slag to be used in admixture with fresh flux is not recommended.

8 EQUIPMENT

8.1 Power Source

Welding power source, instruments, cables and accessories shall comply with the requirements of the appropriate Indian Standards where available. The contractor shall be responsible for ensuring that their capacity is adequate for the welding procedure to be used and maintaining all welding plant and ancillary equipment in good working order.

8.2 Earthing

All power sources and implements in connection with the welding operation shall be adequately earthed. The welding return lead from the work shall be adequate in cross section and shall be correctly connected and earthed.

8.2.1 The importance of proper earthing cannot be over-stressed since incorrect earthing may lead to lower current, lower arc voltage, overheating of electrode holders, defective welds, etc.

8.3 Instrumentation

Adequate means of measuring the current shall be available, either as part of the welding power, source or by the provision of a portable ammeter.

8.3.1 In the cases of automatic and semi-automatic welding, means shall be provided for measuring the arc voltage, current and/or wire feed speed, and the rate of flow of shielding gases.

9 BUTT-WELD DETAILS

9.1 The details of all butt-welds, for example, form of joint, angle between fusion faces and gap between parts, shall be arranged to permit the use of a satisfactory welding procedure and the combination of weld detail and welding procedure shall be such that the resultant joint will comply with the requirements of the design (*see* Annexes A,B, C and D).

9.2 Throat Thickness

The ends of butt joints in plate shall be welded so as to provide the full throat thickness. This may be done by the use of extension pieces or other means approved by the purchaser.

9.3 Weld Profile

In the as-welded condition, the weld face shall be ground (having some reinforcement) of the surface of the parent metal. Where a flush surface is required, the excess weld metal shall be dressed off. When no dressing is to be carried out, the permissible weld profile shall either be as specified in the application standard or be subject to agreement between the purchaser and the fabricator.

9.4 Full Penetration

Full penetration single V.U.J bevel or square butt welds shall be completed by grinding, chipping or gouging the root run from opposite side to sound metal and then depositing a sealing run of weld metal on the back of the joint. Where these or other butt welds are to be welded from one side only, suitable backing material shall be used except where it is agreed between the purchaser and the contractor that, by the adoption of an approved special method of welding, full penetration will be obtained without the use of backing material. It should be appreciated, however, that under fatigue and corrosive conditions backing material may be undesirable.

9.5 Backing Material

9.5.1 Backing material, if used, shall be of same quality as that of parent material or as agreed to by the purchaser.

NOTE — Care shall be taken when using copper as a backing material as there is a risk of copper pick up in the weld metal.

9.5.2 Where backing material is employed, the joint shall be arranged in such a way as to ensure that complete fusion of the parts to be joined is readily obtained.

9.6 Back Gouging

In all complete penetration butt-welds, where these are to be welded from both sides, certain welding procedures allow this to be done without back gouging, but where complete penetration cannot be achieved, the back of the first run shall be gouged out by suitable means to clean sound metal before welding is started on the gouged out side (*see* Fig. 1).

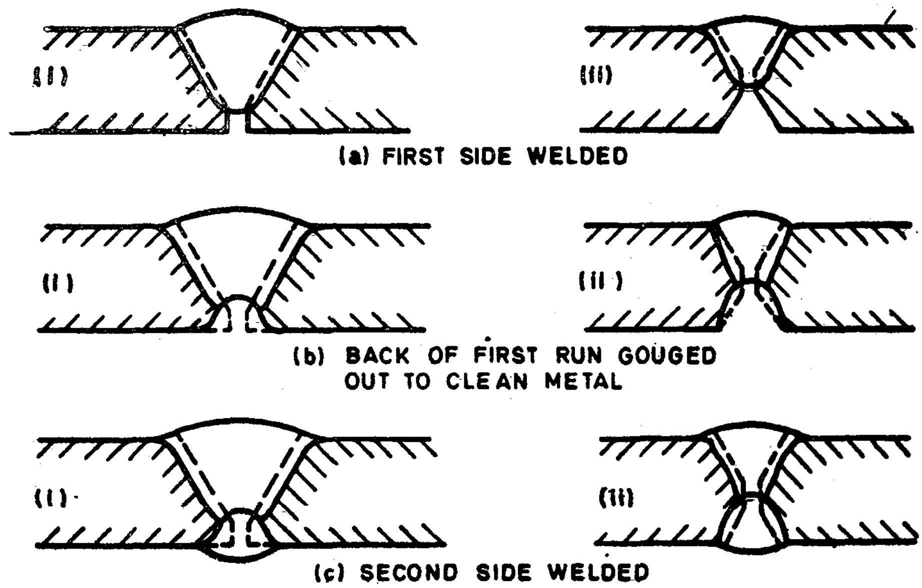


FIG. 1 METHOD OF GOUGING OUT COMPLETE PENETRATION BUTT-JOINTS WELDED FROM BOTH SIDES

10 PARTIAL PENETRATION BUTT-WELDS

10.1 A butt-weld which is designed as a partial penetration weld shall have a throat thickness not less than specified.

10.2 An incomplete penetration butt-weld which is welded from one side only shall not be subjected to a bending moment which would cause the root of the weld to be in tension, unless this is allowed by the application standard.

10.3 The use of incomplete penetration butt-welds to resist repeating or alternating dynamic forces should be avoided (*see* Annex A).

11 FILLET WELD DETAILS

11.1 A fillet weld, as deposited, shall be not less than the specified dimensions which shall be clearly indicated as throat thickness and/or leg length as appropriate, taking into account the use of deep penetration processes or partial preparations (*see* Annex D).

11.2 For concave fillet welds, the actual throat thickness shall be not less than 0·7 times the specified leg length. For convex fillet welds, the actual throat thickness shall be not more than 0·9 times the actual leg length.

11.3 Where the specified leg length of a fillet weld at the edge of a plate or section is such that the parent metal does not project beyond the weld, melting of the outer corner or corners, which reduces the throat thickness, shall not be allowed (*see* Fig. 2).

NOTE — Guidance on the design of fillet welds is given in A-2.

12 WELDS IN SLOTS

Slots that are required to be filled with weld metals shall only be filled after the fillet weld has been inspected and approved. When filling slots with weld metal, care shall be taken to avoid cracking.

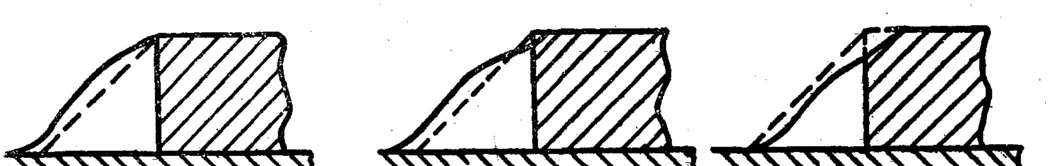


FIG. 2 FILLET WELDS APPLIED TO THE EDGE OF A PART

13 PREPARATION OF JOINT FACES

13.1 If preparation or cutting of the material is necessary, this shall be done by shearing, chipping grinding, machining, thermal cutting or thermal gouging. Other methods shall only be used by agreement between the contracting parties. When shearing is used, the effect of work hardening shall be taken to ensure that there is no cracking of the edges.

13.2 In cases where the cut edge is not a fusion face, the effect of embrittlement from shearing, thermal cutting or thermal gouging shall not be to the detriment of the performance of the fabrication. As a general guide, a hardness of 350 HV is considered to be the maximum allowable value for a thermally cut edge that is not fully fused into a weld.

13.3 Local hardening can be reduced by suitable thermal treatment or removed by mechanical means. The removal of 1 mm to 2 mm from a cut face normally eliminates the layer of hardness. When using thermal cutting, local hardening can be reduced by considerable decrease in normal cutting speed or by pre-heating before cutting. The steel supplier should be consulted for recommendations on achieving a reduction in hardness.

14 FUSION FACES

14.1 The preparation of fusion faces, angle of bevel, root radius and root face shall be such that the limits of accuracy required by the appropriate application standard can be achieved. When however, no appropriate application standard exists and this standard is itself to be used, it is recommended that, for manual welding, the tolerances on limits of gap and root face should be ± 1 mm on the specified dimensions for material up to and including 12 mm thick and ± 2 mm for material over 12 mm thick. The tolerance on the included angle between the fusion faces of a V preparation is recommended to be $\pm 5°$ and for U and J preparations $^{+10°}_{\ \ 0}$. For an automatic process, closer limits are necessary and particular requirements depend on the characteristics of the process.

14.2 It shall be ensured, if necessary, by suitable non-destructive tests that the fusion faces and adjacent surfaces shall be free from cracks, notches or other irregularities which might be the cause of defects or would interfere with the deposition of the weld.

14.3 Fusion faces and the surrounding surfaces shall be free from heavy scale, moisture, oil, paint or any other substance which might affect the quality of the weld or impede the progress of welding. Certain proprietary protective coatings are specially formulated with the intention that they should not interfere with welding. The use of such coatings is not excluded by the requirements of this clause but, shall be demonstrated by means of specimen welds that the coating complies with the above requirements.

15 ASSEMBLY FOR WELDING

15.1 Parts to be welded shall be assembled such that the joints to be welded are easily accessible and visible to the operator.

15.2 Jigs and manipulators should be used, where practicable, so that the welding can be carried out in the most suitable position. Jigs shall maintain the alignment with the minimum restraint so as to reduce the possibility of locked in-stress.

16 ALIGNMENT OF BUTT JOINTS

The root edges or root faces of butt joints shall not be out of alignment by more than 25 percent of the thickness of the thinner material for material up to and including 12 mm thick, or by more than 3 mm for thicker material. For certain applications and welding processes, closer tolerances may be necessary.

17 FIT-UP OF PARTS JOINED BY FILLET WELDS

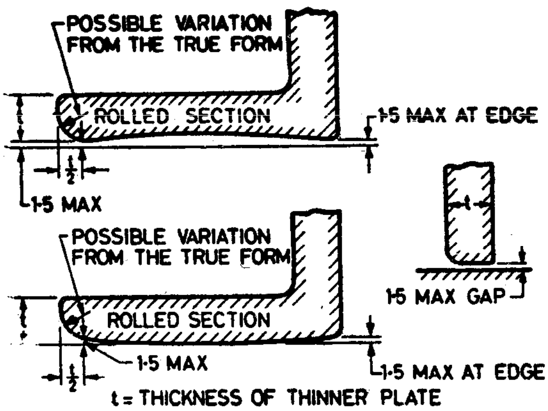
17.1 The edges and surfaces to be joined by fillet welds shall be in as close a contact as possible, since any gap increases the risk of cracking. In no case should the gap exceed 1·5 mm (*see* **11** and Annex F).

17.2 Because of variation in the shape of sections due to mill tolerances, and subsequent methods of forming, deviations from the true profile are likely to be met. When such sections are attached to any plate or member by a fillet weld, the fit-up at a rounded edge of a section shall be within 1·5 mm measured at a distance from the edge not exceeding half the thickness of the section (*see* Fig. 3A). When the full throat thickness is assumed in stress calculation and the rolled section has a thickness t greater than 12 mm, the rounded portion shall be filled with a single pass of weld proceeds. The rounded portion shall be filled up with a single pass of weld as shown in Fig. 3C.

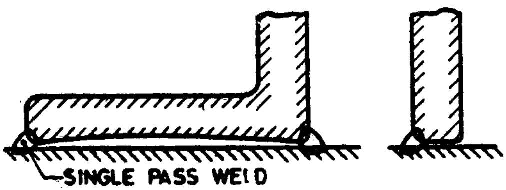
17.3 Good workmanship as regards fit up for fillet welds is more important than for butt welds. It is also important with high tensile steel than with mild steel.

18 TACK WELDS

18.1 Tack welds shall be not less than the throat thickness or leg length of the root run to be used in the joint and shall be subject to the



3A



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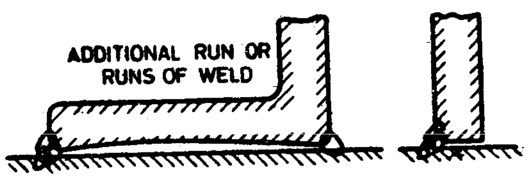


3C

FIG. 3 ALLOWANCE FOR THE ROUNDED TOE OF A SECTION

same welding conditions as those specified for the root run. The length of the tack weld shall not be less than four times the thickness of the thicker part or 50 mm whichever is the smaller.

18.2 Where a tack weld is incorporated in a welded joint, the shape, size and quality of the tack shall be suitable for incorporation in the finished weld (*see* **32**) and it shall be free from all cracks and other welding defects. Tack welds which crack, shall be cut out and rewelded.

18.3 In joints welded by an automatic process or where smaller tack welds are desired, the conditions for deposition shall be as given in **24**.

18.4 Tack welds shall not be made at extreme ends of joints.

19 TEMPORARY ATTACHMENTS

Welded temporary attachments should be avoided as far as possible, but when used the welds should be remote from principal joints as far as practicable and shall be made in accordance with **18** and **24**.

20 PROTECTION FROM THE WEATHER

20.1 Surfaces to be welded shall be dry. When rain or snow is falling or during periods of high wind, necessary precautions shall be taken to protect outdoor welding areas. Warming shall be carried out at all ambient temperatures below 10°C and whenever there is evidence of condensation taking place on the metal surfaces.

20.2 Droughts shall be prevented from blowing along the bores of structural hollow sections when the bore will be penetrated during welding.

20.3 Where gas-shielded welding processes are being used, air currents at speeds as low as 8 km/h can remove the shielding gas, and, therefore, sufficient screening shall be used to keep winds and droughts away from the welding area. Droughts shall be prevented from blowing along structural hollow sections to be welded.

21 STRAY ARCING ON WORK

Stray arcing shall be avoided as this can leave local hard spots or cracking which may need to be removed by mechanical means and be checked by inspection depending upon the application. Removed hard spots can be made good by the deposition of weld metal in accordance with this standard.

Stray arcing can occur:

a) between the electrode and the work away from the weld preparation;

b) between the electrode holder and the work;

c) between the work and the welding earth return lead connection;

d) between the work and any part at earth potential;

e) with automatic and semi-automatic welding, between parts of the welding head or torch (for example loose contact tube in MIG gun) and the workpiece; and

f) with the TIG process, between the tungsten electrode and the work which can give rise to tungsten inclusions in the workpiece. This contamination is not so serious as copper contamination but where the inclusions are large and angular or numerous they should be removed by mechanical means

Items (b), (c) and (e) result in localized contamination with copper. The contaminated area may be brittle and/or cracked due to intergranular penetration of copper. These areas shall be removed by mechanical means as above.

Items (c) and (d) can be avoided by a firm earth connection (*see* 8.2).

22 INTER-RUN CLEANING

Each run of weld bead shall be thoroughly cleaned to remove particles of slag, spatters, etc, before the subsequent bead is superimposed during multi-pass welding. Similarly, each layer of weld should be thoroughly cleaned of slag, spatters, etc, before depositing subsequent layers of weld with particular reference to thorough cleaning of toes of the welds. Visible defects, such as cracks, cavities and other deposition faults, if any, shall be removed to sound metal before depositing subsequent run or layer of weld.

23 DETAILS OF WELDING PROCEDURE

A typical welding procedure sheet is given in Annex E.

24 WELDING PROCEDURES TO AVOID CRACKING

24.1 Cracking is a defect which may impair service performance (*see* 32). Depending upon the particular duty of a joint, consideration shall be given to the avoidance of the following:

a) Hydrogen induced delayed cracking (*see* Annex F),

b) Solidification cracking (*see* Annex G), and

c) Lamellar tearing (*see* Annex H),

24.1.1 It is emphasized that the welding procedure is arrived at by the adherence to the graphs given for guidance in Annex F, coupled with past experience and quality control methods, if any.

25 APPROVAL AND TESTING OF WELDING PROCEDURES

25.1 If so required by the purchaser, the contractor shall carry out procedure tests in accordance with IS 7307 (Part 1) : 1974 to demonstrate by means of a specimen weld of adequate length on a steel representative of that to be used, that he can make satisfactory welds with the welding procedure to be used on the contract. The test weld shall include weld details from the actual construction and it shall be welded in a manner simulating the most unfavourable instances of fit-up, electrode condition, etc, within the requirements of this standard which it is anticipated may occur on the particular fabrication. Where material analysis are available, the welding procedure test shall be carried out on material with the highest carbon equivalent.

25.2 After welding, but before the relevant test given in IS 7307 (Part 1) : 1974 are carried out, the test weld shall be held as long as possible at room temperature, but in any case not less than 72 hours, and shall then be examined for cracking. The examination procedure shall be agreed between purchaser and contractor as being sufficiently rigorous to be capable of revealing significant defects in both parent metal and weld metal.

26 APPROVAL AND TESTING OF WELDERS

The contractor shall satisfy the purchaser that the welders are suitable for the work upon which they will be employed. For this purpose the welders shall have satisfied the relevant requirements of IS 7318 (Part 1) : 1974. If the welders will be working to approved welding procedures, they shall satisfy the relevant requirements of of IS 7310 (Part 1) : 1974.

27 IDENTIFICATION

When specified by the purchaser, adequate means of identification either by an identification mark or other record, shall be provided to enable each weld to be traced to the welders by whom it was made. Attention is drawn to the danger of hard stamping in highly stressed area and the designer should give guidance as to the location of such marks. Indentation used for marking in radiographic examination come into the same category.

28 PEENING

28.1 Peening of welds shall be carried out only by agreement between the purchaser and the contractor.

28.2 If specified, peening may be employed to be effective on each weld layer except the first. Peening, to be effective, should induce some cold work in the layer subjected to peening. Peening shall be avoided between the temperature range of 250-450°C because peening in this range may result in loss of notch toughness.

29 REMOVAL OF TEMPORARY ATTACHMENTS

When welded attachments used to facilitate construction are required to be removed, this shall be done carefully by cutting or chipping and the surface of the material shall always be finished smooth by grinding. The practice of hammering off temporary attachments is not recommended.

30 SUPERVISION

It shall be the responsibility of the contractor to ensure that all welding is carried out in accordance with the terms of this standards, and he shall provide all the supervision to fulfil this requirement.

31 INSPECTION AND TESTING

31.1 The method of inspection shall be in accordance with IS 822 : 1970 and extent of inspection and testing shall be in accordance with the relevant application standard or, in the absence of such a standard, as agreed between the contracting parties (*see* **4**).

NOTE — Because of the risk of delayed cracking, a period of at least 48 hours is recommended before inspection is made of as-welded fabrications. Whatever period is used it should be stated in the inspecion records.

31.2 The purchaser or his representative shall have access to the contractor's work at all reasonable times, and the contractor shall provide him with all facilities necessary for inspection during manufacture and on completion.

31.3 Welds which by agreement are to be inspected and approved shall not be painted or otherwise obscured until they have been accepted.

32 QUALITY OF WELDS AND CORRECTIONS

32.1 Quality of Welds

Welded joint shall be free from defects that would impair the genuine service performance of the construction. Such acceptance requirements, covering both surface and sub-surface defects, shall be as specified in the application, standard or be the subject of agreement between the contracting parties (*see* **4**).

32.2 Corrections of Faulty Welds

When welds do not comply with the requirements of **32.1**, the defective portions shall be removed. They shall then be rewelded and reinspected in accordance with this standard. Unacceptable under cutting shall be made good by grinding or preferably, by the deposition of additional weld metal in accordance with this standard. If undercutting is blended out by grinding, care should be taken to ensure that the design thickness of the parent metal is not reduced.

32.2.1 Defective welds (whole or portions) shall be corrected either by removing, replacing or as follows:

a) Excessive convexity, reduced to size by removal of excess weld metal; and

b) Shrinkage cracks, cracks in parent plate and crater, defective portions removed down to sound metal and rewelded.

32.2.2 Wherever corrections necessitate the deposition of additional weld metal, an electrode or welding rod of a size not exceeding 4 mm may be used.

32.2.3 A crack shall be removed throughout its length and depth. To ensure that the whole of the crack is removed, visual or magnetic inspection or any other equally positive means may be used and material beyond 10 to 25 mm of each end of the crack preferably be removed.

32.2.4 In removing defective parts or a weld gouging, chipping, oxygen cutting or grinding shall not extend into the parent metal to any substantial amount beyond the depth of weld penetration unless cracks or other defects exist in the parent plate. The weld or parent plate shall not be nicked or undercut in chipping, grinding, gouging or oxygen cutting.

32.2.5 Improperly fitted or misaligned parts may be cut apart and rewelded. Members distorted by the heat of welding may be straightened by mechanical means or by the careful application of a limited amount of heat. The temperature of such areas shall not exceed 650°C (dull red heat). Under no circumstances shall the heated portions be quenched. The parts to be heated for straightening shall be substantially unloaded at the time.

33 POST WELD HEAT TREATMENT

When heat treatment of welds is specified this shall be done in accordance with the standard for the particular application where this exists or shall be fully detailed, taking account of the effect on joint properties, where there is no such standard.

34 CLEANING AND PROTECTIVE COATING

All welds shall be cleaned of slag and other deposits after completion. Till the work is inspected and approved, painting shall not be done. The surfaces to be painted shall be cleaned of spatter, rust, loose scale, oil and dirt.

ANNEX A

(*Clauses* 9.1, 10.3 *and* 11.3)

NOTES ON DESIGN (*see also* Annex H)

(Typical application standards covering weld design aspects are IS 816 : 1969 and IS 1024 : 1979)

A-1 BUTT JOINTS (*see* also Annex B)

A-1.1 Butt joints between parts of unequal cross section arranged in line will result in a local increase in stress in addition to the stress concentration caused by the profile of the weld itself. If the centre planes of the two parts joined do not coincide, local bending also will be induced at the joints. If the stresses induced by these effects are unacceptable, the parts should be shaped so as to reduce the stresses. Examples of plain and shaped parts are shown in Fig 4. The slope of the taper should be based on design requirements. If no such requirement is stated, it is recommended that the slope should not be steeper than 1 in 4.

A-1.2 An incomplete penetration butt weld which is welded from one side only, should not be subjected to a bending moment about the longitudinal axis of the weld which would cause the root of the weld to be in tension, unless this is allowed by the application standard.

A-1.3 The use of incomplete penetration butt welds to resist repeating or alternating dynamic forces should be avoided where possible but, where they are used, the design stresses should be suitable for the loading conditions.

A-1.4 Welded joints subjected to fluctuating loads should be designed so that the stresses satisfy the requirements of IS 1024 : 1979.

A-2 FILLET WELDS

A-2.1 The effective length of an open ended fillet weld should be taken as the overall length less twice the leg length, thereby discounting the contribution of the stop and start positions which are generally of reduced profile. In any case, the effective length should not be less than four times the leg length. Fillet welds terminating at the ends or sides of parts should be returned not less than twice the leg length of the weld unless access of the configuration render this impracticable. This procedure is particularly important for fillet welds on the tension side of parts carrying a bending load.

A-2.1.1 In fillet welded joints carrying a compressive load, it should not be assumed that the parts joined are in contact under the joint. For critical applications the use of a full penetration weld should be considered.

A-2.1.2 A single fillet weld should not be subjected to a bending moment about the longitudinal axis of the joint which would cause the root of the weld to be in tension.

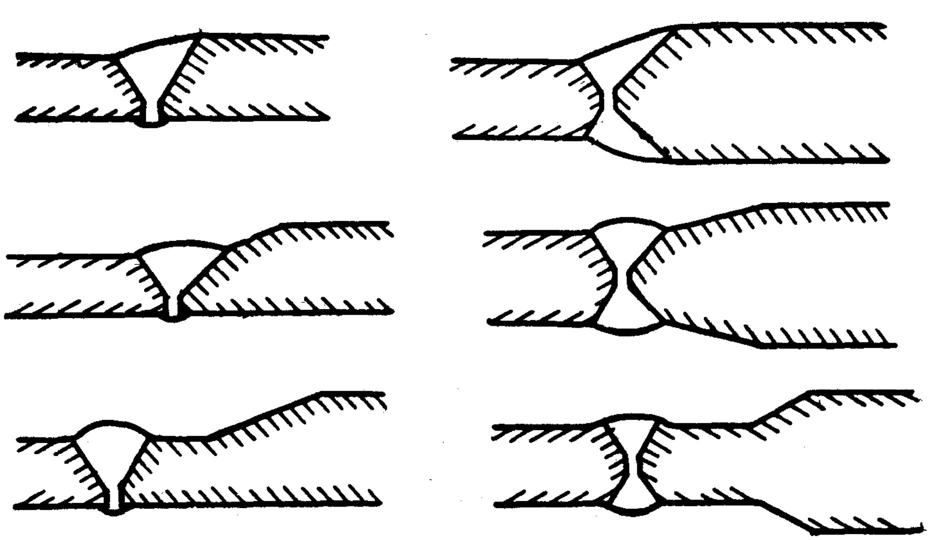


FIG. 4 BUTT JOINTS OF UNEQUAL CROSS SECTION

A-2.1.3 Where fillet welds are used in slots or holes through one or more of the parts being joined, the dimensions of the slot or hole should generally comply with the following limits in terms of the thickness of the parts in which the slot or hole is formed:

a) The width or diameter should be not less than three times the thickness of 25 mm, whichever is the greater;

b) Corners at the enclosed ends of slots should be rounded with a radius of not less than 1·5 times the thickness or 12 mm, whichever is the greater; and

c) The distance between the edge of the part the edge of the slot or hole, or between adjacent slots or holes, should be not less than twice the thickness and not less than 25 mm for holes.

A-2.1.4 Fillet welds connecting parts, the fusion faces of which form an angle of more than 120° or less than 60°, should not be relied upon to transmit calculated loads at the full working stresses unless permitted to do so by the standard for the particular application.

A-2.1.5 The design throat thickness of a flat or convex fillet weld connecting parts the fusion faces of which form an angle of between 60° and 120°, may be derived by multiplying the leg length by the appropriate factor as follows:

Angle Between Fusion Faces Degree	*Factor by Which Leg Length is Multiplied to Give Design Throat Thickness*
60 — 90	0·7
91 — 100	0·65
101 — 106	0·6
107 — 113	0·55
114 — 120	0·5

A-2.1.6 Due account should be taken of fabrication, transport, and erection stresses particularly for those fillet welds which have been designed to carry only a light load during service.

A-2.1.7 Welded joints subjected to fluctuating loads should be designed so that the stresses satisfy the requirements of IS 1024 : 1979.

A-2.1.8 Minimum sizes of fillet welds shall be as given below to avoid cracking:

Thickness of Thicker Part		*Size of Fillet Weld*
Over	Up to and Including	
mm	mm	mm
—	6	3
6	12	4
12	18	6
18	36	8
36	56	10
56	150	12
150	—	16

ANNEX B

(*Clauses* 9.1 *and* A-1)

NOTES ON BUTT WELDS (FOR OTHER THAN STRUCTURAL HOLLOW SECTIONS)

B-1 INTRODUCTION

B-1.1 The recommended dimensions of the preparation are intended primarily for manual welding in the flat position for general types of welded constructions. Since overhead and vertical welding require manipulation of the electrode, comparatively easy access to the root of the weld is desirable for welding in these positions. This is obtained by using a wider angle for the weld preparation, or sometimes by increasing the root gap. In the case of horizontal butt welds the preparation may have to be asymmetrical with respect to the horizontal plane with a narrow bevel angle for the lower section to be welded. When using electrodes with a thick covering, some modification to the root details of the weld preparation may be necessary. For submerged arc welding, reference may be made to IS 4353 : 1967 and IS 3613 : 1974.

B-2 SUITABLE METHODS OF MAKING WELD PREPARATIONS

B-2.1 Single and double V and bevel preparations may be machined or machine flame cut. Single and double U and J preparations usually have to be machined. The choice of a machined or machine flame cut preparation should be at the option of the contractor except when specified by the purchaser or an appropriate application standard. Methods like air-arc gouging are also employed wherever applicable.

B-2.1.1 In assessing the merits of the two methods of preparation and the type of joint, the relative costs of machining, flame cutting or air-arc gouging and length of weld should be taken into account.

B-3 DISTORTION

B-3.1 Where the control of distortion is important, the following factors should be given due considerations:

a) U and J preparation as compared with V and bevel preparations serve to reduce distortion by virtue of the lesser amount of weld metal required. Likewise, double preparations are better than single preparations, in that the stresses are balanced also, the weld metal can be deposited in alternate runs on each side of the joint. In the control of distortion, accuracy of preparation and fit-up of parts are important considerations as well as a carefully planned and controlled welding procedure.

b) A more uniform distribution of heat can be obtained by using back step sequence.

c) Clamping may not completely eliminate warping but is likely to be more effective if clamps are kept in position until the balancing weld sequences are completed.

d) When possible parallel joints may be welded in opposite direction to minimize distortion.

e) While welding thin sections to very thick sections, use of copper backing material may be effective in minimizing distortion.

B-4 TYPICAL FORMS OF WELD PREPARATION

B-4.1 In the case of square butt joints *a* and *b*, the width of the gap depends mainly on the size and type of electrode and the gap should be chosen accordingly.

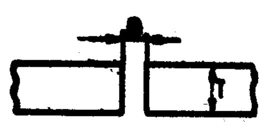
B-4.1.1 The two joints *c* and *d* are probably the most common butt weld preparations used in general work. A root face without a gap usually facilitates assembly and minimizes contraction. The production of a sound weld, with or without gouging out of the back of the first run, is a function of the gap, root face and the type of electrode used. More reliable production of sound weld, can be achieved by using back gouging.

While the double *V* preparation *e* and *f* usually show a saving in weld metal. It is more difficult in these joints to ensure full fusion at the centre of the weld. If a root face is provided for assembly purposes and full fusion is a requirement, adequate gouging out of the back of the first run is essential.

The single and double *U* preparation *g*, *h* and *j* are designed to give easy access for the electrode and to ensure good arcing conditions particularly for the first run.

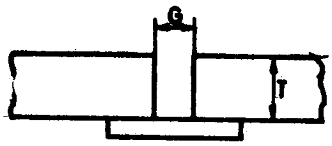
Single and double *J* preparations *k* and *l* and single and double bevel preparations *m* and *n* are used where only one joint member can be prepared. Preparations *m* and *n* are used for lesser thicknesses and where plate edges cannot be machined. To ensure weld soundness great care should be exercised, especially at the root of the double bevel butt weld.

a) Open square butt weld (without backing)

Weld detail		*Welding position*	*Thickness T*	*Gap G*
			mm	mm
Welded from both sides		Flat	3-6	3 *Max*
		Horizontal-vertical or vertical	3-5	3 *Max*

See 14 for tolerances.

b) Open square butt weld (with backing)

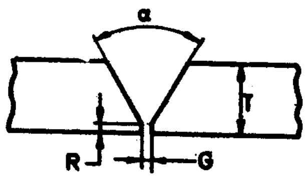
Weld detail		*Welding position*	*Thickness T*	*Flat Position only* — *Gap G*
			mm	mm
Welded from one side with steel backing which may be either temporary or permanent, in which case it may be part of the structure or an integral part of one member		All positions	3-5 5-8 8-16	6 8 10

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

Where this preparation is used for meterial over 16 mm thick, the gap may be required to be increased.

See **14** for tolerances. *See* also **9.4**.

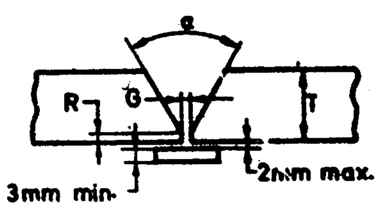
c) Single V butt weld (without backing)

Weld detail		*Welding position*	*Thickness T*	*Flat position only*		
				Gap G	*Angle α*	*Root face R*
			mm	mm		mm
Welded from both sides or one side only		All positions	5-12 Over 12	2 2	60° 60°	1 2

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances. *See* also **9.4**.

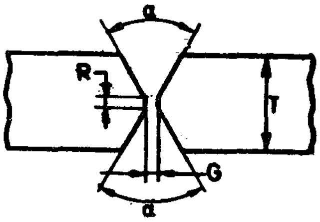
d) Single V butt weld (with backing)

Weld detail		*Welding position*	*Thickness T*	*Flat position only*			
				Gap *G*	Angle α	Root face *R*	Root Run
			mm	mm			
Welded from one side with steel backing which may be either temporary or permanent, in which case it may be part of the structure or an integral part of one member		All positions	Over 10	{6 {10	45° 20°	0 0	Single Double

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances. *See* also **9.4**.

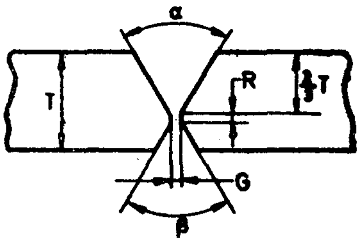
e) **Double V butt weld**

Weld detail		*Welding position*	*Thickness T*	*Flat position only*		
				Gap *G*	Angle α	Root face *R*
			mm	mm		mm
Welded from both sides		All positions	Over 12	3	60°	2

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

f) **Asymmetric double V butt weld**

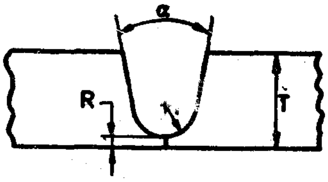
Weld detail		*Welding position*	*Thickness T*	*Flat position only*			
				Gap *G*	Angle α	Angle β	Root face *R*
			mm	mm			mm
Welded from both sides		All positions	Over 12	3	60°	60°	2

If the deeper V is welded first, and full root penetration is required, the angle β may be increased to 90° to facilitate back gouging.

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

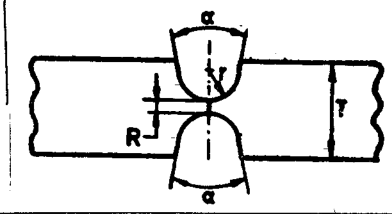
g) **Single U butt weld**

Weld detail		*Welding positions*	*Thickness T*	*Flat position only*		
				Angle α	Radius *r*	Root face *R*
			mm		mm	mm
Welded from both sides		All positions	Over 20	20°	5	5

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

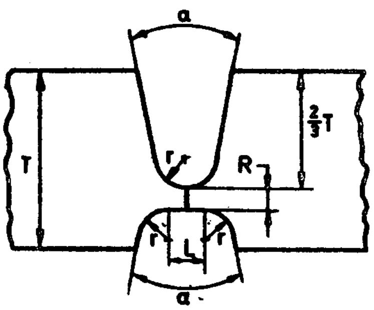
h) **Double U butt weld**

Weld detail		*Welding position*	*Thickness* *T*	*Flat position only*		
				Angle α	Radius r	Root face R
			mm		mm	mm
Welded from both sides		All positions	Over 40	20°	5	5

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

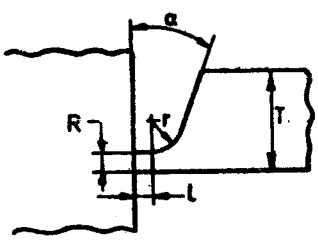
j) **Asymmetric double U butt weld**

Weld detail		*Welding position*	*Thickness* *T*	*Flat position only*			
				Land L	Angle α	Ra- dius r	Root face R
			mm	mm		mm	mm
Welded from both sides		All positions	Over 30	6	20°	5	5

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

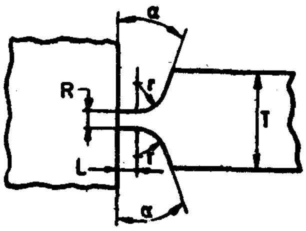
k) **Single J butt weld**

Weld detail		*Welding position*	*Thickness* *T*	*Flat position only*			
				Land L	Angle α	Radius r	Root face R
			mm	mm		mm	mm
Welded from both sides		All positions	Over 20	5	20°	5	5

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See **14** for tolerances.

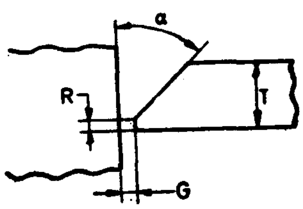
m) Double J butt weld

Weld detail		*Welding position*	*Thickness T*	*Flat position only*			
				Land *L*	Angle α	Radius *r*	Root face *R*
Welded from both sides.		All positions	mm Over 40	mm 5	20°	mm 5	mm 5

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See 14 for tolerances.

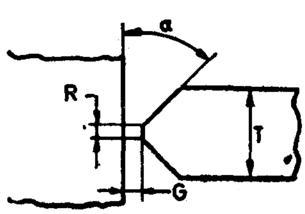
n) Single bevel butt weld

Weld detail		*Welding position*	*Thickness T*	*Flat position only*		
				Gap *G*	Angle α	Root face *R*
Welded from both sides		All positions	mm 5-12 Over-12	mm 3 3	45° 45°	mm 1 2

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See 14 for tolerances.

p) Double bevel butt weld

Weld detail		*Welding position*	*Thickness T*	*Flat position only*		
				Gap *G*	Angle α	Root face *R*
Welded from both sides		All positions	mm Over 12	mm 3	45°	mm 2

The dimensions of the weld preparation may have to be modified for welding in positions other than flat, in which case they should be the subject of agreement between the contracting parties.

See 14 for tolerances.

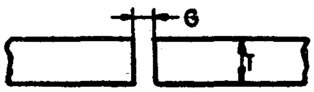
ANNEX C

(*Clause* 9.1)

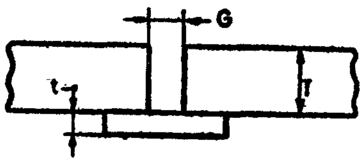
TYPICAL DETAILS FOR BUTT WELDS FOR STRUCTURAL HOLLOW SECTIONS

NOTE — All preparations are for welding from one side only and in all positions.

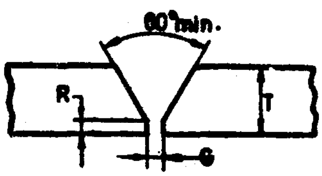
a) Square butt weld (without backing)

Weld detail	*Thickness T*	*Gap G*	
		Min	*Max*
	mm	mm	mm
	Up to 3	0	3

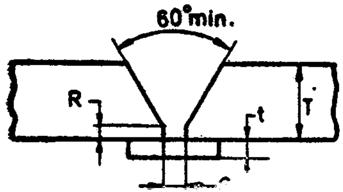
b) Square butt weld (with backing)

Weld detail	*Thickness T*	*Gap G*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*
	mm	mm	mm	mm	mm
	3	3	5	3	3
	5	5	6	3	5
	6	6	8	3	6

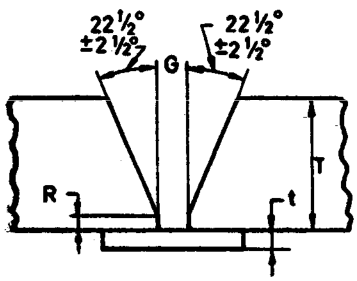
c) Single V (without backing)

Weld detail	*Thickness T*	*Gap G*		*Root face R*	
		Min	*Max*	*Min*	*Max*
	mm	mm	mm	mm	mm
	Up to 20	2	3	1	2·5

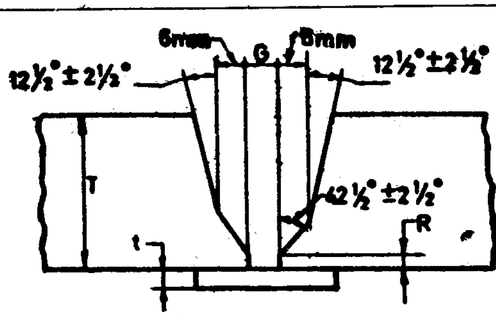
d) **Single V (with backing)**

Weld detail	*Thickness T*	*Gap G*		*Root face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm Up to 20	mm 5	mm 8	mm 1	mm 2·5	mm 3	mm 6

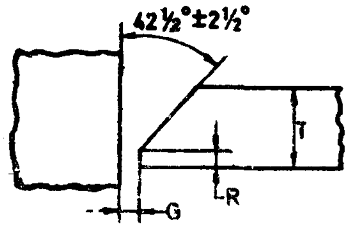
e) **Single V flame cut preparation (with backing)**

Weld detail	*Thickness T*	*Gap G*		*Roof face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm 20-30	mm 8	mm 10	mm 2	mm 3	mm 3	mm 10

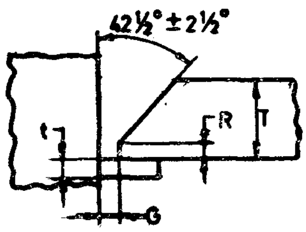
f) **Double angle V (with backing)**

Weld detail	*Thickness T*	*Gap G*		*Root face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm 20 and over	mm 8	mm 10	mm 2	mm 3	mm 3	mm 10

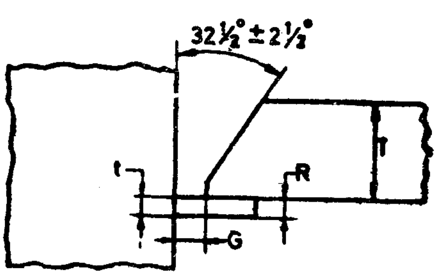
g) Single bevel (without backing)

Weld detail	*Thickness T*	*Gap G*		*Root face R*	
		Min	*Max*	*Min*	*Max*
	mm Up to 20	mm 2·5	mm 4	mm 1	mm 3

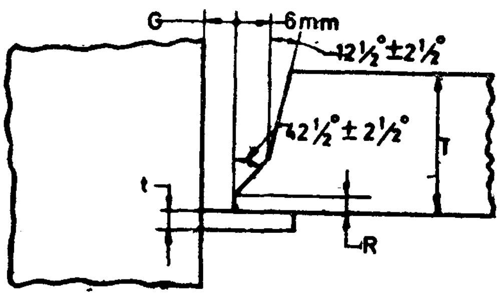
h) Single bevel (with backing)

Weld detail	*Thickness T*	*Gap G*		*Root face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm Up to 20	mm 5	mm 8	mm 1	mm 3	mm 3	mm 6

j) Single bevel flame cut preparation (with backing)

Weld detail	*Thickness T*	*Gap G*		*Root face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm 20-30	mm 8	mm 10	mm 1	mm 3	mm 3	mm 10

k) Double angle bevel (with backing)

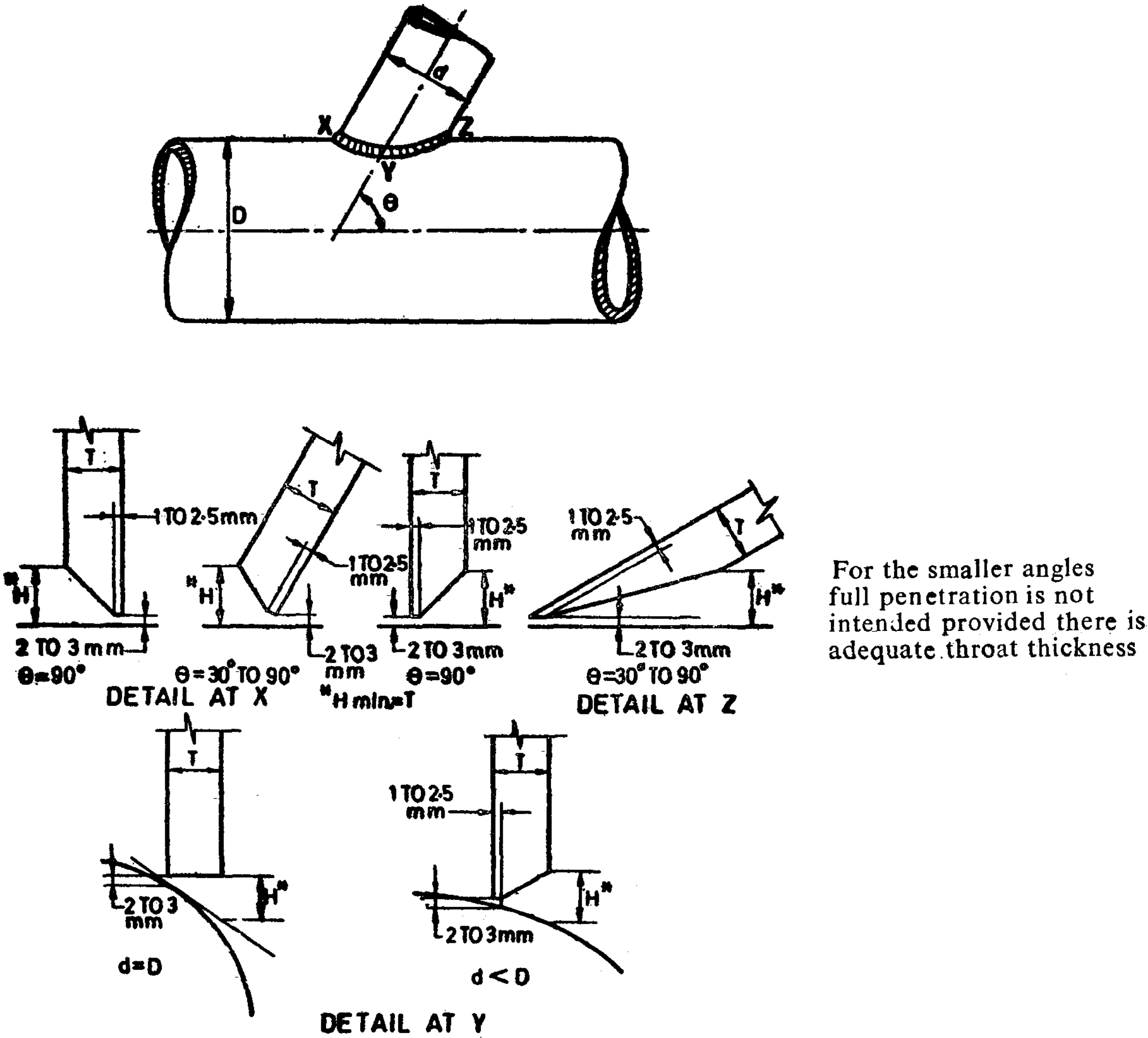
Weld detail	*Thickness T*	*Gap G*		*Root face R*		*Thickness of backing, t*	
		Min	*Max*	*Min*	*Max*	*Min*	*Max*
	mm 20 and over	mm 8	mm 10	mm 1	mm 3	mm 3	mm 10

ANNEX D

(*Clauses* 9.1 *and* 11.1)

TYPICAL DETAILS FOR BRANCH CONNECTIONS FOR STRUCTURAL HOLLOW SECTIONS

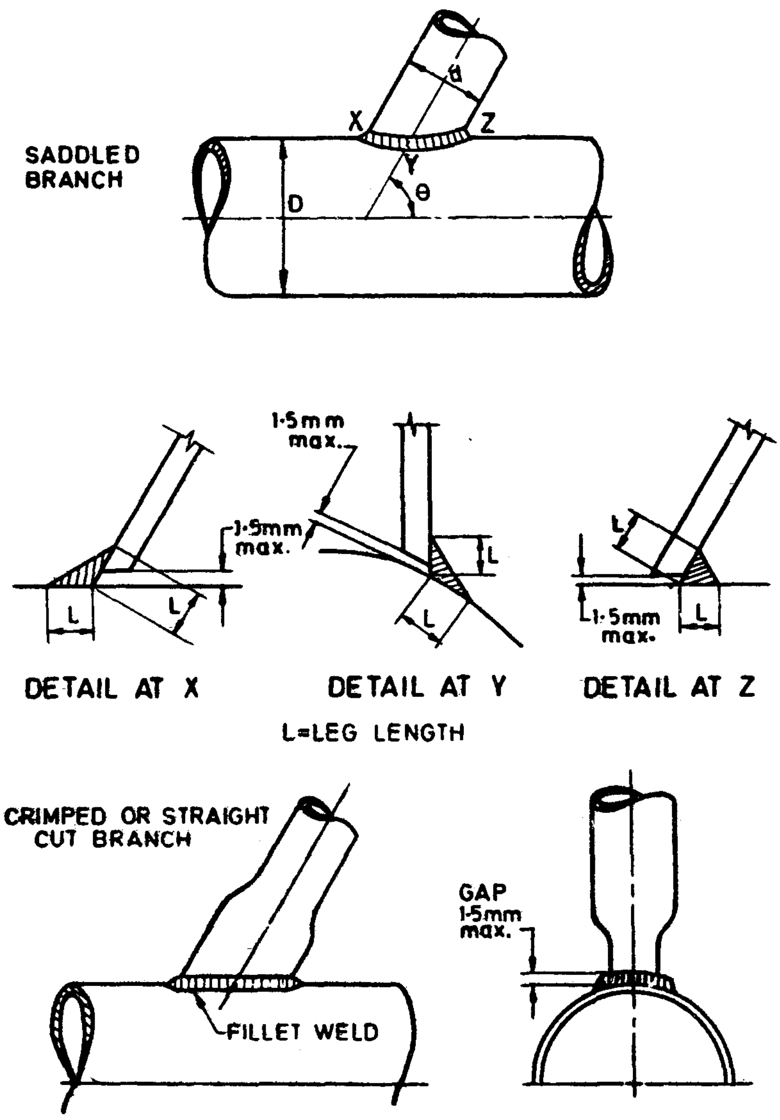
D-1 CIRCULAR STRUCTURAL HOLLOW SECTIONS : BUTT WELDS (THICKNESS UP TO 30 mm)



NOTE — The angle of intersection θ of the axes of the circular hollow sections should not be less than 30° unless adequate efficiency of the junction has been demonstrated.

D-2 CIRCULAR STRUCTURAL HOLLOW SECTIONS: FILLET WELDS

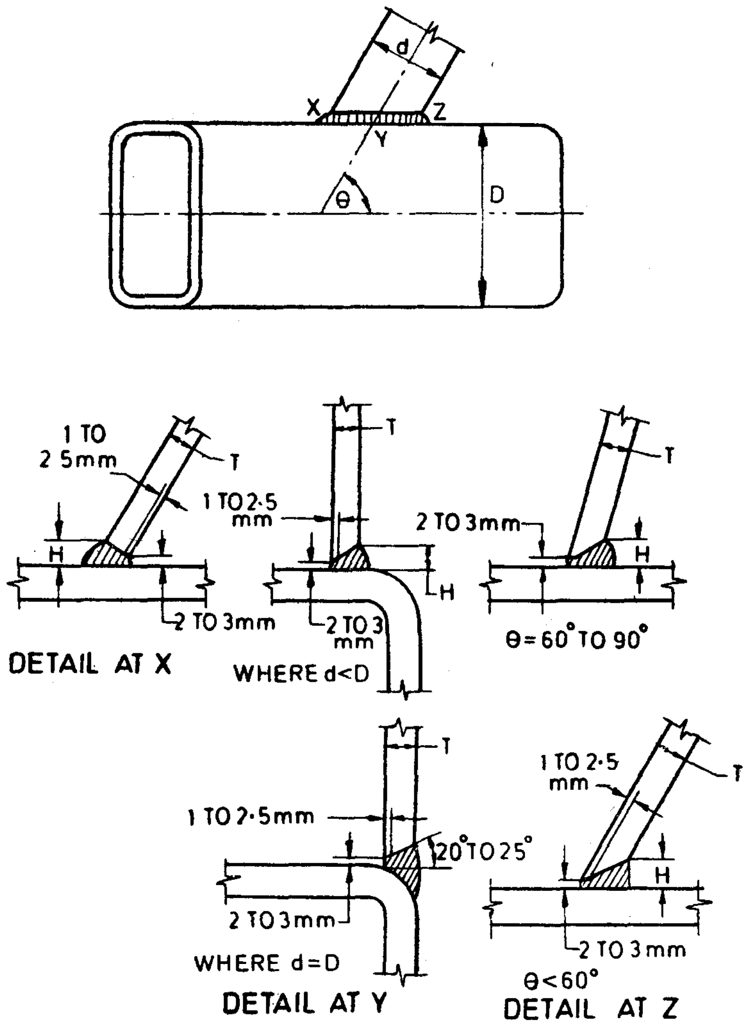
Leg lengths should be such that the stresses in fillet welds are in accordance with the permissible stresses given in the relevant specification and that the welds will transmit the loads in the member.



For the smaller angles full penetration is not intended provided there is adequate throat thickness

NOTE — The angle of intersection θ of the axes of the circular hollow sections should not be less than 30° unless adequate efficiency of the junction has been demonstrated.

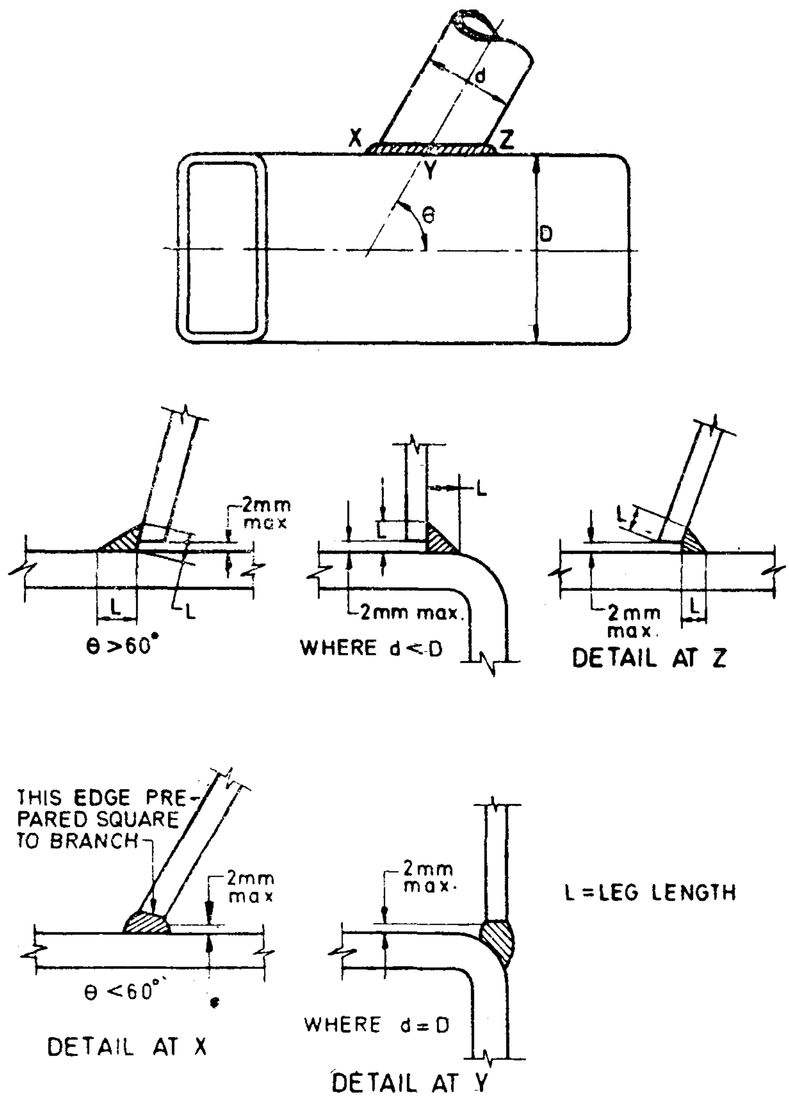
D-3 RECTANGULAR STRUCTURAL HOLLOW SECTIONS : BUTT WELDS



For the smaller angles full penetration is not intended provided there is adequate throat thickness

NOTE — The angle of intersection θ of the axes of the rectangular hollow section should not be less than 30° unless adequate efficiency of the junction has been demonstrated.

D-4 RECTANGULAR STRUCTURAL HOLLOW SECTIONS: FILLET WELDS



For the smaller angles full penetration is not intended provided there is adequate throat thickness

NOTE — The angle of intersection θ of the axes of the rectangular hollow sections should not be less than 30° unless adequate efficiency of the junction has been demonstrated.

ANNEX E

(*Clause* 23)

PROCEDURE SPECIFICATION SHEET FOR METAL ARC WELDING

E-1 GENERAL

E-1.0 The procedure specification sheet for metal arc welding shall contain the following information:

a) Process (*see* **E-1.1**);

b) Parent plate (*see* **E-1.2**);

c) Filler metal (*see* **E-1.3**);

d) Welding position (*see* **E-1.4**);

e) Preparation of parent plate, such as joint preparation cleaning the edges of rust, grease, etc (*see* **E-1.7**);

f) Nature of electric current (*see* **E-1.8**);

g) Welding technique (*see* **E-1.7**);

h) Cleaning (*see* **E-1.8**);

j) Defects (*see* **E-1.9**);

k) Peening (*see* **E-1.10**);

m) Treatment of underside of welding groove (*see* **E-1.11**);

n) Preheating and interpass temperatures (*see* **E-1.12**);

p) Heat treatment (*see* **E-1.13**); and

q) Welding procedure data sheet (*see* **E-1.14**).

E-1.1 Process

The welding shall be done by the manual or semi-automatic or automatic metal arc process.

E-1.2 Parent Plate

The parent plate shall conform to the specifications for (insert here reference to standard or other code designations, or give the chemical analysis and physical properties).

E-1.3 Filler Metal

The filler metal shall conform to Indian Standard classification number (*see* IS 814 : 1991).

E-1.4 Welding Position

The welding shall be done in (state) the position or positions in which the welding is to be carried out.

E-1.5 Preparation of Parent Plate

The edges or surfaces of the parts to be joined by welding shall be prepared by (state whether) sheared, machined, ground, gas cut, etc as shown on the attached sketches and shall be cleaned of all oil or grease and excessive amounts of scale or rust, except that a thin coat of linseed oil, if present, need not be removed. (The sketch referred to show the arrangement of parts to be welded with the spacing and details of the welding groove, if used. Such sketches should be comprehensive and cover the full range of material or parent plate thicknesses to be welded.)

E-1.6 Nature of Electric Current

The current used shall be (state whether) direct or alternating, and if alternating give the OCV. The parent plate shall be connected to the positive or negative pole.

E-1.7 Welding Technique

The welding technique, electrode sizes, and mean voltage and currents for each electrode shall be substantially as shown on the attached sketches. (The sketches referred to may be the same as mentioned under 'Preparation of Parent Plate' or may be separate sketches. They should show for the minimum thickness and for several intermediate thicknesses of parent plate, the welding technique to be used, whether weaving or beading, the number of layers or passes and diameter of electrode with the mean voltage and current for each layer of pass, and in the case of vertical welds, the progression of each pass, whether upward or dowaword.)

E-1.8 Cleaning

All slag or flux remaining on any bead of welding shall be removed before laying down the next successive bead.

E-1.9 Defects

Any crack or other welding defects that appear on the surface of any bead of welding shall be removed by chipping, grinding or gas gouging before depositing the next successive bead of welding.

E-1.10 Peening

If peening is to be used, it shall be incorporated as part of the specification, a description being given of the degree of peening to be done.

E-1.11 Treatment of Underside of Welding Groove

The method of preparing the under or second side of a groove for welding on that side should be stated in this paragraph.

E-1.12 Preheating and Interpass Temperatures

This paragraph should describe any preheating that should be done.

E-1.13 Heat Treatment

This paragraph should describe any heat treatment or stress relieving that is given to the welded parts after welding.

E-1.14 Welding Procedure Data Sheet

For uniformity of record a recommended form of Manufacturer's Welding Procedure Data Sheet is given below:

TYPICAL WELDING PROCEDURE DATA SHEET

Specification No. ________ Date ________

Welding Process ________ Manual or Machine ________

Material Specification : Grade ________ of IS : ________ Batch/Cast No. ________

Thickness (if pipe, diameter and wall thickness) ________

Filler Metal Specification ________

Weld Metal Analysis ________

FLUX OR SHIELDING GAS

Flux Trade Name or Composition ________

Inert Gas Composition ________

Trade Name ________ Flow Rate ________

Is Backing Strip Used

Preheat Temperature Range ________

Interpass Temperature Range ________

Postheat Treatment ________

WELDING PROCEDURE

Single or Multiple Pass ________

Single or Multiple Arc ________

Welding Position(s) ________

FOR INFORMATION ONLY

Electrode/Filler Wire Diameter ________

Trade Name ________

Type of Backing ________

Forehand or Backhand ________

WELDING TECHNIQUES

Joint Details ________

Amps ________ Volts ________

Electrode Consumed (cm/m) ________

Current ________ Polarity ________

Size of Reinforcement ________

Whether Removed ________

Inspection and Test Schedules ________

Signature

For and on Behalf of Manufacturer

Date ________

Welding Engineer
(Inspecting Authority)

ANNEX F

(*Clauses* 7.7.2.1, 17.1, 24.1 *and* 24.1.1)

AVOIDANCE OF HYDROGEN CRACKING

F-1 GENERAL

F-1.1 If the cooling rate associated with welding is too rapid, excessive hardening may occur in the heat affected zone. This may be unacceptable in it self, but if sufficient hydrogen is present in the weld, the hardened zone may crack spontaneously under the influence of residual stress after the weld has cooled to near ambient temperature. The occurrence of cracking depends on a number of factors: the composition of steel, the welding procedure, welding consumables and the stress involved. Welding conditions can be selected to avoid cracking which ensure that the heat affected zone cools sufficiently slowly, by control of weld run dimensions in relation to material thickness and if necessary by applying pre-heat and controlling interpass temperature. The hydrogen input to the weld can be controlled by using hydrogen controlled welding processes and consumables.

F-1.1.1 In giving general welding procedures based on ladle analysis and appropriate to a wide range of practical conditions, realistic conditions have been assumed in order to establish the procedures detailed in this appendix, and these are recommended except when alternative procedures have been demonstrated as satisfactory either by experience or test.

F-2 CONDITIONS FOR AVOIDING HYDROGEN CRACKING

Welding conditions for avoiding hydrogen cracking in carbon manganese steels have been drawn up in graphical form in Fig. 5a to 5n for the range of compositions, expressed as carbon equivalent values, covered by this standard. The conditions have been drawn up to take account of differences in behaviour between different steels of the same carbon equivalent (making allowance for scatter in hardenability) and of normal variations between ladle and product analysis. They are valid for the avoidance of heat effected zone cracking in normal welding situations, but ignore the possibility of weld metal hydrogen cracking due to conditions of high restraint.

F-3 CONDITIONS FOR WHICH PROCEDURES BASED ON FIGURES 5a to 5n ARE VALID

F-3.1 Composition : Carbon Equivalent Values

The graphs relating combined thickness, arc energy and pre-heat required given in Fig. 5a to 5n are provided to assist the fabricator in selecting optimum welding procedures. In the absence of mill sheet data, the carbon equivalent values in Table 1 provide a good basis for the deviations of welding procedures.

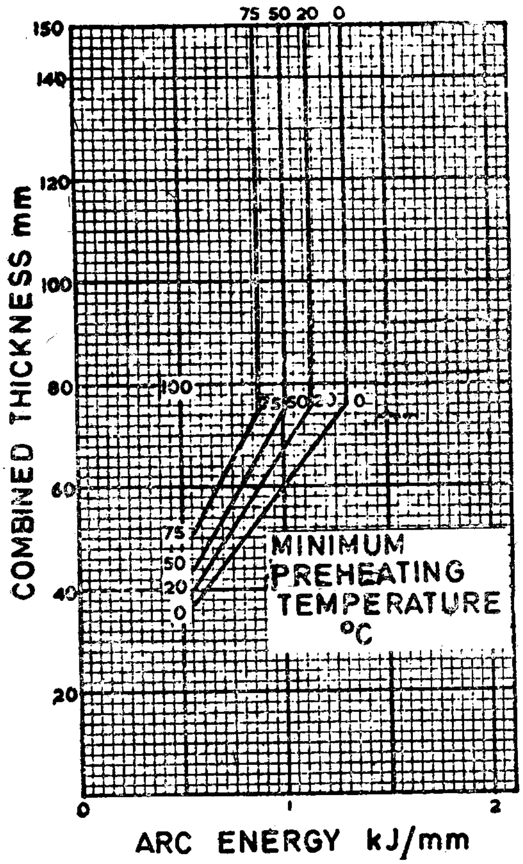
Attention is drawn to the need to compare the carbon equivalent of material delivered as derived from the mill sheets, with that used in deriving the welding procedure from Table 1. The table refers to further simplified tables (*see* Tables 2 to 5) for manual metal-arc fillet welding conditions. Where the mill sheet carbon equivalent is higher than the value used for deriving the welding procedure, or the joint is not a fillet weld, or the welding process is not manual metal-arc, or the fabricator is able to take advantage of a lower carbon equivalent value identified from the mill sheets, reference should be made to the appropriate graph or graphs within Fig. 5a to 5n. Where steels of different carbon equivalent or graph are being joined, the higher carbon equivalent value should be used. If, of the elements in the formula in **5** for calculating carbon equivalent, only carbon and manganese are stated on the mill sheet, then 0.03 shall be added to the calculated value to allow for residual elements.

For carbon manganese steels of low carbon content (less than about 0·10 percent) the carbon equivalent formula specified in **5.1** does not adequately indicate the risk of heat-affected zone hydrogen cracking and may underestimate it. Thus welding procedures for such steels may require modification. In addition, welding procedures derived from **24.1.1** may not be adequate for avoiding weld metals hydrogen cracking. When welding steels of low carbon equivalent (less than approximately 0·42). This is more likely to be the case when welding thick sections (that is greater than about 50 mm) and with higher yield steels. Whether or not this causes an increased risk of heat-affected zone cracking, the weld deposit would generally be harder and more susceptible to cracking itself.

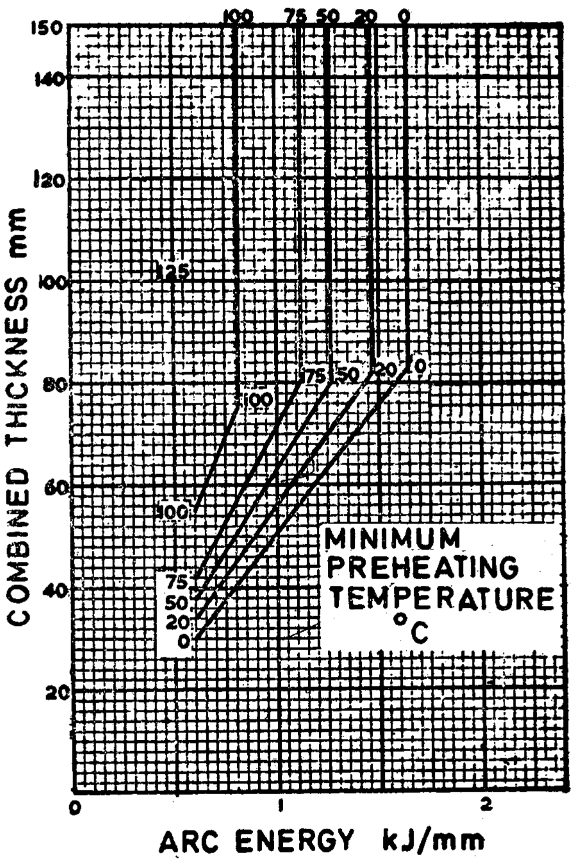
Recent experience and research has indicated that lowering the inclusion content in the steel, principally by lowering the sulphur content (also the oxygen content) may increase the hardenability of the steel. From a practical point of view this effect may result in increase in the hardness of the heat-affected zone, and possibly a small increase in the risk of heat-affected zone hydrogen cracking, Accurate quantification of the effect is not presently practicable but some increase in hardness (and risk of heat affected zone hydrogen cracking) might be observed in steels with sulphur levels less than approximately 0·008 percent.

F-3.2 Hydrogen Scales

The scale to be used in Fig. 5a to 5n will depend principally on the weld deposit diffusible hydrogen content given by the consumables, appropriately dried to the manufacturer's recommendations, when sampled and analyzed to IS 814 : 1991 using evolution over mercury. That standard deals with the testing of covered electrodes, but with slight modifications of specimen size it can be used to assess other consumables and welding processes. This standard permits only the use of mercury as a collecting fluid for diffusible hydrogen and the levels given below are based on measurements using mercury.



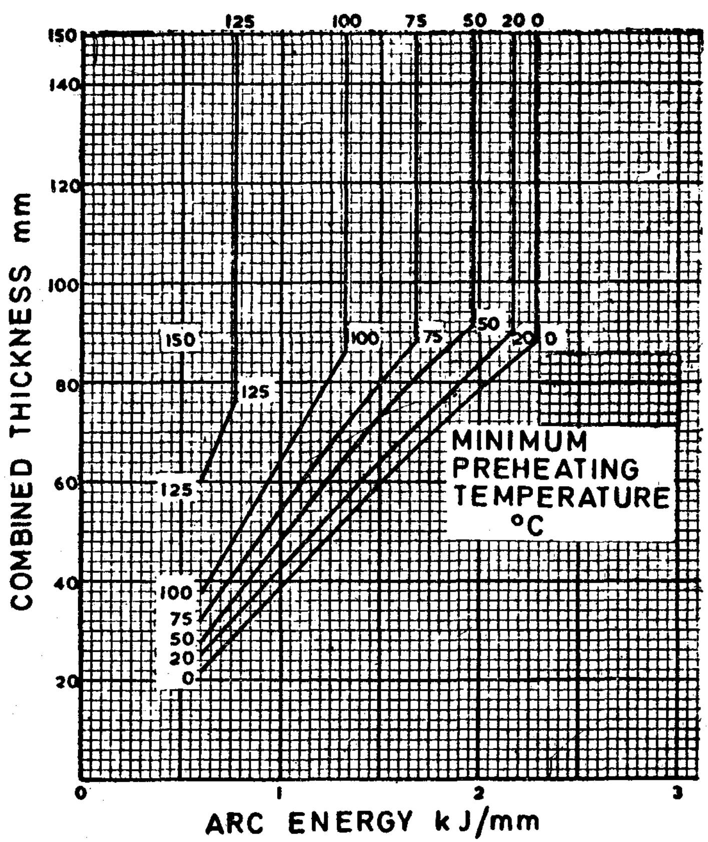
5a



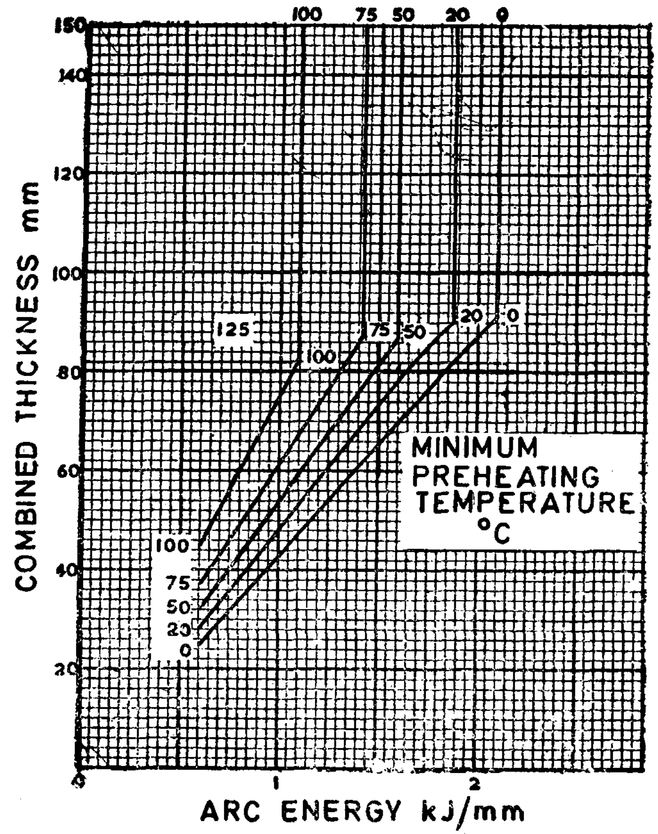
5b

		Hydrogen Scale (*see* F-3·2)			
		A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	(a)	0.37	0·39	0·40	0·45
	(b)	0.38	0·40	0·41	0·46

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd*



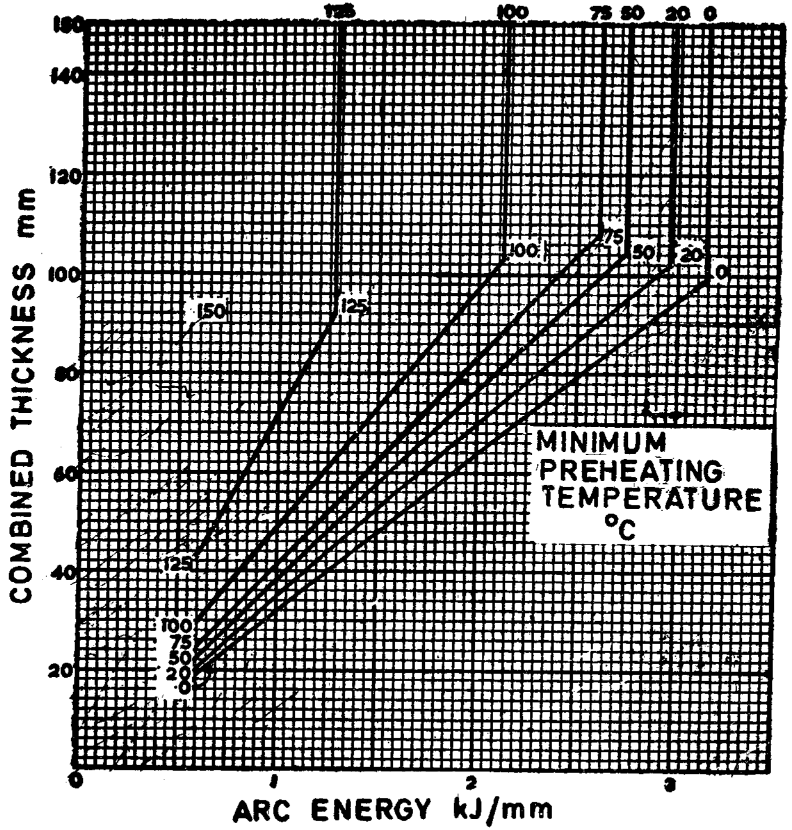
5d



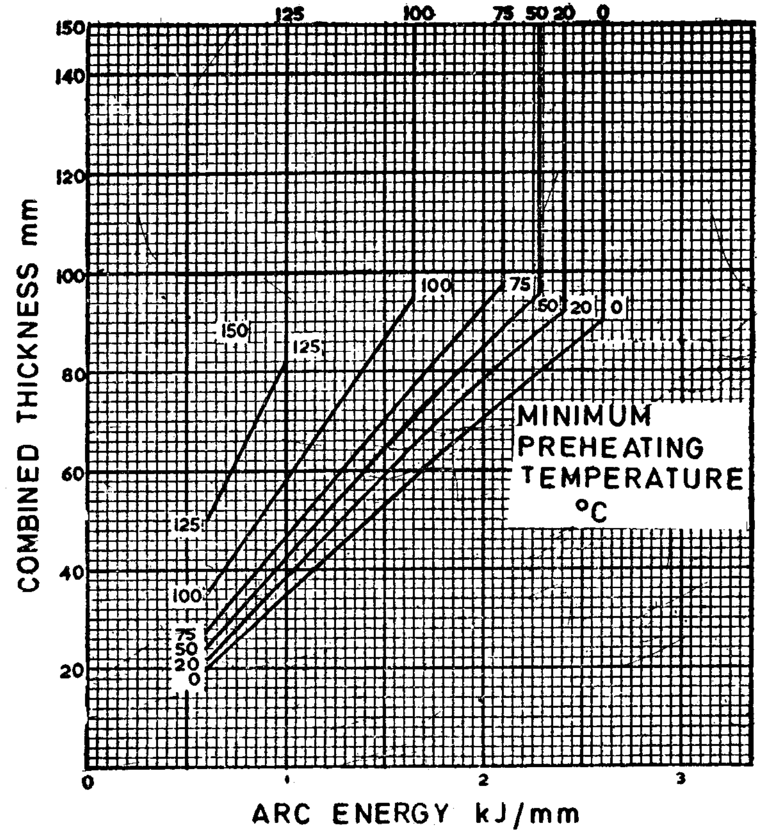
5c

		Hydrogen Scale (*see* F-3·2)			
		A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	(c)	0·39	0·41	0·43	0·48
	(d)	0·40	0·42	0·44	0·49

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*



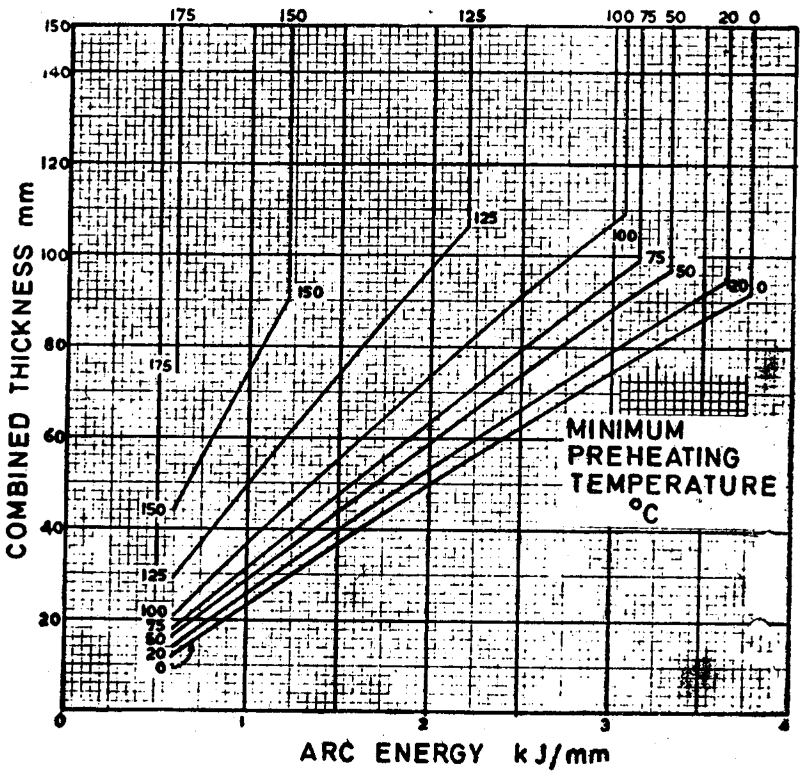
5f



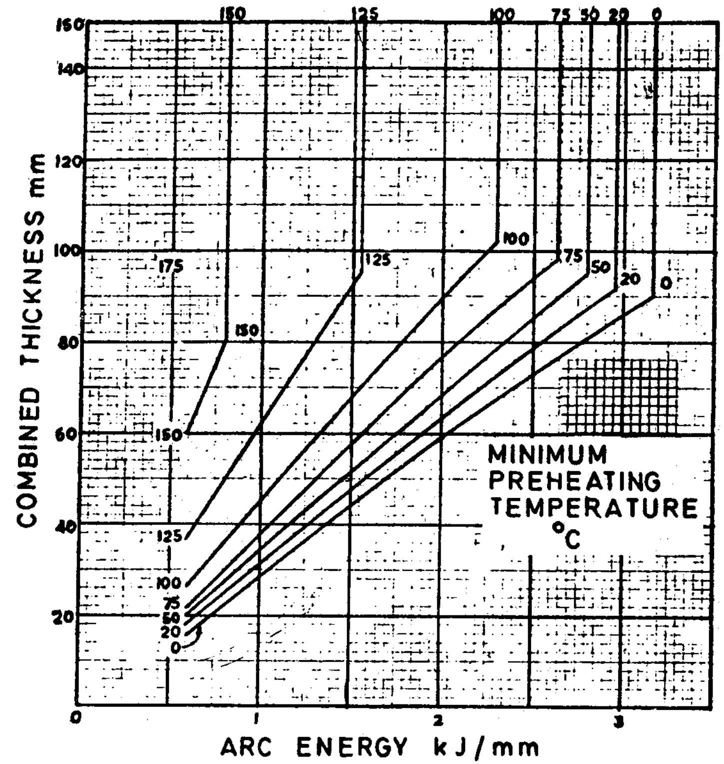
5e

		Hydrogen Scale (*see* F-3.2)			
		A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	(e)	0.41	0.43	0.45	0.50
	(f)	0.42	0.44	0.46	0.51

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*



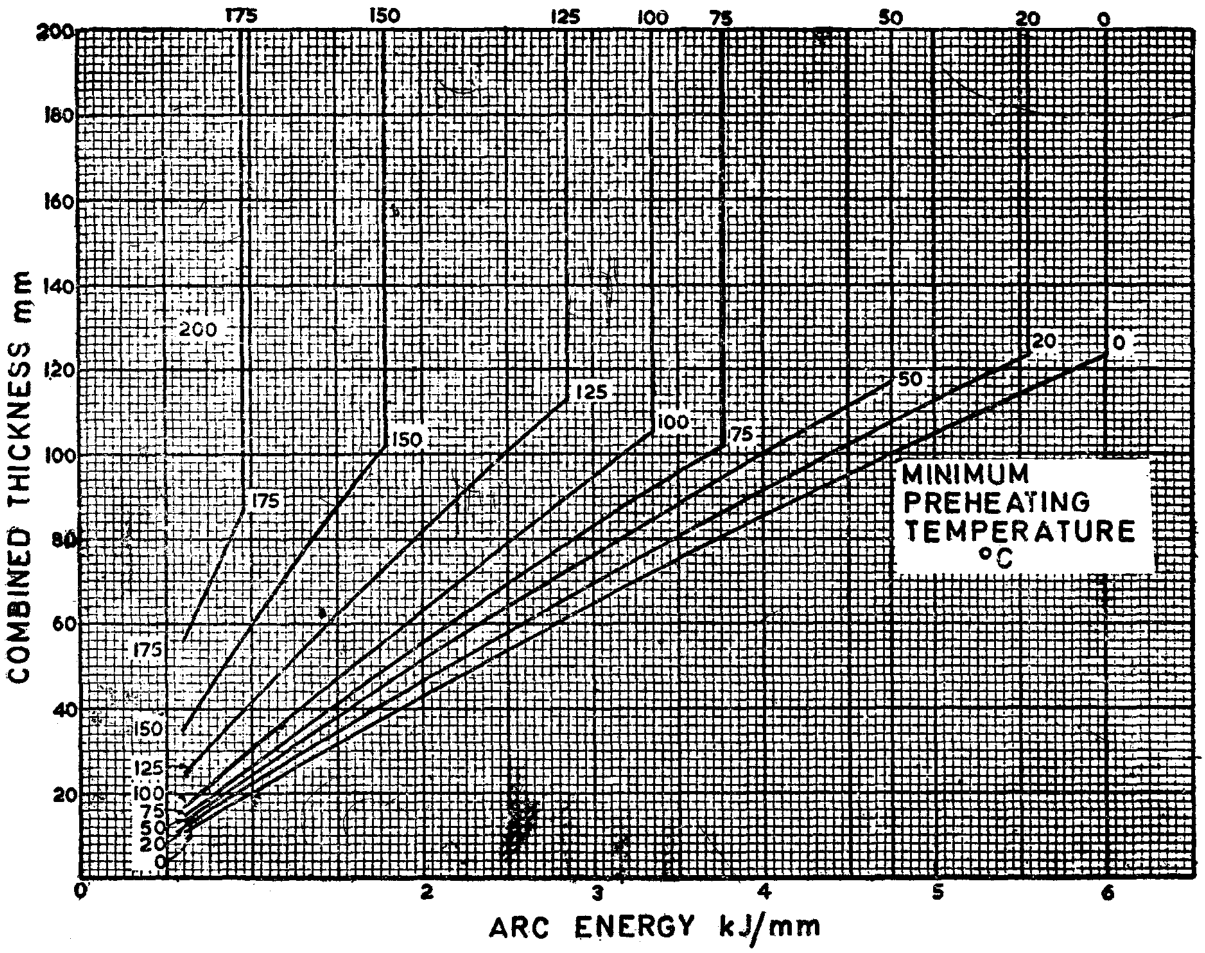
5h



5g

		Hydrogen Scale (*see* F-3·2)			
		A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	(g)	0·43	0·45	0·47	0·52
	(h)	0·45	0·47	0·49	0·55

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*

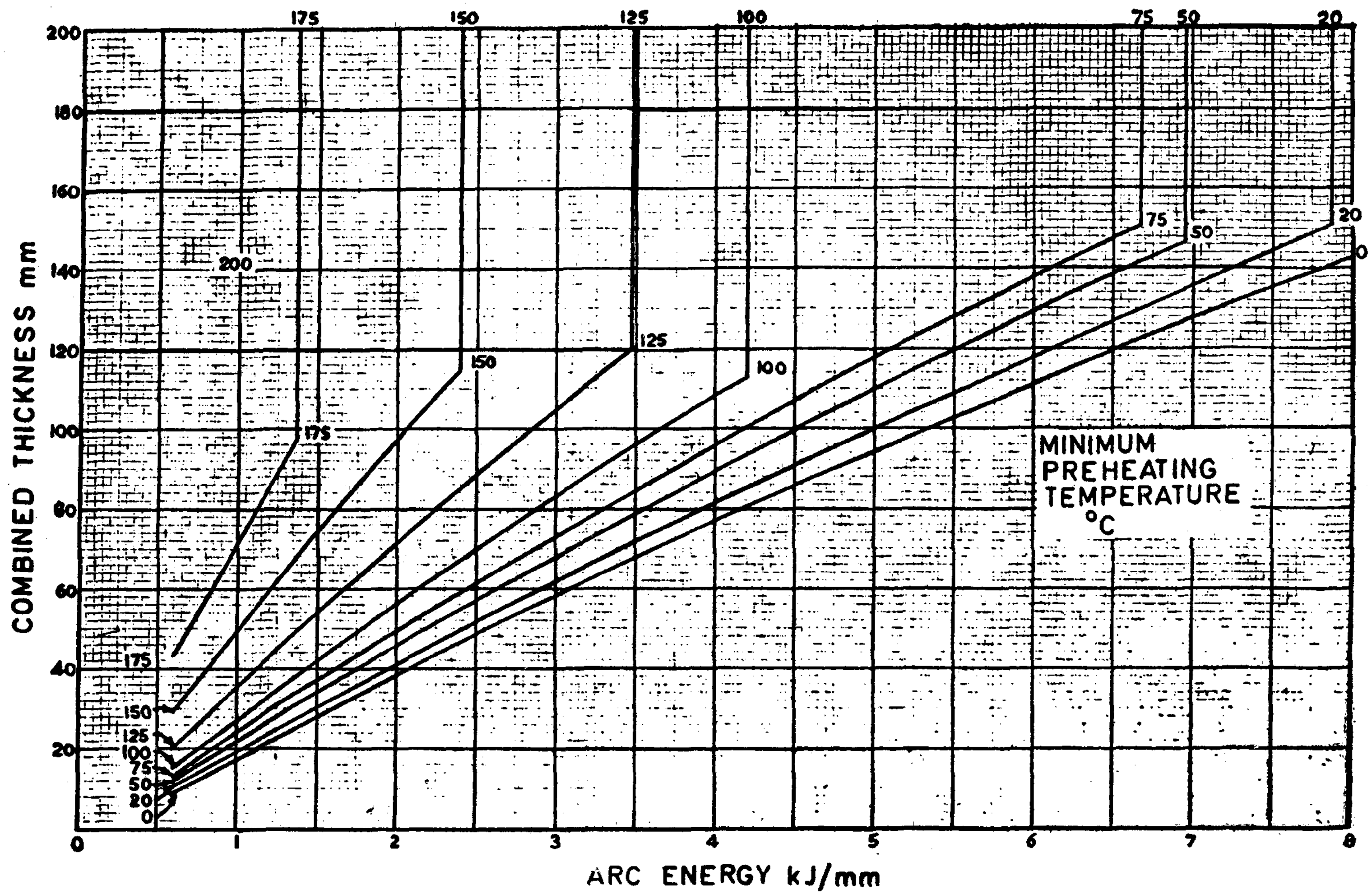


5j

	Hydrogen Scale (*see* F-3.2)			
	A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	0·47	0·49	0·51	0·57[1]

[1] For guidance only

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*

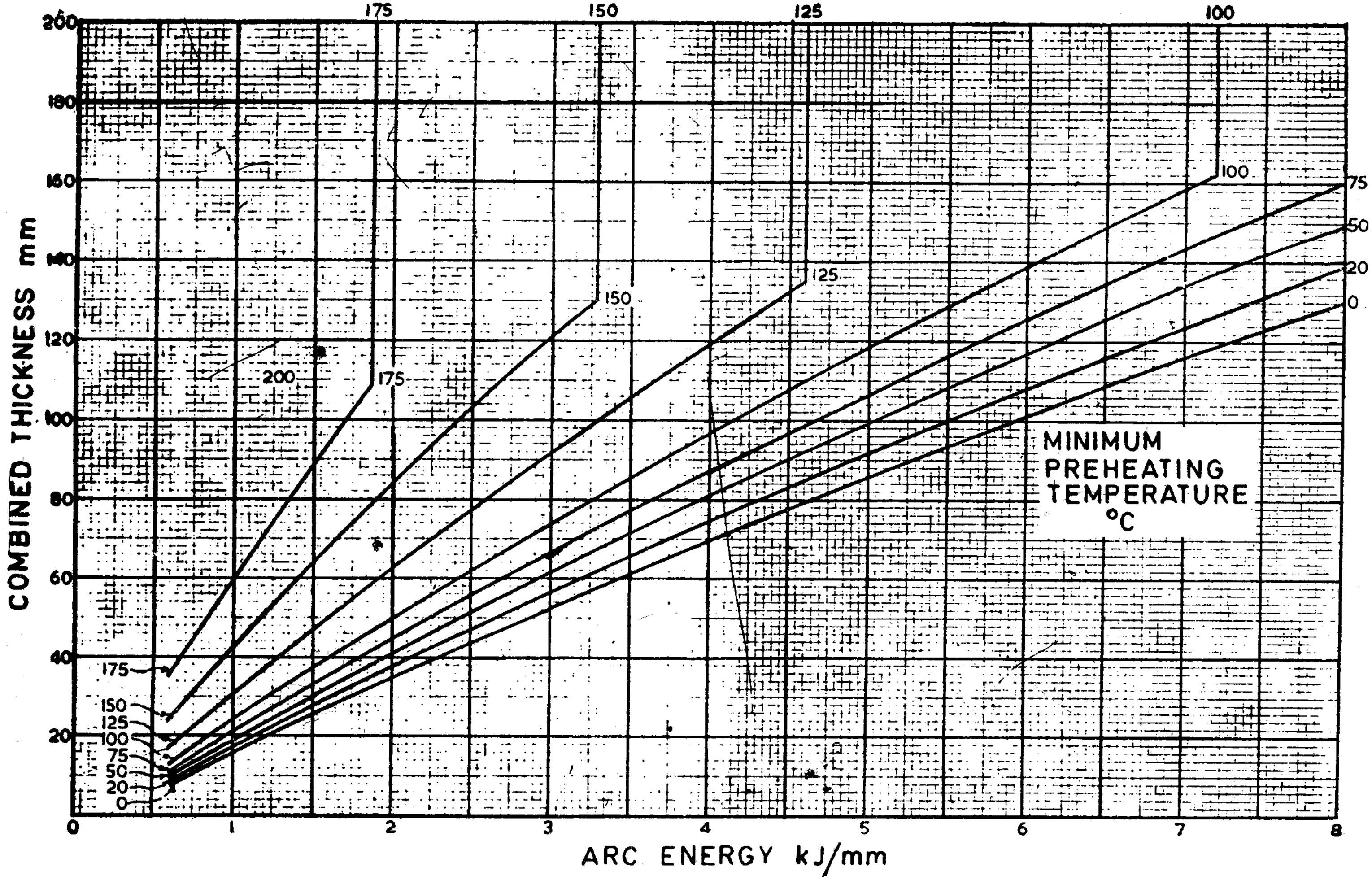


5k

	Hydrogen Scale (*see* F-3·2)			
	A	*B*	*C*	*D*
To be used for carbon equivalent not exeeeding	0·49	0·51	0·53	0·59[1)]

[1)] For guidance only

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*

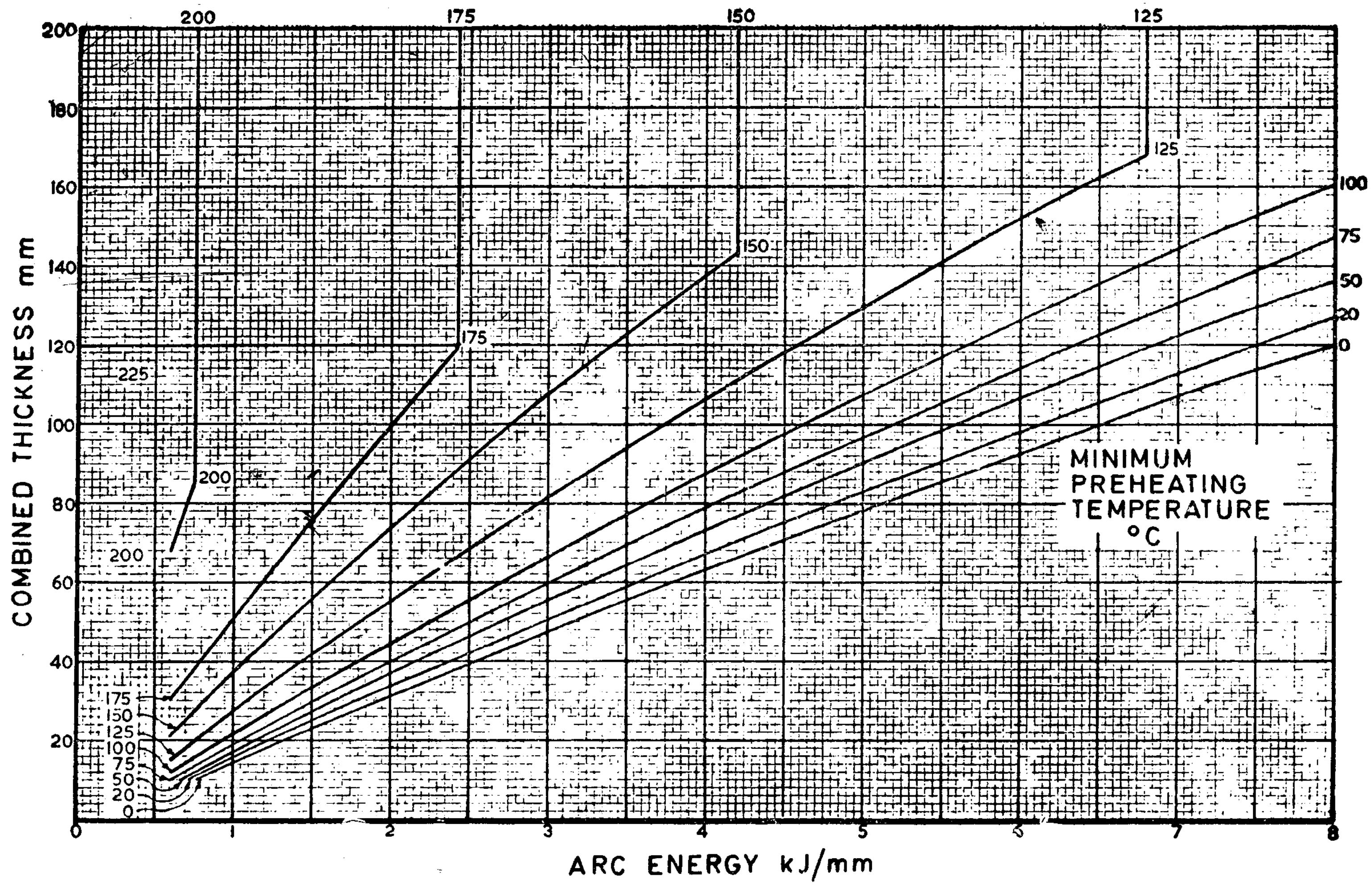


51

	Hydrogen Scale (*see* F-3.2)			
	A	*B*	*C*	*D*
To be used for carbon equivalent not exceeding	0.51	0.53	0.55[1]	0.60[1]

[1] For guidance only

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*

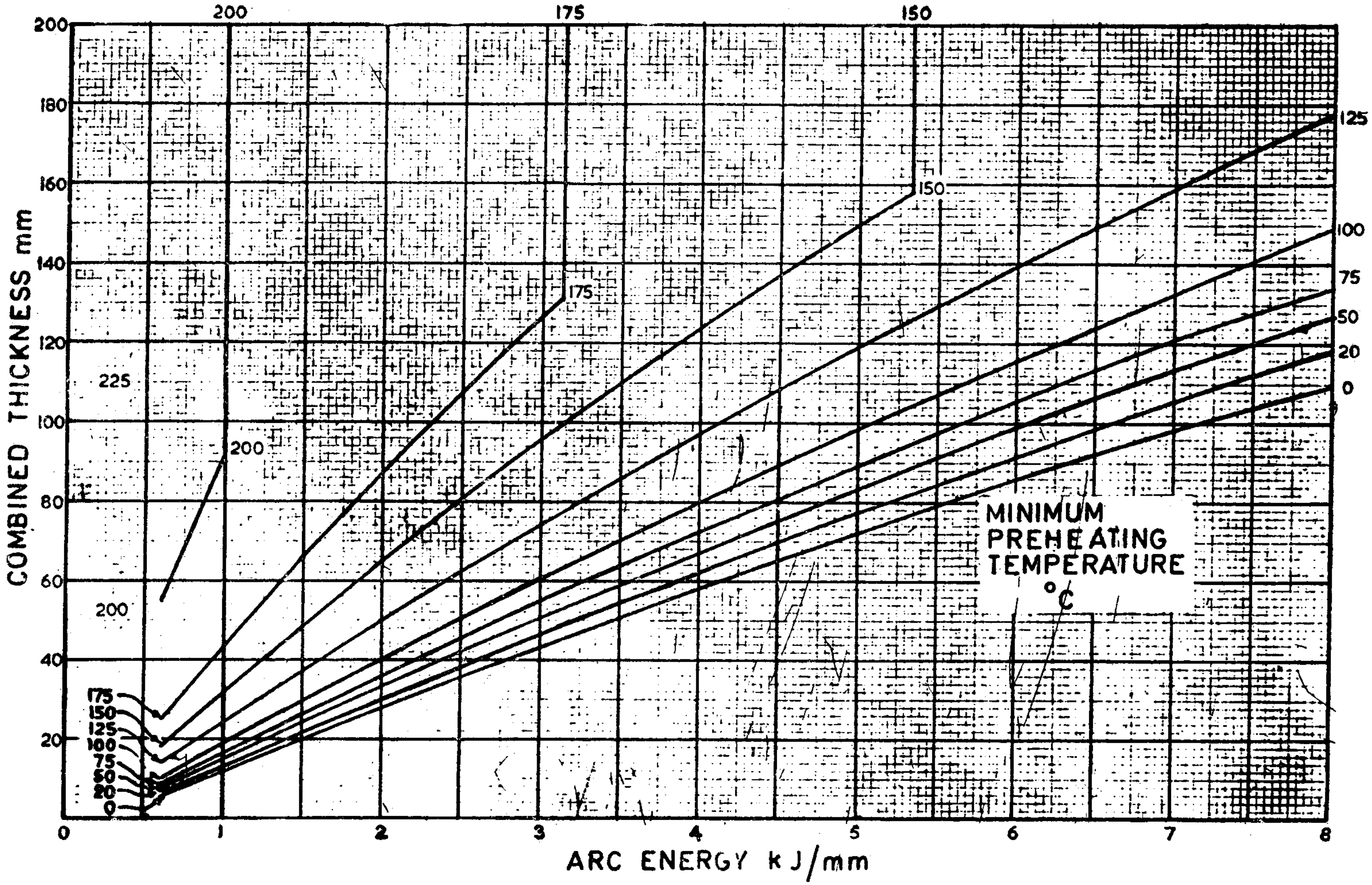


5m

	Hydrogen Scale (*see* F-3·2)		
	A	*B*	*C*
To be used for carbon equivalent not exceeding	0·53	0·55[1)]	0·57[1)]

[1)] For guidance only

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT — *Contd.*



5n

	Hydrogen Scale (*see* F-3.2)		
	A	*B*	*C*
To be used for carbon equivalent not exceeding	0.55[1)]	0.57[1)]	0.59[1)]

[1)] For guidance only

FIG. 5 CONDITIONS FOR WELDING STEEL OF STATED CARBON EQUIVALENT

F-3.2.1 Scale A should be used under conditions of normal fit for consumables which give weld deposit hydrogen contents more than 15 ml/100 g after any appropriate drying treatment.

F-3.2.2 Scale B should be used under conditions of normal fit for consumables which given weld deposit hydrogen contents not more than 15 ml/100 g (but more than 10 ml/100 g) after any appropriate drying treatment.

F-3.2.3 Scale C should be used under conditions of normal fit for consumables which give weld deposit hydrogen contents not more than 10 ml/100 g (but more than 5 ml/100 g) after any appropriate drying treatment. Scale C should also be used under conditions of close fit for consumables otherwise defined for Scale B.

F-3.2.4 Scale D should be used under conditions of normal fit for consumables which give weld deposit hydrogen contents not more than 5 ml/100 g after any appropriate drying treatment.

F-3.2.5 Covered electrodes in Classes E1 — —, E2 — —, E3 — —, E4 — —, E5 — —, and E9 — — should be used with Scale A, unless otherwise assessed.

F-3.2.6 Covered electrodes in Classes E6 — — (including E6 — — H and E6 — — HJ) unless otherwise assessed should be used with Scale B.

F-3.2.7 Solid electrode wire for gas-shielded arc welding should be used with Scale C unless otherwise assessed.

F-3.2.8 The scale should be used also with other suitably assessed consumables after appropriate drying treatments, as recommended by the manufacturer.

F-3.2.9 TIG welding should be used with Scale D similarly with other suitably assessed consumables after drying or other treatments, for example, clean solid electrode wires for gas-shielded arc welding, and some E6 — — covered electrodes after drying at temperatures recommended by the manufacturer. It should be noted that on occassions these temperatures could exceed 400°C.

F-3.2.10 Submerged arc welding, flux cored wire welding and continuous covered wire welding consumables can have hydrogen levels corresponding to any of the Scales A to D and, therefore, need assessing in the case of each named product.

F-3.3 Pre-Heating

This is the temperature of the parent material immediately before welding commences. It is assumed to be locally applied and measured for at least 75 mm on each side of the weld line. If possible the temperature should be measured on the face opposite to that being heated. Alternatively, if there is access to only one face, the heat source should be removed to allow for temperature equalization (1 minute for each 25 mm of plate thickness) before measuring. The pre-heat temperature will also be the minimum interpass temperature in the case of multi-run welds, except where advantage can be taken of using filling runs larger than the root run.

F-3.4 Combined Thickness (*see* **Fig. 6**)

This is the sum of the plate thicknesses averaged over a distance of 75 mm from the weld line. If the thickness increases greatly just beyond 75 mm from the weld line it may be necessary to use a higher combined thickness value.

F-3.5 Fit Up

Fit-up in fillet welds is defined as 'normal' in this context when the root gap is 1.5 mm and when the root gap is 0.4 mm or less, the fit is referred to as 'close'.

NOTE — It may be necessary for reasons other than the avoidance of hydrogen cracking to limit fillet weld root gaps to maximum values somewhat less than 3 mm.

F-3.6 Arc Energy

Arc energy values given in this Appendix are relevant to manual metal-arc welding with covered electrodes using a.c. and d.c. positive.

$$\text{Arc energy (kJ/mm)} = \frac{\text{Arc voltage} \times \text{Welding current}}{\text{Welding speed (mm/s)}} \times \frac{1}{1\,000}$$

F-3.6.1 An appropriated factor shall be applied for processes other than manual metal arc welding with covered electrodes.

F-3.6.1.1 For guidance in using other welding process, the arc energy values calculated from this formula should be divided by the following factors to give the values to be used in Fig. 5:

Submerged arc welding (single wire)	0·8
TIG Welding	1·2
MIG/MAG welding (solid, cored or self shielded wire)	1·0

NOTE — It may be necessary in some applications to limit energy input values either to avoid solidification cracking or to achieve toughness. This should be established by welding procedure tests where satisfactory evidence is not available.

F-3.7 Weld Run Dimensions

Welding conditions in Fig. 5a to 5n are specified in terms of arc energy These values may be

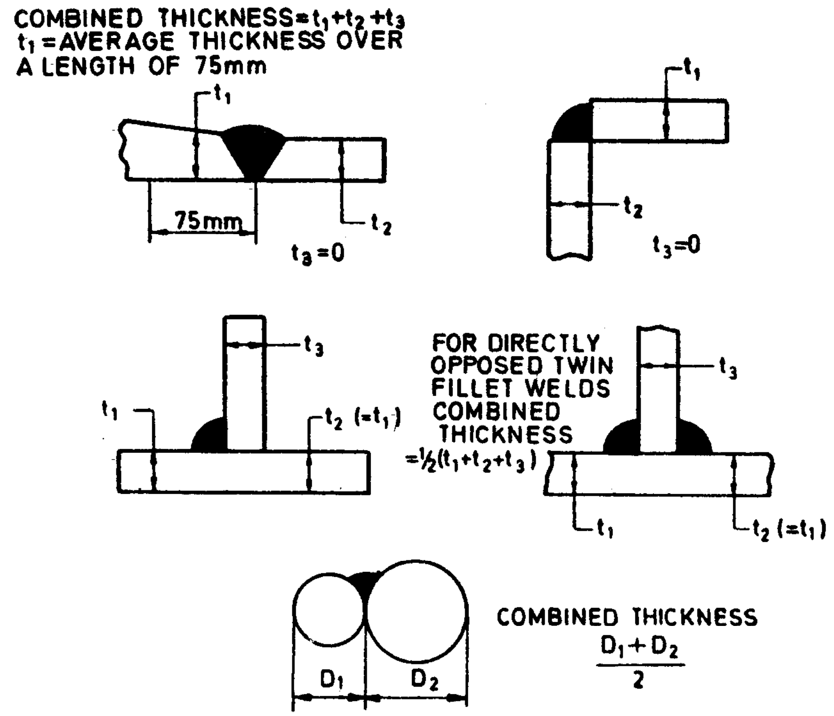


FIG. 6 EXAMPLES OF COMBINED THICKNESS

converted in terms of electrode size, weld run length and run out ratio by Tables 9A to 9C.

Where minimum fillet leg lengths are specified, Table 10 should be used to obtain the appropriate arc energy values.

F-3.8 Restraint

Restraint is that appropriate to normal situations, not for extreme cases such as for filling holes or slots.

F-4 RELAXATIONS

F-4.1 If some of the factors involved are more favourable than those enumerated in **F-3.3**, alternative procedures may be used provided they have been proved as satisfactory either by experience or tests. Guidance on some aspects is given below.

F-4.1.1 *General Pre-heating*

If the whole component, or a width more than twice that stated in **F-3.3**, is pre-heated it is generally possible to reduce the pre-heating temperature by as much as 50°C.

F-4.2 Limited Heat Sink

If the heat sink is limited in one or more directions (for example, when shortest heat path is $<$ 10 $\times$ leg length), especially in the thicker plate (for example, when fillet welding a narrow flange to the web of a girder) it is possible to reduce pre-heating levels.

F-4.3 Austenitic Stainless Steel Electrodes

In some circumstances where sufficient pre-heating to ensure crack free welds is impracticable, an advantage may be gained by using certain austenitic electrodes. In such cases, pre-heating may be reduced or eliminated.

F-5 EXAMPLE FOR USING THIS ANNEXURE

Step 1 — Decide carbon equivalent values using Table 1 and **F-3.1**. Assume a steel of carbon equivalent value 0.45.

Step 2 — Decide provisionally on welding process and consumables. Classify as A, B, C or D using **F-3.2** to determine which carbon equivalent scale to use.

Assume manual metal-arc welding using electrodes conforming to IS 814 : 1991 and that weld hydrogen level is appropriate to Scale B.

Step 3 — Decide whether fillet or butt-weld and refer to Table 1.

Assume fillet weld.

Table 1 refers to Table 6.

Step 4 — Decide minimum specified individual fillet leg length required by design drawing.

Assume 5 mm.

Table 6, Scale B, 5 mm leg length now requires Step 5.

Step 5 — Decide combined thickness of joint to welded with single run fillet of 5 mm leg length.

Refer to **F-3.4**.

Assume calculated combined thickness of 70 mm.

Step 6 — Return to Table 6 and read off the minimum pre-heat required; Scale B, 5 mm fillet of 70 mm combined thickness requires pre-heating to 100°C.

Step 7 — Tables 6 and 10 give arc energy values (*see* **F-3.6**) corresponding to the 5 mm fillet using the particular electrode, chosen (1·7 kJ/mm). Tables 9A, 9B and 9C give the electrodes size and run out conditions which correspond.

Thus Table 9B offers a choice of electrode size and run lengths from 450 mm of electrode ranging;

From 3·2 mm diameter and 145 mm run length to 8 mm diamenter and 910 mm run length.

Practical considerations would probably limit this to a maximum diameter of 5 mm electrode and corresponding run length of 355 mm.

Variation at Step 3:

Step A — Assume butt weld

Table 1 refers to Fig. 5a, 5e, 5g and 5h.

Figure 5g is relevant to 0.45 carbon equivalent and scale B.

Step B — Decide minimum run dimensions to be used in making butt weld.

This will most often be the root run.

Assume 4 mm electrode to be run out in about 320 mm of run length.

Refer to Table 9B. This gives minimum arc energy for individual runs forming the butt weld of 1.2 kJ/mm.

Step C — Decide combined thickness of butt joint, referring to **F-3.4**. Assume calculated combined thickness of 50 mm.

Step D — Return to Fig. 5g and plot coordinates of 1.2 kJ/mm arc energy and 50 mm combined thickness.

Read off minimum pre-heating and interpass temperature (by interpolation, if necessary, or by reading the pre-heat line immediately above or to the left of the co-ordinated point) which in the present example is 100°C.

Variation at either Step 7 or Step D.

In the event that pre-heat is undesirable, proceed as follows:

Step W — Re-examine Fig. 5g to determine minimum arc energy for no pre-heat (20°C line, normally).

For fillet example : 2·2 kJ/mm

For butt example : 1·6 kJ/mm

Step X — If by reference to Table 9B these arc energies are practically feasible, proceed using electrode diameter and run length chosen from Table 9B.

If not feasible, proceed to Step Y.

Step Y — Using Table 6 for the fillet example of Fig. 5a and 5e for weld example, examine the feasibility of using lower hydrogen levels (by the use of higher electrode drying temperatures or change of consumables) (*see* **F-3.2**) to avoid the need for pre-heat at acceptable arc energy levels.

Table 1 References to Tables and Figures to be Used for Different Carbon Equivalent Values

(*Clauses* F-3.1 *and* F-5)

Quality of Specification	Steel Grade	Carbon Equivalent Value	Manual Metal-Arc Fillet Welds: Refer to Table No. Given Below	Other Processes, or Consumables, or Joints Other Than Fillet Welds Refer to Figure No. Given Below	For Higher or Lower Carbon Equivalent Values Observed From Mill Sheet
(1)	(2)	(3)	(4)	(5)	(6)
IS 2062 : 1992	Fe 410 WC	0·39	3	5a and 5c	Select graph from Figures 5a to 5n according to carbon equivalent and scale (*see* F-3·2)
IS 8500 : 1991	Fe 440, Fe 440B	0·40	3	5a, 5b and 5d	
IS 2062 : 1992	Fe 410WB	0·41	4	5b, 5c and 5e	
IS 8500 : 1991, IS 2062 : 1992	Fe 490, Fe 490B, Fe 410 WA	0·42	5	5d and 5f	
—	—	0·43	5	5c, 5e and 5g	
IS 8500 : 1991	Fe 540, Fe 540B	0·44	6	5d and 5f	
—	—	0·45	6	5a, 5e, 5g and 5h	
IS 8500 : 1991	Fe 570, Fe 570B	0·46	7	5b and 5f	
IS 8500 : 1991	Fe 590, Fe 590B	0·48	7	5c	
—	—	0·50	8	5e	

NOTES

1 If the amount of residual elements is not known, a value of 0·03 should be added to the $C + \frac{Mn}{6}$ value to obtain the equivalent, except in the case of steel from a known supply of low residual element content.

2 The carbon equivalent values for grades of steel covered in IS 8500 : 1991 and IS 2062 : 1992 are recommended values.

Table 2 Simplified Conditions for Fillet Welds in Steel with a Maximum Carbon Equivalent of 0·38 Using Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potental Scalei	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	0	0	0	50	50	75	100	100	100
	5	1·4	0	0	0	0	0	0	20	50	50
	6	2·0	0	0	0	0	0	0	0	0	0
	8	2·8	0	0	0	0	0	0	0	0	0
	10	3·8	0	0	0	0	0	0	0	0	0
Scale B or D	4	1·3	0	0	0	0	0	0	0	0	0
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint, a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 3 Simplified Conditions for Fillet Welds in Steel having Maximum Carbon Equivalent of 0·40 Using Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	0	0	0	50	100	125	125	125	125
	5	1·4	0	0	0	0	20	75	100	100	100
	6	2·0	0	0	0	0	0	0	20	50	50
	8	2·8	0	0	0	0	0	0	0	0	0
	10	3·8	0	0	0	0	0	0	0	0	0
Scale B	4	1·3	0	0	0	0	0	20	50	50	50
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2.2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale C	4	1·3	0	0	0	0	0	0	0	0	0
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may neverthless be necessary to avoid weld metal hydrogen cracking.

Table 4 Simplified Conditions for Fillet Welds in Steel Having Maximum Carbon Equivalent of 0·41 Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of Following Combined Thicknessess								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	0	50	100	125	125	125	125	125	125
	5	1·4	0	0	0	0	50	100	100	125	125
	6	2·0	0	0	0	0	0	0	50	75	100
	8	2·8	0	0	0	0	0	0	0	0	0
	10	3·8	0	0	0	0	0	0	0	0	0
Scale B	4	1·3	0	0	0	0	20	50	75	100	100
	5	1·7	0	0	0	0	0	0	20	50	50
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale C	4	1·3	0	0	0	0	0	20	50	50	50
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale D	4	1·3	0	0	0	0	0	0	0	0	0
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 5 Simplified Conditions for Fillet Welds in Steel Having Maximum Carbon Equivalent of 0·43 Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of Following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	0	20	100	125	125	150	150	150	150
	5	1·4	0	0	0	75	100	125	125	150	150
	6	2·0	0	0	0	0	20	75	100	100	125
	8	2·3	0	0	0	0	0	0	0	50	50
	10	3·8	0	0	0	0	0	0	0	0	0
Scale B	4	1·3	0	0	0	20	75	100	125	125	125
	5	1·7	0	0	0	0	0	50	75	100	100
	6	2·2	0	0	0	0	0	0	0	50	75
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale C	4	1·3	0	0	0	0	20	50	75	100	100
	5	1·7	0	0	0	0	0	0	20	50	50
	6	2.2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale D	4	1·3	0	0	0	0	0	0	0	0	0
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 6 Simplified Conditions for Fillet Welds in Steel Having Maximum Carbon Equivalent of 0·45 Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of Following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	0	75	125	125	150	150	175	175	175
	5	1·4	0	0	50	100	125	125	150	150	150
	6	2·0	0	0	0	0	75	100	125	125	150
	8	2·8	0	0	0	0	0	0	50	100	125
	10	3·8	0	0	0	0	0	0	0	0	0
Scale B	4	1·3	0	20	20	75	100	125	125	150	150
	5	1·7	0	0	0	75	75	100	125	125	125
	6	2·2	0	0	0	0	0	20	75	100	125
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale C	4	1·3	0	0	0	20	75	100	125	125	125
	5	1·7	0	0	0	0	0	50	75	100	100
	6	2·2	0	0	0	0	0	0	20	50	75
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0
Scale D	4	1·3	0	0	0	0	0	0	0	0	0
	5	1·7	0	0	0	0	0	0	0	0	0
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 7 Simplified Conditions for Fillet Welds in Steel Having Maximum Carbon Equivalent of 0·48 Manual Metal-Arc Welding Electrodes

(*Clause* F-3.1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of Following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	20	100	125	150	175	175	175	175	175
	5	1·4	0	20	100	125	125	150	150	175	175
	6	2·0	0	0	0	75	100	125	125	150	150
	8	2·8	0	0	0	0	20	75	100	125	150
	10	3·8	0	0	0	0	0	0	20	75	100
Scale B	4	1·3	0	20	75	125	125	150	150	150	175
	5	1·7	0	0	20	75	100	125	125	150	150
	6	2·2	0	0	0	0	50	100	125	125	150
	8	3·4	0	0	0	0	0	0	20	50	75
	10	5·0	0	0	0	0	0	0	0	0	20
Scale C	4	1·3	0	0	50	100	100	125	125	150	150
	5	1·7	0	0	0	50	75	100	125	125	125
	6	2.2	0	0	0	0	20	50	100	100	125
	8	3·4	0	0	0	0	0	0	0	20	20
	10	5·0	0	0	0	0	0	0	0	0	0
Scale D	4	1·3	0	0	0	0	20	50	75	100	100
	5	1·7	0	0	0	0	0	0	20	50	50
	6	2·2	0	0	0	0	0	0	0	0	0
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 8 Simplified Conditions for Fillet Welds in Steel Having Maximum Carbon Equivalent of 0·50 Manual Metal-Arc Welding Electrodes

(*Clause* F-3·1)

Hydrogen Potential Scale	Specified Minimum Leg Length[1]	Minimum Arc Energy[1]	Minimum Pre-heating Temperature for Welding Plates of Following Combined Thicknesses								
			20 mm	30 mm	40 mm	50 mm	60 mm	70 mm	80 mm	90 mm	Un-limited[2]
	mm	kJ/mm	°C	°C	°C	°C	°C	°C	°C	°C	°C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Scale A	4	1·0	50	125	150	175	175	175	200	200	200
	5	1·4	0	75	125	125	150	175	175	175	200
	6	2·0	0	0	50	100	125	125	150	150	175
	8	2·8	0	0	0	0	50	100	125	125	150
	10	3·8	0	0	0	0	0	20	50	100	125
Scale B	4	1·3	0	50	125	125	150	150	175	175	175
	5	1·7	0	0	50	100	125	125	150	150	175
	6	2·2	0	0	0	50	100	125	125	150	150
	8	3·4	0	0	0	0	0	0	50	100	125
	10	5·0	0	0	0	0	0	0	0	0	75
Scale C	4	1·3	0	20	100	125	125	150	150	150	175
	5	1·7	0	0	20	75	100	125	125	150	150
	6	2·2	0	0	0	0	50	100	125	125	150
	8	3·4	0	0	0	0	0	0	20	50	75
	10	5·0	0	0	0	0	0	0	0	0	20
Scale D	4	1·3	0	0	0	20	75	00	100	125	125
	5	1·7	0	0	0	0	0	50	75	100	100
	6	2·2	0	0	0	0	0	0	0	50	75
	8	3·4	0	0	0	0	0	0	0	0	0
	10	5·0	0	0	0	0	0	0	0	0	0

[1] For individual run.

[2] In situations of high restraint a higher pre-heating temperature may nevertheless be necessary to avoid weld metal hydrogen cracking.

Table 9A Electrode Run Lengths for Different Arc Energies, Manual Electrodes Whose Coating Contain Little or No Iron Powder: IS 814, Classes E1 — —, E2 — —, E6 — —

(*Clauses* F-3·7 *and* F-5)

Arc Energy, kJ/mm		0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	8·0
Run length, mm, from 410 mm of a 450 mm electrode of diameter, mm:	2·5	220	165	130	110	95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3·2	355	270	215	180	150	135	120	105	95	85	—	—	—	—	—	—	—	—	—	—
	4	550	415	330	275	235	205	185	165	150	130	110	95	80	—	—	—	—	—	—	—
	5	870	650	520	435	370	325	290	260	235	205	175	150	130	115	105	95	85	—	—	—
	6	—	940	750	625	535	470	415	375	340	300	250	215	185	165	150	135	125	115	105	95
	6·3	—	1040	830	690	590	520	460	415	375	330	275	235	205	185	165	150	135	125	115	105
	8	—	—	—	1110	955	840	745	670	610	535	445	380	335	295	265	245	225	205	190	165
	10	—	—	—	—	—	—	1160	1040	950	835	695	595	520	465	415	380	350	320	300	260
Run out ratio for electrode of diameter, mm:	2·5	0·53	0·40	0·32	0·27	0·23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3·2	0·87	0·65	0·52	0·44	0·37	0·33	0·29	0·26	0·24	0·21	—	—	—	—	—	—	—	—	—	—
	4	1·35	1·01	0·81	0·67	0·58	0·50	0·45	0·40	0·37	0·27	0·27	0·23	0·20	—	—	—	—	—	—	—
	5	2·12	1·59	1·27	1·06	0·91	0·79	0·71	0·64	0·58	0·51	0·42	0·36	0·32	0·28	0·25	0·23	0·21	—	—	—
	6	—	2·40	1·84	1·53	1·31	1·14	1·02	0·92	0·83	0·73	0·61	0·52	0·46	0·41	0·37	0·33	0·31	0·28	0·26	0·23
	6·3	—	2·53	2·02	1·68	1·44	[illegible]	1·12	1·01	0·92	0·81	0·67	0·58	0·50	0·45	0·40	0·37	0·34	0·31	0·29	0·25
	8	—	—	—	2·72	2·34	[illegible]	1·82	1·64	1·49	1·39	1·09	0·94	0·82	0·73	0·65	0·59	0·54	0·50	0·47	0·41
	10	—	—	—	—	—	—	2·83	2·55	2·31	2·04	1·70	1·46	1·28	1·13	1·02	0·93	0·85	0·78	0·73	0·64

Table 9B Electrode Run Lengths for Different Arc Energies, Manual Electrodes Whose Coatings Contain Little or No Iron Powder: IS 814, Classes E2 — — J, E3 — — J, and E6 — — J

(*Clauses* F-3·7 *and* F-5)

Arc Energy, kJ/mm		0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	8·0
Run length, mm, from 410 mm of a 450 mm electrode of diameter, mm:	2·5	250	190	150	125	105	95	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3·2	410	310	245	205	175	155	135	125	110	100	80	—	—	—	—	—	—	—	—	—
	4	640	480	385	320	275	240	215	190	175	155	125	110	95	85	—	—	—	—	—	—
	5	1000	750	600	500	430	375	335	300	275	240	200	170	150	135	120	110	100	90	85	—
	6	—	1090	875	730	620	545	485	435	395	350	290	250	220	195	175	160	145	135	125	105
	6·3	—	1220	980	820	700	610	545	490	445	390	325	280	245	215	195	175	160	150	140	120
	8	—	—	—	—	1100	965	860	775	705	620	515	440	385	345	310	280	260	240	220	195
	10	—	—	—	—	—	—	—	1210	1100	965	805	690	605	535	485	440	405	370	345	300
Run out ratio for electrode of diameter, mm:	2·5	0·62	0·46	0·37	0·31	0·26	0·23	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3·2	1·01	0·76	0·60	0·50	0·43	0·38	0·34	0·30	0·27	0·24	0·20	—	—	—	—	—	—	—	—	—
	4	1·57	1·18	0·94	0·79	0·67	0·59	0·52	0·47	0·43	0·38	0·31	0·27	0·24	0·21	—	—	—	—	—	—
	5	2·46	1·84	1·48	1·23	1·05	0·92	0·82	0·74	0·67	0·59	0·49	0·42	0·37	0·33	0·29	0·27	0·25	0·23	0·21	—
	6	—	2·66	2·13	1.78	1·52	1·33	1·18	1·06	0·97	0·85	0·71	0·61	0·53	0·47	0·43	0·39	0·36	6·33	0·30	0·27
	6·3	—	2·99	2·40	2·00	1·71	1·50	1·33	1·20	1·00	0·96	0·80	0·68	0·60	0·53	0·48	0·44	0·40	0·37	0·34	0·30
	8	—	—	—	—	2·70	2·36	2·10	1·89	1·72	1·51	1·26	1·08	0·94	0·84	0·76	0·69	0·63	0·58	0·54	0·47
	10	—	—	—	—	—	—	—	2·95	2·69	2·36	1·96	1·68	1·47	1·31	1·18	1·07	0·98	0·91	0·84	0·74

Table 9C Electrode Run Lengths for Different Arc Energies, Manual Electrodes Whose Coatings Contain Little or No Iron Powder: IS 814, Classes E2, — — K, E3 — — K, and E6 — — K

(*Clauses* F-3·7 *and* F-5)

Arc Energy, kJ/mm		0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0	2·2	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	6·5	7·0	8·0
Run length, mm, from 410 mm of a 450 mm electrode of diameter, mm:	2·5	325	240	195	160	135	120	105	95	85	—	—	—	—	—	—	—	—	—	—	—
	3·2	530	395	315	265	225	200	175	160	145	125	105	90	—	—	—	—	—	—	—	—
	4	830	620	495	415	355	310	275	250	225	200	165	140	125	110	100	90	80	—	—	—
	5	—	975	780	650	555	485	430	390	355	310	260	220	195	170	155	140	130	120	110	95
	6	—	—	1120	935	800	700	620	560	510	450	370	320	280	250	225	205	185	170	160	140
	6·3	—	—	1230	1030	880	770	685	620	560	495	410	350	310	275	245	225	205	190	175	155
	8	—	—	—	—	—	1240	1100	1000	905	800	665	570	500	445	400	360	330	305	285	250
	10	—	—	—	—	—	—	—	—	—	1240	1030	890	780	690	620	565	520	480	445	390
Run out ratio for electrode of diameter, mm:	2·5	0·79	0·59	0·48	0·40	0·34	0·30	0·26	0·24	0·22	—	—	—	—	—	—	—	—	—	—	—
	3·2	1·30	0·97	0·78	0·65	0·56	0·49	0·43	0·39	0·35	0·31	0·26	0·22	—	—	—	—	—	—	—	—
	4	2·02	1·52	1·22	1·01	0·87	0·76	0·67	0·61	0·55	0·49	0·40	0·35	0·30	0·27	0·24	0·22	0·20	—	—	—
	5	—	2·38	1·90	1·58	1·36	1·18	1·05	0·95	0·86	0·76	0·63	0·54	0·48	0·42	0·38	0·35	0·32	0·29	0·27	0·24
	6	—	—	2·74	2·28	1·95	1·71	1·52	1.36	1·24	1·10	0·91	0·78	0·68	0·61	0·55	0·50	0·46	0·42	0·39	0·34
	6·3	—	—	3·01	2·51	2·15	1·88	1·67	1·51	1·37	1·20	1·00	0·86	0·75	0.67	0·60	0·55	0·50	0·46	0·43	0·38
	8	—	—	—	—	—	3·04	2·71	2·43	2·21	1·96	1·62	1·39	1·22	1·08	0·97	0·88	0·81	0·75	0·70	0·61
	10	—	—	—	—	—	—	—	—	—	3·04	2·53	2·17	1·90	1·69	1·52	1·38	1·26	1·17	1·08	0·95

Table 10 Values of Arc Energy to be Used in Figure 5 for Single Run Fillet Welds

(*Clauses* F-3.7 *and* F-5)

Minimum Leg Length	Arc Energy for Following Electrode Classification		
	E2 — — E3 — —	E6 — — E6 — —J	E2— —K
mm	kJ/mm	kJ/mm	kJ/mm
(1)	(2)	(3)	(4)
4	1·0	1·3	—
5	1·4	1·7	0·8
6	2·0	2·2	1·1
8	2·8	3·4	1·6
10	3·8	5·0	2·3
12	5·5	6·5	3·1

NOTE — These values are to be used only when the contractor is required to make fillet welds of the specified minimum leg length tabulated below. In other cases arc energy should be controlled by control of elecrode run out (Tables 9A to 9C) or directly through welding parameters.

ANNEX G

(*Clause* 24.1)

GUIDANCE ON SOLIDIFICATION CRACKING

G-1 Solidification cracking of the weld metal is usually found as centreline cracking. It is more often found in root runs and, although frequently open at the surface and visible after deslagging, may be just below the surface and covered by up to 0.5 mm of sound metal. Solidification cracks can be deep and can seriously reduce the efficiency of a joint. When welding carbon manganese steels, this type of cracking is most commonly found in submerged arc welds, rarely with manual metal-arc welding but can sometimes be a problem with gas and self-shielded processes.

G-2 Solidification cracking is associated with impurities, particularly sulphur and phosphorus, and is promoted by carbon picked up from the parent metal at high dilution levels whilst manganese reduces the risk of cracking. Because welding consumables are generally purer than the materials being welded, impurity levels and crack susceptibilities are usually greatest in weld runs of high dilution, for example, root runs of butt welds. To minimize the risk of cracking, consumables are preferred with low carbon and impurity levels and relatively high manganese contents.

G-3 For submerged arc welds a formula[1] has been developed in which the solidification crack susceptibility in arbitrary units known as Units of Crack Susceptibility (UCS) has been related to the composition of the weld metal { in percent (*m/m*) } as follows:

$$230C + 190S + 75P + 45Nb - 12.3Si - 5.4Mn - 1$$

This formula is valid for weld metal containing the following:

C	0.08[2] to 0.23
S	0.010 to 0.050
P	0.010 to 0.045
Si	0.15 to 0.65
Mn	0.45 to 1.6
Nb	0 to 0.07

[1] See Bailey, N., and Jones, S.B. Solidification cracking of ferritic steels during submerged arc welding. The Welding Institute, 1977.

[2] Contents of less than 0.08 percent to be taken as equal to 0.08 percent.

Alloying elements and impurities in the weld metal up to the following limits do not exert a marked effect on values of UCS:

1 percent Ni	0·02 percent Ti
0·5 percent Cr	0·03 percent Al
0·4 percent Mo	0·002 percent B
0·07 percent V	0·01 percent Pb
0·3 percent Cu	0·03 percent Co

In the above formula, values of less than 10 UCS indicate a high resistance to cracking and above 30 a low resistance. Within these approximate limits the risk of cracking is higher in weld runs with a high depth/width ratio, made at high welding speeds or where fit-up is near the maximum allowable.

For fillet weld runs having a depth/width ratio of about 1·0, UCS values of 20 and above indicate a risk of cracking whilst for butt welds the values of about 25 UCS are critical. Decreasing the depth/width ratio from 1·0 to 0·8 in fillet welds may increase the allowable UCS by about 9. However very low depth/width ratios, such as are obtained when penetration into the root is not achieved, also promote cracking.

ANNEX H

(*Clause* 24.1 *and* Annex *A*)

LAMELLAR TEARING

H-1 In certain types of joint, when the restraint is high and stresses build up during the welding of a rigid structure, lamellar tearing is likely when welding susceptible plate material. It is not yet possible to specify plate in such a way as to avoid material susceptible to lamellar tearing, but when this type of cracking is possible the contractor should discuss with the steelmaker the possibility and practicability of carrying out additional tests on the parent material to check that the susceptibility to lamellar tearing has been minimized (*see* **4**).

H-2 A suitable test is the short transverse tensile test (*see* Fig. 7) to measure the reduction in area. This parameter, measured on a standard specimen diameter, has been correlated with the incidence of lamellar tearing in different types of fabrication.

The short transverse reduction of area (STRA) has been correlated with the incidence of lamellar tearing in different types of fabrication (*see* Fig. 8). In the case of low oxygen steels (aluminium treated or vacuum degassed types) sulphur content has been found to be a useful guide to the inclusion content and thus to STRA. Figure 9 gives the likely lowest and highest values of STRA to be expected in an aluminium treated steel of a given sulphur content. The data are for plate 12·5 mm to 50 mm thick but it should be noted that the relationship of STRA (in percent) to sulphur content (in percent) is to some extent thickness dependent. Steels giving reduction of area values of 20 percent STRA are considered lamellar tearing resistant and material with guaranteed STRA are available. These are usually aluminium treated steels of low sulphur content, although additions of rare

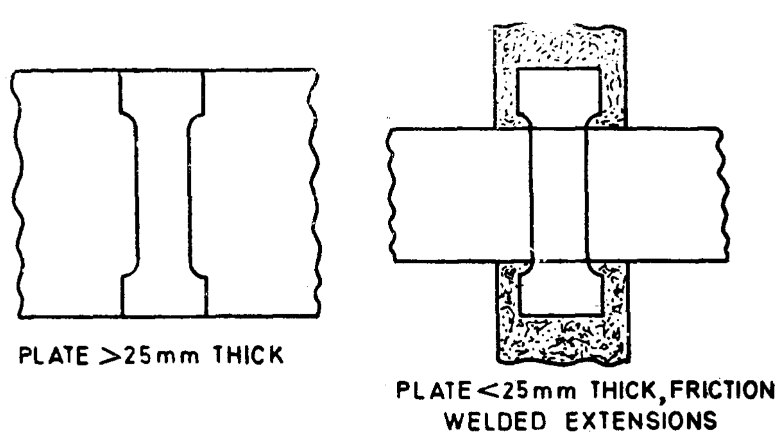


FIG. 7 EXTRACTION OF SHORT-TRANSVERSE CYLINDRICAL TENSILE TEST SPECIMEN FROM PLATE

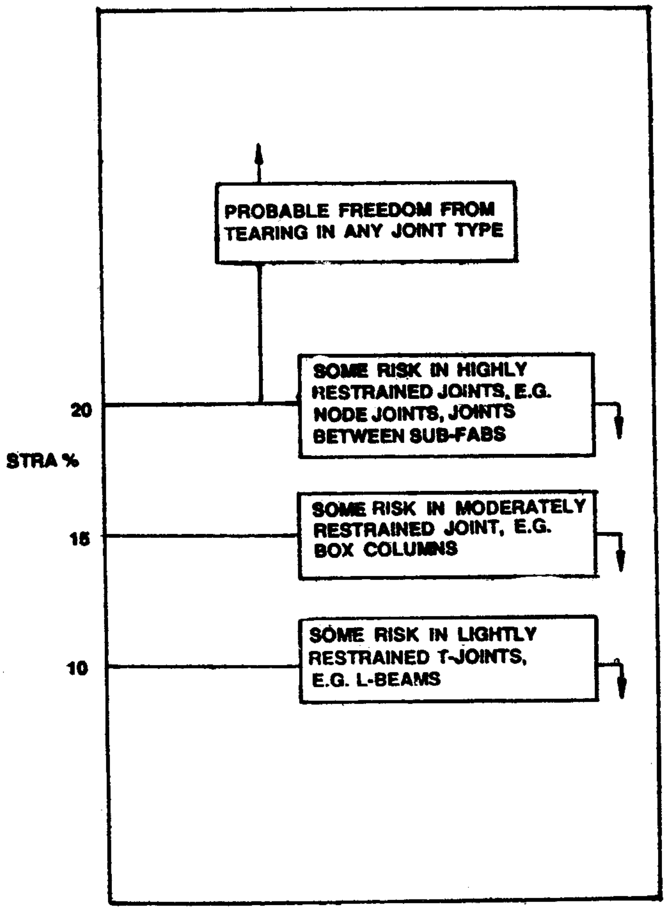


FIG. 8 SUGGESTED STRA VALUES APPROPRIATE TO RISK OF LAMELLAR TEARING IN JOINTS OF DIFFERING RESTRAINT (VALUES BASED ON 6.4 mm DIAMETER SPECIMEN)

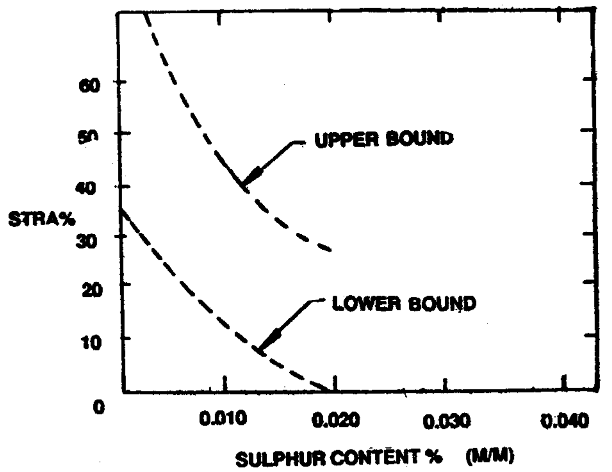


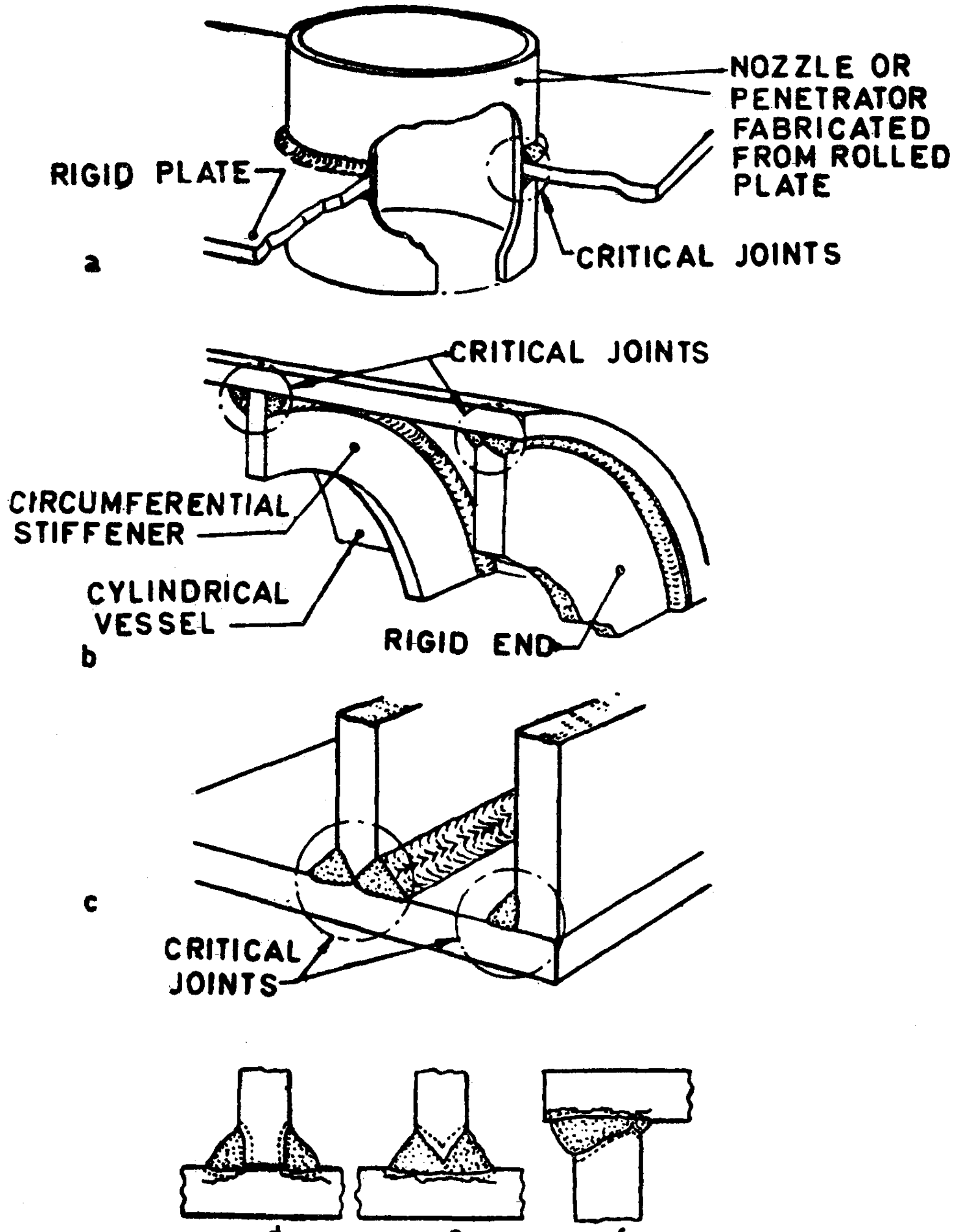
FIG. 9 STRA AGAINST SULPHUR CONTENT FOR PLATES 12.5 mm TO 50 mm THICK (INCLUSIVE)

earth or calcium compounds may also be made both to reduce the inclusion content and to favourably alter the inclusion shapes.

H-3 Lamellar tearing occurs predominantly in plate material. Susceptibility depends on the presence of non-metallic inclusions distributed parallel to the plate surface. These inclusions are not necessarily amenable to detection by existing non-destructive inspection techniques. Cracks can occur in parent plate and heat-affected zones and run generally parallel to the plate surface. The through-thickness strain needed to cause cracking is usually higher, than can result from the residual stresses of a single weld and thus lamellar tearing is generally associated with the welding of fairly large, highly restrained structures.

H-4 Examples of the types of detail and joint configuration in which lamellar tearing is possible are shown in Fig. 10 typical locations of the cracks being illustrated. If the risk of tearing is known to be high, susceptible joints and details (the T fillet, *see* Fig. 10d, is less susceptible than the T butt, *see* Fig. 10e) should be avoided or modified. For example, by using set-on rather than set-through nozzles; by chamfering the horizontal plate in Fig. 10 so that the stress is not perpendicular to the plate; by buttering with soft weld metal to absorb strains in metal not susceptible to lamellar tearing, or possibly by replacing susceptible plate by forgings or castings.

H-5 Although lamellar tears frequently initiate from other defects such as hydrogen cracks, measures taken to eliminate the later may not help to prevent tearing. In particular, the use of a higher pre-heating temperature with a set-in nozzle (*see* Fig. 10a) is known to be harmful.



a) Nozzle or penetrator through a rigid plate.
b) Stiffener or rigid end in a cylindrical fabrication.
c) Rigid box section.
d) T joint with fillet weld.
e) T joint with compound butt and fillet welds.
f) Corner joint with butt weld.

FIG. 10 DETAILS (a) TO (c) AND JOINT CONFIGURATION (d) TO (f) IN WHICH LAMELLAR TEARING IS POSSIBLE WHEN FABRICATING LARGE STRUCTURES WITH A HIGH DEGREE OF RESTRAINT FROM PLATE

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