IS 2811 (1987): Recommendations for Manual Tungsten Inert-gas Arc Welding of Austenitic Stainless Steel [MTD 12: Welding Applications]

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(Reaffirmed 1998)

Indian Standard

RECOMMENDATIONS FOR MANUAL TUNGSTEN INERT-GAS ARC WELDING OF AUSTENITIC STAINLESS STEEL

(First Revision)

1. Scope — Covers recommendations on material, equipment and general workmanship for the manual tungsten inert-gas arc welding of austenitic stainless steel. The recommendations are primarily intended for general engineering applications.

1.1 This standard is not applicable for welding of tubes and pipes, and does not stipulate the allowable stresses in welds.

2. Terminology

2.1 For the purpose of this standard, the definitions as given in IS : 812-1957 'Glossary of terms relating to welding and cutting of metals', shall apply.

3. Parent Metals, Filler Rods and Wires

3.1 The parent metals that are covered in this standard and the corresponding filler rods and wires used for welding them are given in Table 1.

3.1.1 The filler rods and wires specified in **3.1** are for general purposes only. For special purposes, filler rods and wires may be used by agreement between the purchaser and the fabricator.

3.2 The filler wire sizes and current ranges used to weld different thicknesses of parent metal are given in Table 2.

3.2.1 The filler rods and wires should be smooth, bright and free from grease and surface corrosion.

4. Current Condition

4.1 Direct current equipment with the electrode connected to the negative pole shall be used for welding stainless steels. Alternating current equipment may also be used for thicknesses from 0·71 to 3·15 mm.

4.1.1 If alternating current equipment is used for welding stainless steel of lower thickness any device to suppress the direct current component should preferably be disconnected from the circuit.

5. Welding Torch

5.1 Gas-cooled or water-cooled torches may be employed with ceramic or metallic nozzles. Gas-cooled torches are generally used for light gauge work with a short duty cycle whereas water-cooled torches are used for higher currents and heavy duty cycles.

5.2 Ceramic nozzles are preferred over metallic nozzles since the later has to be separately water-cooled and properly insulated.

5.3 The use of gas lense is recommended for achieving laminar flow of the gas for more efficient shielding. This is suitable for narrower grooves and for long electrode extensions.

Welding General Sectional Committee, SMDC 14 [Ref : Doc : SMDC 14 (2819)]

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TABLE 1 RECOMMENDED FILLER RODS AND WIRES FOR AUSTENITIC STAINLESS STEELS

(*Clause* 3.1)

Parent Metal in Accordance with IS : 1570 (Part 5)-1985*	Recommended Filler Wires and Rods in Accordance with IS : 5856-1970†
× 02Cr19Ni10	S – B01L
× 04Cr19Ni9	S – B01 or S – B01L‡
× 07Cr18Ni9	S – B01
× 04Cr18Ni10Ti	S – B01 Nb
× 04Cr18Ni10Nb	S – B01 Nb
× 04Cr17Ni12Mo2	S – B02 Mo or S B01 Mo L‡
× 02Cr17Ni12Mo2	S – B02 MoL
× 04Cr17Ni12Mo2Ti	S – B02 MoNb
× 15Cr24Ni13	S – B04 or S – B04 Nb
× 20Cr25Ni20	S – B05 or S – B04 Nb

*Schedules for wrought steels : Part 5 Stainless and heat resisting (*second revision*).
†Specification for corrosion and heat resisting chromium nickel steet solid welding rods and bare electrodes.
‡Minimum UTS of 490 MPa.

TABLE 2 RECOMMENDED FILLER ROD SIZES AND WELDING CURRENT RANGES FOR BUTT WELDS

(*Clause* 3.2)

Material Thickness mm	Filler Rod Size mm	Current Range Amperes
0·71	1·2 or 1·6	10-40
1·0	1·6 or 2·5	20-50
1·2	1·6 or 2·5	30-60
1·6	1·6 or 2·5	40-80
3·15	2·5 or 3·0	70-140
5·0	2·5 or 3·0	90-100
6 3	2·5 or 3·0	100-180
	4·0	180-300
> 6·3	2·5 or 3·2 or 4·0 or 5·0	200-350

6. Electrodes

6.1 Non-consumable electrodes made of tungsten are used because of its high melting point. Any of the 4 grades given in Table 3(A) can be used depending on the nature of the job. Tungsten electrodes with 1 or 2 percent thoria are superior to pure tungsten electrodes in several respects. They have higher electron emissivity, better current carrying capacity, longer life and greater resistance to contamination. With these electrodes, arc starting is easier and arc is also more stable. Two percent thoriated electrodes should be used with dc straight polarity (electrode negative). Pure tungsten or thoriated or zirconiated tungsten electrode should be used for welding with ac.

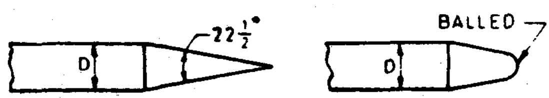
TABLE 3A CHEMICAL COMPOSITION OF NON-CONSUMABLE TUNGSTEN ELECTRODES

Grade	Tungsten, Percent, Minimum	Thorium Oxide, Percent	Zirconium Oxide, Percent	Other Impurities, Percent, Maximum
Tungsten (pure)	99·5	—	—	0·5
Tungsten (1 percent thoriated)	98·5	0·8-1·2	—	0·5
Tungsten (2 percent thoriated)	97·5	1·7-2·2	—	0·5
Tungsten (½ percent zirconia)	99·2	—	0·15-0·40	0·5

6.2 The tungsten electrodes should be clean and free from all contamination by the molten filler rod or parent metal. All contaminations should be dressed clean by light grinding. When using direct current with the electrode connected to the negative pole, the electrode tip should be ground to a point having an angle of approximately 22½° as shown in Fig. 1A. Alternatively, the tip may be chemically treated to attain the required angle. While using ac, the electrode should be used with a balled end (*see* Fig. 1B).

6.2.1 To avoid contamination of the tungsten electrode and the work, it is preferable to establish the arc using a high frequency spark generator. This unit enables the super-imposition of a high frequency, high voltage on the normal supply for a short time suitable enough for arc establishment. The arc may be struck on a similar material and the electrode be brought to its working temperature prior to actual commencement of work.

6.2.2 In case of ac, the high frequency unit is continuously in operation in order to maintain the arc at each current reversal.



1A Pointed End 1B Balled End

FIG. 1 RECOMMENDED ELECTRODE TIP PREPARATION

6.3 The electrodes employed should be of adequate size to carry the current required without over-heating the electrode. The maximum current for different electrodes sizes are given in Table 3B.

TABLE 3B TYPICAL CURRENT RATINGS OF TUNGSTEN ELECTRODES

Electrode Diameter mm	Direct Current Amperes (Pure or Thoriated, W)		Alternating Current Amperes (Pure or Thoriated or Zirconiated, W)	
	DCSP (−)	DCRP (+)	Unbalanced	Balanced
0·5	5-20	—	5-20	10-20
1·0	15-80	—	15-80	20-60
1·6	50-150	10-20	50-150	60-120
2·0	70-200	10-25	70-200	75-150
2·5	150-250	15-25	140-240	100-180
3·15	250-400	20-35	220-350	160-250
4·0	400-500	35-50	300-400	200-320
5 0	500-750	50-75	400-500	290-390
6·3	750-1 000	75-125	500-630	340-525

7. Argon Gas

7.1 *Quality* — Argon gas conforming to IS : 5760-1983 'Specification for compressed argon (*first revision*)' shall be used.

7.2 The rate of flow of argon should be adequate to obtain a clean weld. This depends on several factors, such as type of parent metal, current used, shape and size of nozzle, type of joint, and whether the work is done indoors or outdoors. Generally, a higher rate of flow is required with higher welding currents for outside corner joints, edge welds and work outdoors. Flow rates of 2 to 7 litres per minute will be found sufficient to weld thickness up to 6·3 mm. For thicknesses above 6 3 mm, flow rates of 5 to 10 litres per minute should be used.

7.3 If tungsten inert gas welding has to be done outdoors during inclement weather, especially during period of high wind, the welding areas should be effectively protected. Droughts tend to break the gas shielding resulting in porous and oxide-contaminated welds.

8. Preparation of Parent Metal

8.1 Before welding, joints should be cleaned thoroughly to remove all foreign substances, such as oil, grease, dirt, paint or other substances which burn in the arc. This is usually achieved by degreasing or pickling or both, preferably followed by scratch brushing with a stainless steel brush. While cleaning, at least 25 mm on either side of the joint should also be degreased and scratch-brushed.

8.2 *Degreasing* — Joint edges can be cleaned with solvent-soaked rags to remove surface oil, grease and dirt, although degreasing is preferably performed in a vapour degreasing plant. Suitable solvents include carbon tetrachloride, light petroleum, acetone and trichloroethylene and various proprietory compositions. Inflammable solvents, such as light petroleum, acetone, etc, should be used with care.

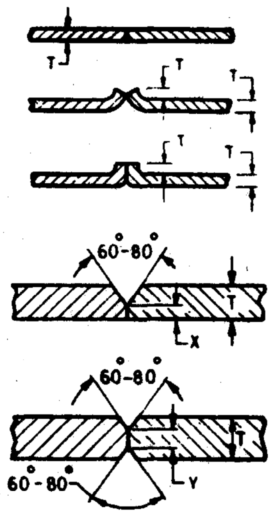
8.2.1 When solvents, such as carbon tetrachloride or trichloroethylene are used, special care should be taken as phosgene (highly poisonous and toxic gas) may be formed while welding from traces of these substances remaining on the job. Phosgene is formed even if vapour reaches the welding arc from the degreasing shop. It is, therefore, essential to ensure that the components are completely dry of solvents before welding and that no fumes from the degreasing shop can reach the welding arc.

8.3 *Pickling* — Heavy oxide films should be cleaned by pickling, immediately before welding. Pickling consists of cleaning with an aqueous solution of 10 percent nitric acid or 10 percent sulphuric acid or 2 percent hydrofluoric acid, followed by brushing with stainless steel wire brushes and by thoroughly rinsing with water.

8.4 *Grinding and Machining* — Following degreasing or pickling or both, if powder cutting has been used, the edges should be cleaned of scale and residue by machining or hand-grinding.

8.5 *Edge Preparation for Down-Hand Welds*

8.5.1 *Butt welds* — It should be prepared in accordance with Fig. 2. The addition of filler material is optional according to joint requirements. The typical details of the joint are given in Table 4.



Material Thickness mm	*Edge Preparation*	*Remarks*
T < 2·5, *Max*		1) *T* = 2·5, *Max*, for single sided, full penetration welds 2) Flanging is recommended where close butt is not feasible 3) Use of gas backing or backing strips is recommended
T > 2·5		1) *X* = 2, *Max*, for single sided, full penetration welds 2) Use of gas backing or backing strip is recommended
T > 4·8		1) *Y* = 2, *Max*, is recommended if back chipping is to be avoided 2, For root run, gas backing or backing strip is recommended

All dimensions in millimetres.

FIG. 2 RECOMMENDED EDGE PREPARATIONS FOR BUTT WELDS (DOWN-HAND AND VERTICAL)

8.5.2 *Tee joints* — It should be prepared in accordance with Fig. 3. Filler metal should be added.

8.5.3 *Corner joint* — It should be prepared in accordance with Fig. 4.

8.5.4 *Lap joint* — It should be prepared in accordance with Fig. 5. Filler material should be added.

***8.6 Edge Preparation for Vertical Joints**

8.6.1 *Butt joint* — It should be prepared in accordance with Fig. 2. For thickness one millimetre or less, the downward technique without the addition of filler metal should be used as this produces a neater finish. For thicker material, the upward technique with the addition of filler metal should be used.

8.6.1.1 For material thicker than 2·5 mm, an edge preparation as given in Fig. 6A is preferred; more than one run is then required.

8.6.1.2 Where access to both sides is possible, the double operator technique may be employed for thicknesses two millimetres and above. The recommended edge preparation is given in Fig. 6B.

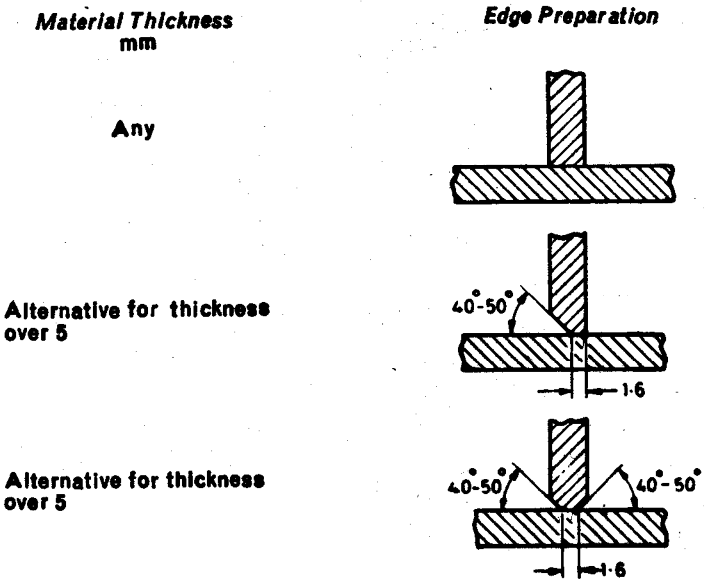
*The figures given in this clause are illustrative only. Modifications as suitable to the fabricator may be employed depending upon the job requirements.

TABLE 4 TUNGSTEN INERT-GAS WELDING FLAT BUTT WELDS WITHOUT BACKING BAR — DIRECT CURRENT (ELECTRODE NEGATIVE)

(*Clause* 8.5.1)

Thickness	No. of Passes	Edge Preparation	Diameter of Shield	Diameter of Electrode	Current	Arc Travel Speed	Filler Rod Size	Argon Flow
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
mm			mm	mm	A	cm/min	mm	l/min
0·71-1·0	1	Flange	10·0	1·0	30	25·0	1·6	1·4-1·8
1·6	1	*a*	10·0	1·6	70	22·5	1·6	2·3-2·8
2·0	1	*a*	10·0	2·5	80	20·0	2·5	2·3-2·8
3·15	1	*a*	12·5	2·5	120	15·0	2·5	2·8-3·3
5·0	1	*b*	12·5	3·15	150	12·5	3·15	3·8-4·2
6·3	2	*b* or *c*	12·5	3·15	206	10·0	5·0	3·8-4·2

a = square edge close butt.
b = 80° included angle single V preparation (close butt).
c = 90° included angle double V preparation (close butt).



All dimensions in millimetres.

FIG. 3 RECOMMENDED EDGE PREPARATION FOR TEE JOINTS

8.6.2 *Tee joints* — Illustrations regarding edge preparation of tee joints are given in Fig. 3. Tee joints are not recommended for thicknesses less than one millimetre. The upward technique with the filler wire addition should be used.

8.6.3 *Corner joint* — It should be prepared in accordance with Fig. 4. Where parent metal thickness is less than one millimetre, the downward technique without the addition of filler metal is recommended. Thicker material should be welded using the upward technique with filler metal.

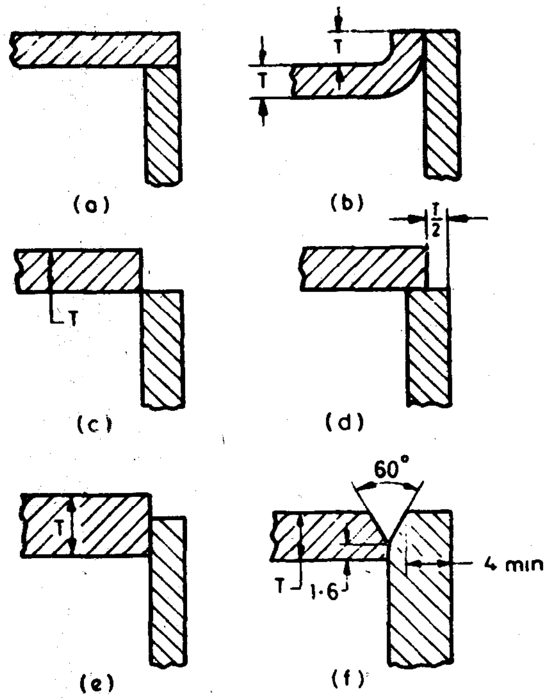
8.6.4 *Lap joint* — It should be prepared in accordance with Fig. 5. The upward technique with the addition of filler metal should be employed.

9. Assembly for Welding

9.1 To maintain alignment during welding, the parts should be located by mechanical means or by tack welding.

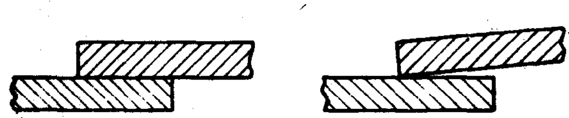
***9.2** If a jig is not used, the edges should be kept in alignment in assembly prior to welding by tack welds spaced at regular intervals along the joints. The tack welds should be either melted out during welding or made a part of and the same quality as the main weld. Defective tack welds should be removed before welding commences. After tack welding, the weld should be scratch-brushed before regular welding is commenced.

*The figures given in this clause are illustrative only. Modifications as suitable to the fabricator may be employed depending upon the job requirements.

Material Thickness mm	*Edge Preparation*	*Remarks*
T up to 1·6		Filler wire addition optional
T over 1·6		Filler wire should be added
		Filler wire should be added

All dimensions in millimetres.

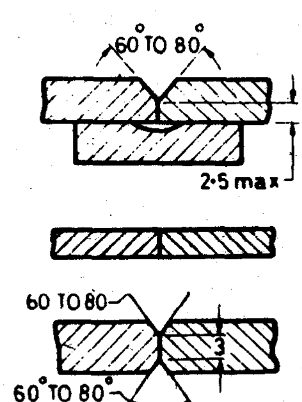
FIG. 4 RECOMMENDED EDGE PREPARATION FOR CORNER JOINTS



(a) (b)

Recommended edge preparation where only one side is welded.

FIG. 5 RECOMMENDED EDGE PREPARATION FOR LAP JOINTS

Material Thickness mm	*Edge Preparation*	*Remarks*
Over 2·5		Single welder in vertical position. In general, recommended for 1 or 2 runs
2 to 3·15		
20 > 5 to 6·3		Double welder technique to be employed in vertical position. For thicknesses greater than 6·3 mm, double welder technique may be used for root run only

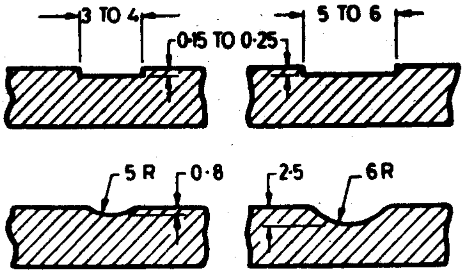
All dimensions in millimetres.

FIG. 6 RECOMMENDED EDGE PREPARATION FOR VERTICAL BUTT WELDS

9.3 Backing bars, when employed, may be of mild steel or copper and should be maintained in a clean condition free from grease, dirt, moisture and rust. Typical backing bars are illustrated in Fig. 7. Argon backing could be used with advantage specially with thinner gauges.

9.3.1 For keeping the backing bars clean, sometimes steel and copper backing bar may be given a thin coating of chromium.

9.3.2 Nitrogen used for back purging shall conform to IS : 1747-1972 'Specification for nitrogen (*first revision*)'.



7A Temporary Metallic Backing Bars

7B Fibre Glass Tape Used for Single-V

7C Fibre Glass Rope Used for Double-V

All dimensions in millimetres.

FIG. 7 TYPE OF TEMPORARY BACKING

10. Preheat and Interpass Temperature

10.1 Preheating is generally not required. However, warming up is to be done if the atmospheric temperature is less than 20°C.

10.2 For multipass welds, it should be ensured that the interpass temperature does not exceed 175°C.

11. Precaution During Welding

11.1 Argon, nitrogen and water supplies shall be opened a short while before starting the arc and kept open a short while after extinguishing the arc in order to ensure complete protection to electrode and weld puddle from atmosphere.

11.2 Nitrogen, when employed for back purging, should have flow rates less than that of argon from the torch.

12. Testing and Inspection

12.1 The method of inspection should be in accordance with the requirements of IS : 822-1970 'Code of procedure for inspection of welds' and IS : 1182-1983 'Recommended practice for radiographic examination of fusion welded butt jonts in steel plates (*second revision*)'

12.2 Welds not complying with such standards should be cut out, rewelded and reinspected.

12.3 The fabricator shall be responsible for the supply of material for testing, preparation of test piece, labour and appliances required for such testing as may be carried out in his premises by the purchaser. If such facilities are not available at his premises for carrying out such prescribed tests; the fabricator shall have the tests carried out elsewhere.

APPENDIX A

(*See* Explanatory Note)

ADDITIONAL DATA ON MANUAL TUNGSTEN INTERT-GAS ARC-WELDING

A-0. General

A-0.1 The electrical equipment for argon welding of stainless steel comprises an alternating current or direct current power sources as the case may be, and a device for high frequency spark starting. These devices ensure a balanced and stable arc.

A-0.2 Care should be taken that air is not entrained into the argon stream through leaks in the connections or leads. The size of the nozzle used should give adequate coverage of the weld area with the shielding gas. The tungsten electrode should be clean. If it should get contaminated during welding, an arc should be drawn on a similar piece of material for a short while to clear the contamination. If this method proves unsuccessful, the contaminated electrode should be lightly ground till the surface is once again clean. Argon cylinders should never be used below a pressure of 0·15 MPa (1·5 kg/cm^2) because of the danger of atmospheric contamination.

A-1. Details of the Process of Welding

A-1.1 *Properties of Argon Arc Welds* — Strength of any particular welded joint will depend on several factors including the skill of the welder and the size of the pieces being joined. The welder's skill influences the quality of the weld and this, as well as the size of the weld required affects the amount of heat put into an assembly and subsequently the extent of annealing of the parent material. Thus, when high quality joints are a critical requirement, the weld strength requirements should be specified and checked by tests, and subsequently workmanship kept to the same standard by frequent and capable inspection.

A-1.2 *Faults in Argon Arc Welds* — The chief faults found in unsatisfactory welds are gas porosity, oxide inclusion, cracks and undercutting, but they can be avoided by attention to welding procedure and by the choice of satisfactory parent metal and filler rod. The appearance of the surface is a good guide to the quality of the weld, the absence of discolouration, 'dirty' edges and undercutting being readily observed. The upper surface of the bead should be smooth, with uniform ripple marks evenly spaced, and the underside free from crevices or excessive 'run through'. The form of the ripples is an indication of the speed of welding for given material and dimensions, and is also a guide to the grain structure of the weld metal.

A-2. Application

A-2.1 The argon arc-welding process has been widely adopted and the following industries represent a few of these:

a) Containers and plant for the chemical and food industries;
b) Road vehicles, structural engineering and buildings;
c) Marine;
d) Aircraft, spacecraft and launch vehicles;
e) General engineering including castings;
f) Pressure vessels, boilers and heat exchangers; and
g) Atomic energy and nuclear power.

A-3. Advantages of Argon Arc-Welding

A-3.1 The advantages of argon arc-welding (specially as applied to stainless steels) can be summarized as follows:

a) Ideal for joining thin materials, sometimes even without filler wire addition;
b) There is no slag formation;
c) There is no spatter as the filler material is added in the weld pool;
d) Enables single sided welding with full penetration (for example, pipes and tubes);
e) Simple edge preparations are sufficient;
f) Loss of alloying elements is much less than in other processes like metal-arc and gas-welding;
g) Less finishing costs (hardly involves operations like grinding, etc);
h) Suitable for welding in all positions; and
j) The process lends itself to many forms of automatic or semi-automatic weldings.

A-4. Limitations of Argon Arc-Welding

A-4.1 The following are the limitations of argon-arc welding:

a) The cost is comparatively high because of slow speed and high cost of argon gas and tungsten electrodes;

b) The equipment is rather more complicated, and hence higher initial cost than that required for shielded metal arc or oxy-fuel gas welding;

c) The process cannot be well used on site work, unless precautions are taken to avoid draughts;

d) The process is not suitable for thick sections because of low deposition rates; and

e) The operation requires adequate care to prevent electrode or base metal contamination.

A-5. Some Typical Problems, their Causes and Remedies

A-5.1 Table 5 given some common problems in argon arc-welding, their likely causes and suggested remedies.

TABLE 5 TROUBLE SHOOTING GUIDE FOR GAS TUNGSTEN ARC-WELDING

Problem	Cause	Remedy
Wasteful electrode consumption	Improper shielding (resulting in oxidation or electrode)	Clean nozzle, bring nozzle closer to work, step up gas flow
	Operating on reverse polarity	Employ larger electrode or change to straight polarity
	Improper size electrode for current required	Use larger electrode
	Excessive heating in holder	Ground finish electrode; change, collect; check for improper collect contact
	Contaminated electrode	Remove contaminated portion, erratic results will continue as long as contamination exists
	Electrode oxidation during cooling	Keep gas flowing after stoppage of arc for at least 10-15 seconds. *Rule* : 1 second for each 10 amperes
Erratic arc	Base metal is dirty, greasy	Use appropriate chemical cleaners, wire brush or abrasives
	Too narrow joint	Open joint groove; bring electrodes closer to work; decrease voltage
	Electrode is contaminated	Remove contaminated portion of electrode
	Too large diameter electrodes	Use smaller diameter electrodes
	Arc too long	Bring holder closer to work to shorten arc
	Improper electrode tip shape	Grind tip suitably
Porosity	Entrapped gas impurities (hydrogen, nitrogen, air, water vapour)	Blow out air from all lines before striking arc; remove condensed moisture from lines; use welding grade (99·999) inert gas
	Possible use of old acetylene hoses	Use only new hoses, acetylene impregnates hose
	Gas and water hoses	Never interchange water and gas hoses (colour coding helps)
	Oil film on base metal	Clean with chemical cleaner not prone to breakup in arc; DO NOT WELD WHILE BASE METAL IS WET
	Indadegnate or excessive gas flow rate	Set correct gas flow rate
	Contact starting with electrode	
Tungsten contamination of workpiece	Electrode melting and alloying with base metal	Use high frequency starter; use copper striker place
	Shattering of electrode by thermal shock	Use less current or larger electrodes, use thoriated or zirconium-tungsten electrode
		Certain electrode ends are not slivered or cracked when using high current values. Use embrittled tungsten to facilitate easy and clean breakage
Crater cracks	Abrupt arc stopping	Use down sloping current

A-6. Safety Precautions

A-6.1 The ultra-violet rays emitted during argon arc-welding of stainless steel are much more intense than those formed during the manual arc-welding of steel because higher current density are used. For this reason, the operator should use protective gloves and darker shade of protective glass. Use can also be made of suitable chemical agents like light deflectant creams — available for protection against ultra-violet radiations.

A-6.2 During the welding of material which has been degreased with trichloroethylene, highly toxic and poisonous fumes will be encountered which cause severe headaches. For this reason, degreasing with this reagent should be carried out in a different room from the welding operation, and all material which has been so degreased should be either hot dried or allowed to stand for sufficiently long time at room temperature to ensure that the material is completely free of degreasing solvent.

EXPLANATORY NOTE

This standard was first published in 1964. The major modifications which have been made in this revision are:

a) Eleven grades of austenitic stainless steel mentioned in IS : 1570 (Part 5)-1972 have been covered,

b) Recommendations of filler rods and wires have been given in accordance with IS : 5856-1970,

c) Electrode tip preparation has been included, and

d) Backing bars or strips of fibre glass have also been permitted to be used in welding.

This standard covers the recommendations for manual tungsten inert-gas arc-welding of austenitic stainless steel (*see* Appendix A).

The method of testing of stainless steel welded by manual tungsten inert-gas arc does not fall within the scope of this standard and hence is not included. However, for testing and inspection, a reference to IS : 822-1970, IS : 1182-1983 and IS : 3600 (Part 1)-1985 'Method of testing fusion welded joints and weld metal in steel: Part 1 General tests (*first revision*)', may be made.

Additional information for general guidance is given in Appendix A.

In the formulation of this standard, due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. Considerable assistance has also been derived from BS 3019 : Part 2 : 1960 'General recommendations for manual inert gas tungsten-arc welding: Part 2 Austenitic stainless and heat resistant steels', issued by the British Standards Institution.

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