British Standard

BRITISH STANDARD

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Incorporating Amendment No. 1

Specification for

Metal arc welding of steel for concrete reinforcement

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Welding Standards Policy Committee (WEE/-) to Technical Committee WEE/43, upon which the following bodies were represented:

British Reinforcement Manufacturers Association
British Steel Industry
Concrete Society
Department of Transport
Federation of Civil Engineering Contractors
High Yield Bar Development Association
Institution of Structural Engineers
UK Certification Authority Reinforcing Steels
Welding Institute
Welding Manufacturers Association

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Contents

Foreword

This British Standard has been prepared under the direction of the Welding Standards Policy Committee.

In using some other, more general, welding process standards, it was found that there were certain difficulties in applying these to reinforcing steels and it was decided to produce a standard devoted specifically to these.

It should be emphasized that the procedures and testing contained in this standard apply solely to assessing the weld and do not take into account design criteria, e.g. fatigue, that are more properly the responsibility of the application standard.

It has been assumed in the drafting of this standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This British Standard specifies requirements for materials of construction, methods for the approval of welding procedures and welders, workmanship and inspection requirements for the joining, by metal-arc welding, of reinforcing steel for concrete structures.

It is intended for use in the welding of reinforcing steel complying with BS 4449 and BS 4482 but also applies to the welding of steel connection devices, inserts, anchors and anchor details, including prefabricated assemblies required in reinforced concrete and precast concrete constructions, in the fabrication shop and in the field.

In addition to the definitive requirements, it also requires the items detailed in clause **3** to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisfied.

The welding processes covered by this British Standard are manual metal-arc welding, gas-shielded welding with solid or flux-cored wires and non-shielded welding, using either a bare wire or cored electrode.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this British Standard the following definitions apply. For other relevant terms the definitions in BS 499-1 apply.

2.1
bar

a steel product of plain round or deformed profile, including a rod or wire of steel

2.2
hot rolled bar

a bar that complies with the requirements of BS 4449

2.3
cold worked bar

a bar that complies with the requirements of BS 4449

2.4
cold reduced wire

wire that complies with the requirements of BS 4482

2.5
deformed bar or wire

bar or wire that is so shaped that its bond with concrete is increased, the degree of deformation being as defined in BS 4449 or BS 4482, as relevant

2.6
size (nominal size, d)

the diameter of a circle with an area equal to the effective cross-sectional area of the bar, rod or wire

2.7
yield stress

the stress measured during the tensile test when the extension is a specified percentage increase in the gauge length

2.8
structural joint

a joint designed to support loads during service

NOTE For example butt joints between bars, or joints between bars and anchorage plates.

2.9
tack weld

a weld used to hold together assemblies of reinforcing bars

2.10
flare-bevel fillet weld

a weld between the curved surface of a reinforcing bar and the flat surface of a plate section (See Figure 1(a).)

2.11
flare-vee fillet weld

a weld between the curved surfaces of two adjacent parallel bars (See Figure 1(b).)

2.12
butt joint

a joint between two bars, having their axes in alignment, joined to each other by a butt weld, the cross section of the bars being welded (See Figure 2.)

2.13
splice joint

a joint between two bars having their axes in alignment, the bars being attached by fillet welds to a common splice member, the cross section of the bars being unwelded (See Figure 3.)

2.14
splice member

a plate, angle, section, sleeve or bar used as a link between two bars in a joint, the two bars being welded separately to the link instead of directly to each other (See Figure 3.)

2.15
lap joint

a connection between two overlapping bars (see Figure 4 and Figure 5.)

2.16
cruciform joint

a joint between two bars, having their axes at right angles, joined to each other by a fillet weld, the cross section of the bars being unwelded (see Figure 6)

3 Information and requirements to be agreed and to be documented

3.1 Information to be supplied by the client

The following information to be supplied by the client shall be fully documented. Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

a) The application standard to be used, where this exists, together with any supplementary requirements.

b) Whether written welding procedures are required (see **11.9**).

c) Whether welding procedure approval testing is required (see clauses **5** and **12**).

d) Quality assurance requirements.

3.2 Information to be supplied by either of the contracting parties

The following information, to be supplied by either of the contracting parties, shall be fully documented and the origin of the information shall be stated.

Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

a) Specification of the parent metal and of the required weld metal together with welded joint properties and details of any backing material.

b) Locations, dimensions and details, i.e. form of joint, gaps between parts etc. of all welds.

NOTE When symbols are used for standard weld forms, they should comply with BS 499-2.

3.3 Requirements to be agreed

The following items to be agreed between the contracting parties, which are specified in the clauses referred to, shall be fully documented.

Both the definitive requirements specified throughout the standard and the documented items shall be satisfied before a claim of compliance with the standard can be made and verified.

a) The method and extent of inspection and testing and the quality requirements in the absence of a relevant application standard (see clause **7**).

b) Approval and testing of welding procedures including any to be undertaken by an independent testing laboratory or authority (see clause **5**).

c) Approval and testing of welders including any to be undertaken by an independent authority (see clause **6**).

d) Selection of metal arc welding consumables (see **9.1** and **9.2**).

e) Whether the requirements for preheating temperatures apply (see **11.2.1**).

f) Acceptance levels for minor local imperfections revealed by macro-etch tests (see **12.3.6**).

4 Materials

4.1 Parent metal

The parent metal shall comply with the requirements for chemical composition and mechanical properties given in BS 4449 or BS 4482 as relevant.

4.2 Backing material

Steel backing material to be fused in the welding process shall have a carbon equivalent and sulphur and phosphorus levels not greater than that specified for the parent metal.

5 Approval and testing of welding procedures

If so required by the client, the contractor shall carry out the relevant testing procedures according to the type of welding process employed (see clause **12**).

6 Approval and testing of welders

The contractor shall satisfy the client that the welders are suitable for the work upon which they will be employed by complying with the requirements of clause **13**.

7 Inspection and testing

7.1 General

The method and extent of inspection and testing shall be in accordance with the relevant application standard where it exists.

If no application standard exists, the method and extent of inspection and testing shall be agreed between the contracting parties (see **3.3**).

NOTE 1 Inspection methods may be visual, including dye penetrant examination or magnetic particle inspection and may include radiography.

NOTE 2 Because of the risk of delayed cracking, a period of at least 48 h is recommended before inspection is made of as-welded fabrications. Whatever period is used it should be stated in the inspection records.

7.2 Quality of welds

The quality of the welded joints shall meet the acceptance levels for visual examination in Table 7 and, if required, the acceptance levels for non-destructive testing given in Table 8.

8 Metal arc welding equipment

8.1 Equipment

Welding power sources, instruments, cables and accessories shall comply with the requirements of the appropriate Parts of BS 638. The capacity of the welding power source and ancillary equipment shall be adequate for the welding procedure to be used and shall be maintained in good working order.

All electrical plant used in connection with the welding operation shall be correctly earthed. The welding return lead from the work shall be of appropriate cross section and shall be correctly connected and earthed.

NOTE Attention is drawn to the advice on safety precautions contained in the Health and Safety at Work Guidance Note PM 64 "Electric safety in arc welding" issued by the Health and Safety Executive and published by HM Stationery Office and to BS 638-6 and BS 638-7.

8.2 Instrumentation

Means of measuring the current shall be available, either as part of the welding plant, or by the provision of a portable ammeter.

In the case of semi-automatic welding, means shall be provided for measuring the arc voltage, current and/or wire feed speed.

Where drying ovens are required, they shall be provided with means of measuring the oven temperature.

9 Metal arc welding consumables

9.1 Manual metal-arc welding

Electrodes shall comply with BS 639 and shall be selected having regard to the particular application, i.e. joint design, welding position and the properties required to meet service conditions [see **3.2** a)].

9.2 Gas-shielded welding

9.2.1 *Filler rods and wires.* Where a solid metal filler rod or wire is used with a gas-shielded process, it shall comply with BS 2901-1 and shall be selected having regard to the particular application, i.e. joint design, welding position and the properties required to meet service conditions [see**3.2** a)].

Cored electrodes, when used with the appropriate shielding gas or gas mixture, shall comply with BS 7084 and shall be selected having regard to the particular application, i.e. joint design, welding position and the properties required to meet service conditions [see **3.2** a)].

9.2.2 *Shielding gases.*When a gas or gas mixture is used, it shall be of the following quality, as appropriate:

a) carbon dioxide complying with type 1 specified in BS 4105;

b) gas mixtures of carbon dioxide and argon that have been proved to be satisfactory as a result of either documented experience or procedure approval tests.

9.3 Non-shielded welding

Electrodes for non-shielded semi-automatic arc welding, which are usually of the cored type, shall be selected having regard to the particular application, i.e. joint design, welding position and the properties required to meet service conditions [see **3.2** a)].

9.4 Storage and handling

9.4.1 *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.

NOTE 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.

9.4.2 *Covered electrodes.* Electrodes shall be stored in their original containers in a dry, preferably heated place adequately protected from the effects of the weather and in accordance with the manufacturer's recommendations. When special protection or other treatment during storage or immediately prior to use is recommended by the electrode manufacturer, they shall be treated in accordance with the conditions detailed by the manufacturer.

In order to ensure that the weld metal deposited by hydrogen-controlled electrodes contains a maximum diffusible hydrogen content of 15 mL/100 g, determined by the methods specified in BS 6693-2 the drying or baking conditions indicated by the electrode manufacturer shall be followed.

Electrodes shall be removed from their original containers before drying or baking. After removal from the oven, the electrodes shall be protected from the exposure to conditions conducive to moisture absorption.

NOTE 1 In order to provide this protection, it may be necessary for welders to be issued with electrodes in quivers or sealed containers.

Electrodes returned to stores shall be treated in accordance with the electrode manufacturer's recommendations before re-issue.

NOTE 2 If electrodes have been exposed to poor storage conditions or it is suspected that they have become damp, the advice of the manufacturer should be sought before use.

10 Welded connections

10.1 General

For the transmission of loads reinforcing bars shall be joined together by butt, splice, lap or cruciform joints.

Where reinforcing steel is to be joined to steel plate, rolled sections or hollow sections by butt or fillet welds, the welding shall comply with this standard and, where relevant, with BS 5135.

10.2 Butt joints

Butt joints shall have full penetration butt welds and the consumables shall be chosen so that the tensile strength of the weld shall be at least as high as the specified tensile strength of the reinforcing bar.

NOTE Suitable end preparations are shown in Figure 2.

10.3 Splice joints

The splice member shall be plate, bar, angle, tube or any shape approved by the client.

Reinforcing bars shall be joined to plate or angle sections by flare bevel fillet welds and, when the splice member is a short length of bar, flare vee fillet welds shall be used (see Figure 3).

NOTE Flare bevel and flare vee fillet welds may be single or double, and splice joints made with short lengths of bars may include one or two bars. The splice joint shown in Figure 3 (c) incorporates two splice bars.

10.4 Lap joints

Lap joints shall be made with flare vee fillet welds (see Figure 4).

NOTE 1 The use of double fillet welds rather than single fillet welds will minimize bar overlap.

NOTE 2 It is recommended that, in the case of lap welds, the ends of the weld should be started and finished on the surface of one of the bars, i.e. away from the gap between the bars (see Figure 5).

10.5 Cruciform joints

Cruciform joints shall be made with flare vee fillet welds which can be intermittent or continuous (see Figure 6).

Procedure tests shall be carried out to determine what length and size of weld is required to produce joints of a given strength.

10.6 Tack welds (locational)

Tack welds to join reinforcing bars together for locational purposes prior to concreting, although essentially non load bearing, shall comply with Appendix A.

10.7 Preparation for welding

The surfaces to be welded shall be free from characteristics that would affect the quality of the weld:

a) cracks, notches or other irregularities that can be shown to interfere with the deposition of the weld or be the cause of defects, and;

b) loose or heavy scale, moisture, rust, oil or grease or other foreign material.

The ends of reinforcing bars to be joined by butt welds shall be prepared by mechanical means e.g. by sawing or by grinding (see Figure 2).

10.8 Assembly

Bars shall be held in the correct position until completion of welding. Each joint shall have clearance and access for the production of a sound weld.

The misalignment of bars to be joined by a direct butt weld shall be not greater than 10 % of their size or 3 mm whichever is the lesser.

Bars to be connected by means of lap joints shall be brought into mutual contact.

Before any tack welds are deposited the bars shall be preheated if necessary and the temperatures used shall be those given in Table 1 and Table 2.

Tack welds for lap joints shall be cleaned free of slag before the final weld is made.

In butt joints that are to be welded from both sides the root of the first side welded shall be ground or gouged to clean metal from the second side before depositing weld metal on that side.

10.9 Weld design

10.9.1 *Weld metal strength.* Electrodes shall be selected that will deposit weld metal with a yield stress comparable to the characteristic strength of the bar to be welded.

For design purposes the yield strength of the weld shall be taken as being equivalent to the characteristic strength of the reinforcing bar.

In the case of shear loading the yield stress in shear shall be taken as:

a) 115 N/mm^2 for weld metal with a yield stress of less than 410 N/mm^2 or

b) 160 N/mm^2 for weld metal with a yield stress of 410 N/mm^2 or more.

10.9.2 *Joint design and strength.* Butt joints shall be formed by complete penetration butt welds.

NOTE 1 With correctly selected consumables the strength of the weld will be not less than the specified tensile strength of the bar.

Splice joints and lap joints shall be formed by flare-bevel or flare-vee fillet welds.

NOTE 2 The load bearing capacity of these welds is the product of the shear strength of the weld metal and the load bearing area of the weld.

Loading Bearing Capacity (in N) = $f_w \times T \times L_w$

where

f_w is the weld metal shear stress (in N/mm^2)

T is the effective throat thickness (in mm)

L_w is the weld length (in mm)

For flare-bevel fillet welds, the effective throat thickness shall be the shortest distance from the plate/bar contact to the surface of the weld minus 0.2 bar size (see Figure 7).

NOTE 3 The allowance of 0.2 bar size is to compensate for possible lack of penetration in the weld root.

To aid detailing the effective throat thickness shall be taken as the width of the weld up to a maximum value of 0.3 bar size.

For flare-vee fillet welds, the effective throat thickness shall be as for flare-bevel fillet welds except that for detailing the effective throat thickness shall be half the weld width up to a maximum of 0.3 bar size.

In the case of welds between bars of different sizes the value used in the calculations shall be that of the smaller bar.

For flare fillet welds, the total minimum weld length, L (in mm), to carry the full tensile load of the bar shall be calculated from the formula:

$$L = \frac{\pi \times 0.87 f_y}{4 \times T \times f_w} \times (\text{bar size})^2$$

where

bar size is the bar diameter (in mm)

T is the effective throat thickness (in mm)

f_y is the specified characteristic strength of the bar (in N/mm^2)

f_w is the weld metal shear stress (in N/mm^2)

The maximum length of fillet shall be 5 times the bar size. Where longer runs are required the weld shall be divided into sections of not less than 1.5 times the bar size. The interval between welds shall be not less than 5 times the bar size.

11 Welding practice

11.1 Adverse weather conditions

Welding shall not be undertaken when it is raining or snowing or during periods of high wind, unless precautions (such as the provision of screens or covers) are taken.

Surfaces to be welded shall be dry and whenever there is evidence of condensation taking place on the material surface, warming shall be carried out to remove such condensation. In any case welding shall not be carried out on any surface which is at a temperature below 0 °C immediately before welding.

11.2 Preheating

11.2.1 *General.* The requirements for the preheating temperatures in **11.2.3** and **11.2.4** shall be applied when welding procedure tests are not carried out. If welding procedure tests are carried out then the requirements in **11.2.3** and **11.2.4** shall be waived provided it can be demonstrated by the procedure tests that the preheat temperatures can be reduced below those specified without adversely affecting the quality of the weld.

11.2.2 *Carbon equivalent.* Values of carbon equivalent to be used in Table 1 and Table 2 and Figure 8 and Figure 9 shall be certified carbon equivalent values for the metal to be welded. Where such certified information is not available, the specified maxima in the material standard (see **4.1**) for the relevant grade of material shall be used.

11.2.3 *Butt joints and cruciform joints.* Butt joints and cruciform joints, including tack welded cruciform joints, shall be preheated, if required, in accordance with the values given in Table 1 and Table 2.

11.2.4 *Lap joints and splice joints.* Lap joints, including tack welded lap joints, and splice joints shall be preheated, if required, in accordance with the values indicated in Figure 8 and Figure 9.

Table 1 — Minimum preheating temperatures for butt joints and cruciform joints: hydrogen controlled consumables[a]

	Minimum preheat temperature		
Nominal bar size mm	25	> 25 to 40	> 40
Carbon equivalent %	°C	°C	°C
0.42 or less	0	0	50
> 0.42 to 0.51	50	75	100

[a] Those depositing weld metal containing not more than 15 mL of hydrogen/100 g deposited metal when assessed by the relevant standard.

Table 2 — Minimum preheating temperatures for butt joints and cruciform joints: non-hydrogen controlled consumables

	Minimum preheat temperature		
Nominal bar size mm	25	> 25 to 40	> 40
Carbon equivalent %	°C	°C	°C
0.42 or less	50	75	100
> 0.42 to 0.51	100	hydrogen controlled consumables to be used	

The joint combined thickness in the figures shall be determined by adding together the sizes of the two bars being welded and the section thickness of any splice plate or angle.

Arc energy (in kJ/mm) shall be calculated from the formula:

$$\text{arc energy} = \frac{VI}{w} \times 10^{-3}$$

where

V is the arc voltage (in V)

I is the welding current (in A)

w is the welding speed (in mm/s)

In the case of manual metal-arc welding the arc energy shall be calculated either from the above formula or be determined by the runout length deposited by an electrode as given in Table 3, Table 4 and Table 5.

11.2.5 *Application of preheating.* When applicable, preheating shall be applied by gas flame or electrical heating elements.

NOTE Flame heating is the most suitable for site work. Intense forms of heating, such as those used for flame cutting should be avoided. The use of nozzles specifically designed for preheating is advised.

Once welding has commenced, the temperature of the joint area shall not be permitted to fall below the recommended preheating level.

If welding is interrupted and the temperature of the joint area falls below the recommended temperature level, the joint shall be preheated again before any further welding.

When preheating is applied, the required temperature shall exist in each bar for a distance of at least 75 mm from the joint or the joint preparation. However, a localized build-up of heat shall not exceed 325 °C at any point.

The preheating temperature of the joint shall be determined using temperature indicating crayons or a contact pyrometer.

The temperature shall be confirmed on the heated face at a time after removal of the heat source (if fixed permanent heaters are not used) related to bar diameter to allow for temperature equalization which shall be of the order of 2 minutes for each 25 mm of bar size.

11.3 Heat build-up during welding

To avoid an excessive build-up of heat that could impair the mechanical properties, the bar temperature shall not be allowed to rise above 325 °C, measured at a point 25 mm away from the weld in any direction.

11.4 Stray arcing

Stray arcing away from the weld preparation shall be avoided. Local hard spots, cracks or blemishes resulting from arc strikes shall be removed by mechanical means and checked to ensure soundness.

NOTE Removed hard spots may be made good by the deposition of weld metal in accordance with this standard, after consultation between contracting parties.

11.5 Cleaning

Where a process generates slag to protect the weld metal, this slag shall be removed from each run of weld before a further run is superimposed and at the end of the final run. Particular attention shall be paid to the junction between the weld metal and the fusion faces.

Visible defects such as cracks, cavities and other deposition faults shall be removed before the deposition of further weld metal.

11.6 Tack welds

Tack welds, which are used for locational purposes only and are not required to carry the full tensile strength of the bar, shall be kept to the minimum necessary to locate the reinforcing steel during handling, erection or subsequent full strength welding.

Tack welds in the form of lap joints shall have a throat thickness not less than 4 mm, and shall have a minimum length of 25 mm. The reinforcing bars shall be preheated before tack welding according to the requirements of Figure 8 and Figure 9.

Tack welds for cruciform joints used to locate reinforcing bars in made up assemblies shall be built up so that the throat thickness is at least one third the size of the smaller bar or 6 mm whichever is greater. The reinforcing bars shall be preheated before welding according to the requirements of Table 1 and Table 2.

Table 3 — Arc energy of runout lengths for electrodes of efficiency ≤ 110 % complying with BS 639

Arc energy	Runout length							
	Electrode diameter, mm							
	2.5	3.2	4	5	6	6.3	8	10
kJ/mm	mm	mm	mm	mm	mm	mm	mm	mm
0.6	220	355	550	870	—	—	—	—
0.8	165	270	415	650	940	1 040	—	—
1.0	130	215	330	520	750	830	—	—
1.2	110	180	275	435	625	690	1 110	—
1.4	95	150	235	370	535	590	955	—
1.6	—	135	205	325	470	520	840	—
1.8	—	120	185	290	415	460	745	1 160
2.0	—	105	165	260	375	415	670	1 040
2.2	—	95	150	235	340	375	610	950
2.5	—	85	130	205	300	330	535	835
3.0	—	—	110	175	250	275	445	695
3.5	—	—	95	150	215	235	380	595
4.0	—	—	80	130	185	205	335	520
4.5	—	—	—	115	165	185	295	465
5.0	—	—	—	105	150	165	265	415
5.5	—	—	—	95	135	150	245	380
6.0	—	—	—	85	125	135	225	350
6.5	—	—	—	—	115	125	205	320
7.0	—	—	—	—	105	115	190	300
8.0	—	—	—	—	95	105	165	260

NOTE The runout length in this case, is the length of weld obtained from a 450 mm electrode allowing 40 mm stub-end wastage.

11.7 Defective joints

Production joints that fail to comply with the requirements of this specification shall have the defective material removed and a new weld made in accordance with the appropriate welding procedure.

11.8 Welding processes

Welding shall be performed using manual metal-arc or semi-automatic gas shielded arc welding, or non-shielded welding.

NOTE Other welding processes may be approved following satisfactory procedure tests.

11.9 Welding procedures

When written welding procedures are required by the client, they shall include such of the following items as are relevant:

a) welding process or processes when more than one is used in making a complete joint;

b) parent metal specification, thickness and other relevant dimensions;

c) whether shop or site welding;

d) cleaning, degreasing etc.;

e) classification, type and size of electrodes and other consumables;

f) for manual welding, the size of electrode, welding current and length of run per electrode or fillet weld leg length and number of runs; when applicable, the temperature and time adopted for drying/baking of welding consumables before use;

g) sketch showing edge preparation, fit-up and approximate number and arrangement of runs in multi-run welds;

h) jigging or tacking, backing, etc.;

i) welding positions;

j) welding sequence;

k) minimum preheating temperature;

l) back gouging or grinding of the root run from the reverse side, to expose clean metal;

m) any other relevant information.

Welders shall be provided with sufficient information to enable the welding procedure to be carried out satisfactorily.

Table 4 — Arc energy of runout lengths for electrodes of efficiency > 110 % and ≤ 130 % complying with BS 639

Arc energy	Runout length							
	Electrode diameter, mm:							
	2.5	3.2	4	5	6	6.3	8	10
kJ/mm	mm	mm	mm	mm	mm	mm	mm	mm
0.6	250	410	640	1 000	—	—	—	—
0.8	190	310	480	750	1 090	1 220	—	—
1.0	150	245	385	600	875	980	—	—
1.2	125	205	320	500	730	820	—	—
1.4	105	175	275	430	620	700	1 100	—
1.6	95	155	240	375	545	610	965	—
1.8	—	135	215	335	485	545	860	—
2.0	—	125	190	300	435	490	775	1 210
2.2	—	110	175	275	395	445	705	1 100
2.5	—	100	155	240	350	390	620	965
3.0	—	80	125	200	290	325	515	805
3.5	—	—	110	170	250	280	440	690
4.0	—	—	95	150	220	245	385	605
4.5	—	—	85	135	195	215	345	535
5.0	—	—	—	120	175	195	310	485
5.5	—	—	—	110	160	175	280	440
6.0	—	—	—	100	145	160	260	405
6.5	—	—	—	90	135	150	240	370
7.0	—	—	—	85	125	140	220	345
8.0	—	—	—	—	105	120	195	300

NOTE The runout length, in this case, is the length of weld obtained from a 450 mm electrode allowing 40 mm stub-end wastage.

12 Approval of welding procedures

12.1 Approved procedures

Welding procedures for all types of joints in reinforcing bars shall be approved prior to use by tests described in **12.3**.

NOTE 1 Procedure tests may be waived if evidence is submitted of previous approval of the welding procedure to be employed, provided that compliance with **3.3** is established.

Approval shall be required for each position in which welds will be made.

Each welding procedure to be used shall be fully documented by the contractor and shall be available for examination.

NOTE 2 A suggested format showing information to be included in a welding procedure is shown in Appendix B.

12.2 Limitation of variables

Approval of the welding procedure shall be established for each grade and type of reinforcing steel to be used. In each test the largest bar size shall be used.

For arc welding processes, the following changes shall be considered changes in essential variables. Any changes in one or more of the following essential variables shall require re-approval:

a) a change from one process to another;

b) an increase in filler metal strength;

c) a change in electrode type, e.g. from basic to rutile covered;

d) a change in electrode or filler wire diameter;

e) a change from one shielding gas or gas mixture to another;

f) in manual metal-arc welding a change in welding current of more than 15 %;

g) in MIG/MAG welding a change in metal transfer mode between spray transfer, globular transfer, short circuiting (dip) transfer, or pulsed arc transfer;

h) a change in welding current from a.c. to d.c. and vice versa or a change in polarity;

i) a change in welding position or a change of direction of welding in a vertical weld;

j) a decrease of more than 20 °C in the preheat temperature;

k) a change in material thickness outside the range 0.75 to 1.5 times the bar size. Any change in material thickness within this range shall only be allowed, provided that the procedure still meets the requirements of Figure 8 or Figure 9 or Table 1 or Table 2.

Table 5 — Arc energy of runout lengths for electrodes of efficiency > 130 % complying with BS 639

Arc energy	Runout length							
	Electrode diameter, mm:							
	2.5	3.2	4	5	6	6.3	8	10
kJ/mm	mm	mm	mm	mm	mm	mm	mm	mm
0.6	325	530	830	—	—	—	—	—
0.8	240	395	620	975	—	—	—	—
1.0	195	315	495	780	1 120	1 230	—	—
1.2	160	265	415	650	935	1 030	—	—
1.4	135	225	355	555	800	880	—	—
1.6	120	200	310	485	700	770	1 240	—
1.8	105	175	275	430	620	685	1 100	—
2.0	95	160	250	390	560	620	1 000	—
2.2	85	145	225	355	510	560	905	—
2.5	—	125	200	310	450	495	800	1 240
3.0	—	105	165	260	370	410	665	1 030
3.5	—	90	140	220	320	350	570	890
4.0	—	—	125	195	280	310	500	780
4.5	—	—	110	170	250	275	445	690
5.0	—	—	100	155	225	245	400	620
5.5	—	—	90	140	205	225	360	565
6.0	—	—	80	130	185	205	330	520
6.5	—	—	—	120	170	190	305	480
7.0	—	—	—	110	160	175	285	445
8.0	—	—	—	95	140	155	250	390

NOTE The runout length, in this case, is the length of weld obtained from a 450 mm electrode allowing 40 mm stub-end wastage.

12.3 Welding procedure approval tests

12.3.1 *General.* The following tests shall be carried out:

a) full section tensile test;

b) macroetch test.

12.3.2 *Welding procedures.* All joints for procedure approval shall be welded in the position that is to be used in practice, that is with the axes of the reinforcing bars horizontal or vertical as shown in Figure 10 and Figure 11.

12.3.3 *Number and type of tests.* The number and type of tests required for procedure approval shall be as given in Table 6 and carried out on test pieces and test specimens shown in Figure 12.

12.3.4 ***Length of test pieces***

12.3.4.1 *Tensile test pieces*

a) *Butt joints and cruciform joints.* The minimum length shall be 8 times the size of the bar plus 500 mm with the weld located centrally.

b) *Splice joints and lap joints.* The minimum length shall be 8 times the size of the bar plus the length of the spliced material plus 500 mm.

12.3.4.2 *Macrosections*

a) *Butt joints, cruciform joints and tack welded cruciform joints.* The length of the test piece shall be 200 mm.

b) *Spliced joints, lap joints and tack welded lap joints.* The length of the test piece shall be sufficient to incorporate a weld or welds of minimum length 5 times the bar size.

12.3.5 ***Tensile tests***

12.3.5.1 *Test conditions.* The weld reinforcement and penetration bead shall be left intact in butt joints.

In splice joints the splicing material used shall be left intact.

12.3.5.2 *Test method.* Test the specimen in tension, keeping the speed of testing as uniform as possible. The strain rate when approaching the specified characteristic strength of the steel shall correspond to a rate of loading not exceeding 10 N/mm^2 per second.

Test cruciform joints with the larger size bar in tension.

Table 6 — Tests required for procedure approval

Joint type	Number and type of tests	
	Tensile tests	Macroetch tests
Butt joints	2	1
Splice joints	2	1
Lap joints	2	1
Cruciform joints	2	1
Tack welded lap joints	—	1
Tack welded cruciform joints	—	1

Determine the tensile strength by dividing the maximum load by the nominal cross-sectional area of the bar.

12.3.5.3 *Test report.* The following shall be reported as results of the test:

a) type of specimen and its dimensions;

b) tensile strength (in N/mm^2);

c) location of the fracture, whether in the weld, in the heat affected zone or in the parent metal;

d) the type and location of any imperfections present on the fracture surfaces.

12.3.5.4 *Acceptance level.* The tensile strength shall be not less than that specified in BS 4449 or BS 4482, as relevant.

12.3.6 ***Macro-etch tests***

12.3.6.1 *Preparation.* The test piece selected for macro examination shall be prepared as follows:

a) *Butt joints.* The welded joints shall be mechanically cut longitudinal to the axis of the bars to show the root of the weld and any reinforcement.

b) *Splice joints, lap joints and tack welded lap joints.* The welded joint shall be cut in two positions to provide two transverse cross sections.

c) *Cruciform joints and tack welded cruciform joints.* The welded joint shall be mechanically cut to show the maximum throat thickness of the weld.

12.3.6.2 *Surface preparation.* The specimens shall be prepared, polished and etched as described in BS 709.

12.3.6.3 *Method.* Examine the test specimens visually, either with or without the additional use of a hand lens of magnification not greater than five diameters.

12.3.6.4 *Test report.* The following shall be reported as results of test:

a) a description of the appearance of the surface under examination, e.g. smoothness of profile, degree of penetration;

b) the presence of any weld imperfections and a full description of their type and location.

12.3.6.5 *Acceptance levels.* Imperfections that are detected by visual examination shall be categorized in accordance with the details given in Table 7. The existence of any imperfection greater than the maximum permitted by Table 7 shall be sufficient cause for rejection. Minor local imperfections, except cracks, that can be established as being due solely to the welder's workmanship need not be cause for rejection.

13 Welder approval

13.1 General

The contractor shall satisfy the client of his welder's ability to make sound welds.

13.2 Changes not affecting approval

The following changes between the approved welding procedure and the procedure used for the welder approval tests shall not entail re-approval of the welder:

a) a change in grade or type of reinforcing bar;

b) a change in weld metal composition;

c) a change from a basic to a rutile covered electrode;

d) a change in preheating temperature.

NOTE **12.1** states the changes affecting an approval welding procedure, but for welder approval purposes more latitude is permitted as only the welder's ability is being tested.

13.3 Limitations of variables

Any changes in one or more of the following variables shall require retest:

a) a change from one process to another;

b) a change in welding position;

c) a change from uncoated steel to galvanized steel.

Table 7 — Acceptance levels (visual and macro examination)

Imperfection type	Permitted maximum	
	Procedure approval and Welder approval (visual and macro-examination)	Production welding (visual examination)
a) Cracks	Not permitted	Not permitted
b) Lack of root fusion[a] Lack of side fusion Lack of inter-run fusion	Not permitted	Not applicable
c) Lack of root penetration[a]	[a]Not permitted	Not applicable
d) Undercut	Depth not to exceed 1 mm	Depth not to exceed 1 mm
e) Excess weld metal	Weld metal to blend smoothly with the parent metal	Weld metal to blend smoothly with the parent metal
f) Overlap	Not permitted	Not permitted
[a] Applies to butt joints only.		

Table 8 — Acceptance levels (radiographic examination) for butt welds

Imperfection type		Permitted maximum
Cavities	a) Isolated pores (or individual pores in a group)	Diameter not greater than 0.125 of bar size and 3 mm maximum
	Distributed porosity	3 % of projected area[a].
Solid inclusions	Slag inclusions	maximum length 10 mm maximum width 2 mm
[a] Projected area is the length of the weld affected by the porosity times the maximum width of the weld.		

13.4 Number and type of tests

The number and type of tests required for welder approval shall be as given in Table 9 and carried out on test pieces and test specimens shown in Figure 12 and described in **12.3.4**.

Test conditions, methods and test reports shall be those described in **12.3.5.1** to **12.3.6.4**.

As an alternative to a tensile and macro-etch test butt joints shall be examined by radiography alone.

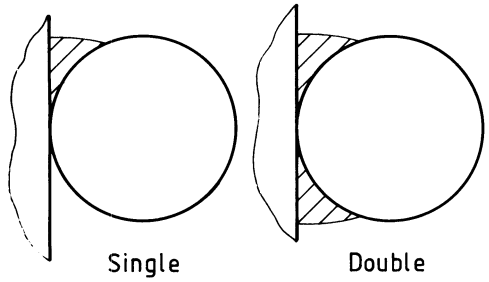
Table 9 — Tests for welder approval

Test piece	Number and type of tests	
	Tensile test	Macroetch test
Butt joint	1	1
Lap joint	1	1
Splice joint	1	1
Cruciform joint	1	1
Tack welded lap joint	—	1
Tack welded cruciform joint	—	1

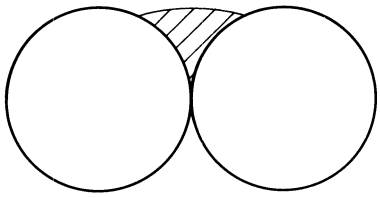
13.5 Acceptance levels

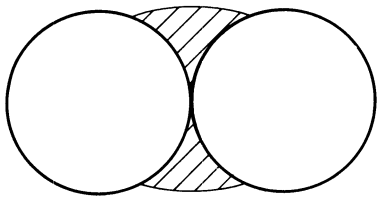
Imperfections that are detected by visual examination shall be categorized in accordance with the details given in Table 7. Imperfections that are detected by radiographic examination shall not be larger or more extensive than those permitted by Table 8.

The existence of any imperfection greater than the maximum permitted by Table 7 and Table 8 shall be cause for rejection.



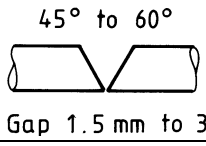
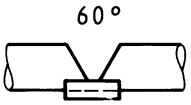
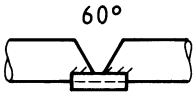
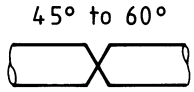
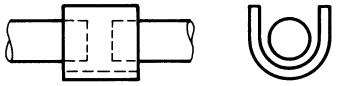
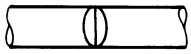
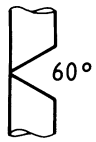
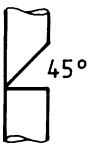
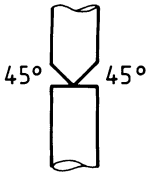
(a) Flare bevel fillet weld





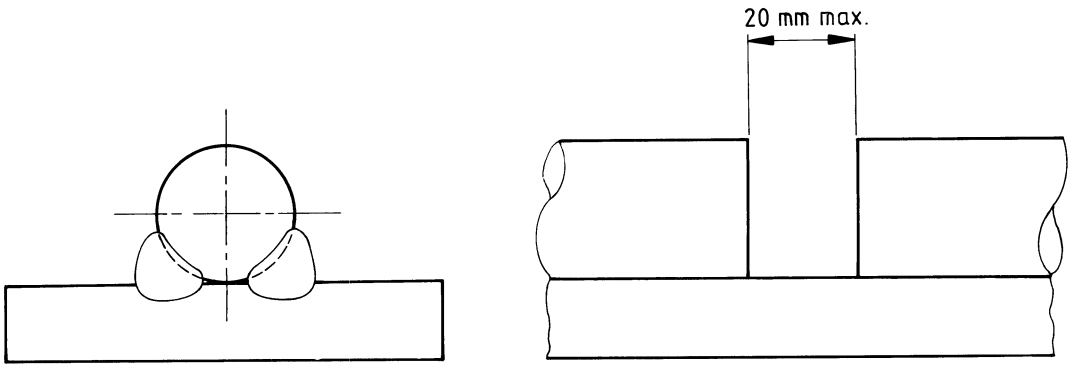
(b) Flare-vee fillet weld

Figure 1 — Flare-bevel and flare-vee fillet welds

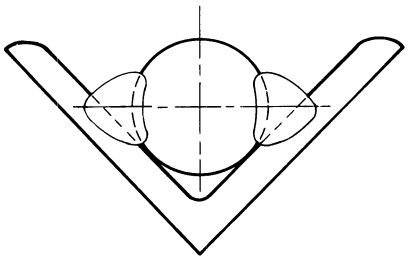
Detail	Size range	Applications
1 	All sizes	Where the root is accessible for back chipping and application of a sealing run.
2 	All sizes	Where access to the root of the weld is unobtainable.
3 	All sizes	Where access to the root of the weld is unobtainable.
4 	25 mm to 50 mm	For general use. Horizontal bars should be rotated for welding in the flat position wherever possible.
5 	5 mm to 50 mm	Faster procedures for general use.
6 	25 mm to 50 mm	Welding carried out in horizontal vertical position. Not often used.
7 	Up to 25 mm	Generally for small diameter vertical bars.
8 	25 mm to 40 mm	For medium size vertical bars.
9 	25 mm to 50 mm	For larger diameter vertical bars.

NOTE The fillet welds in example 3 are to hold the backing strip in place and do not have to develop the full strength of the bar.

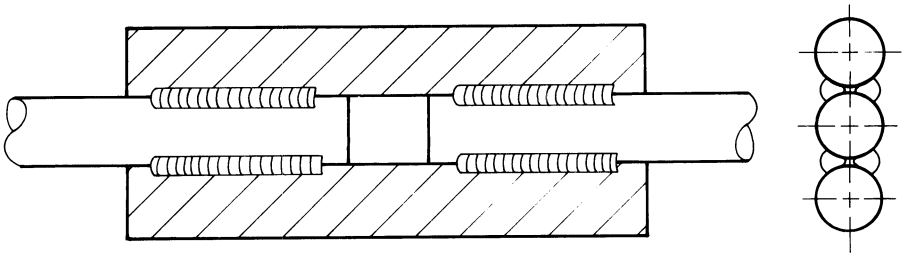
Figure 2 — Butt joints



(a) Splice joint using a plate

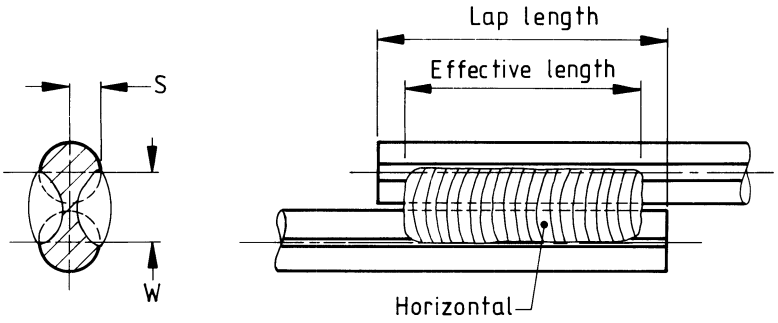


(b) Splice joint using an angle

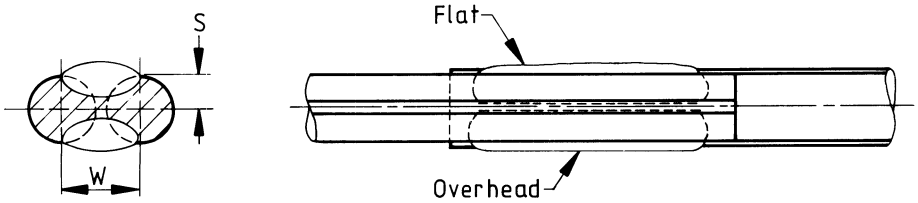


(c) Splice joint using bars as splice members

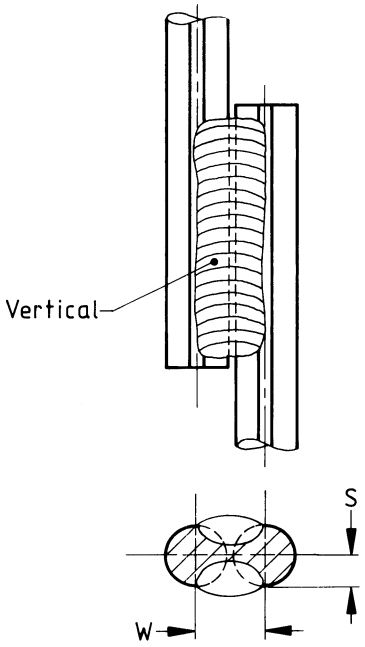
Figure 3 — Splice joints



(a) Lap joint (one bar above the other)



(b) Lap joint (bars side by side)



(c) Lap joint (bars vertical)

Figure 4 — Lap joints

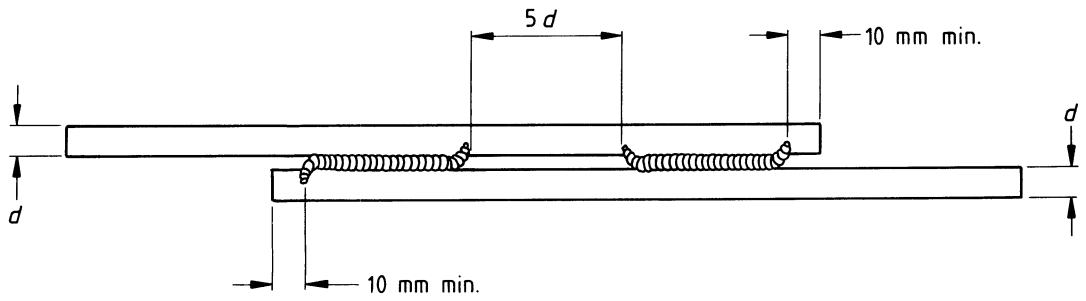


Figure 5 — Start and finish of a lap joint

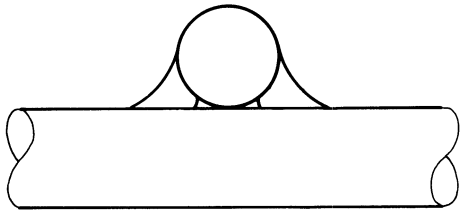
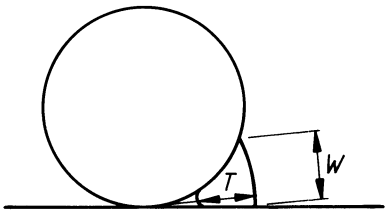
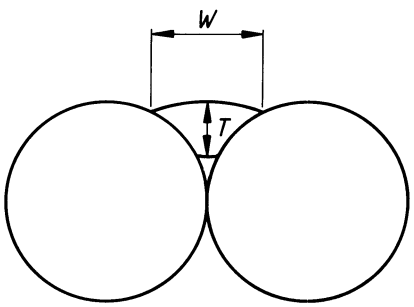


Figure 6 — Cruciform joint



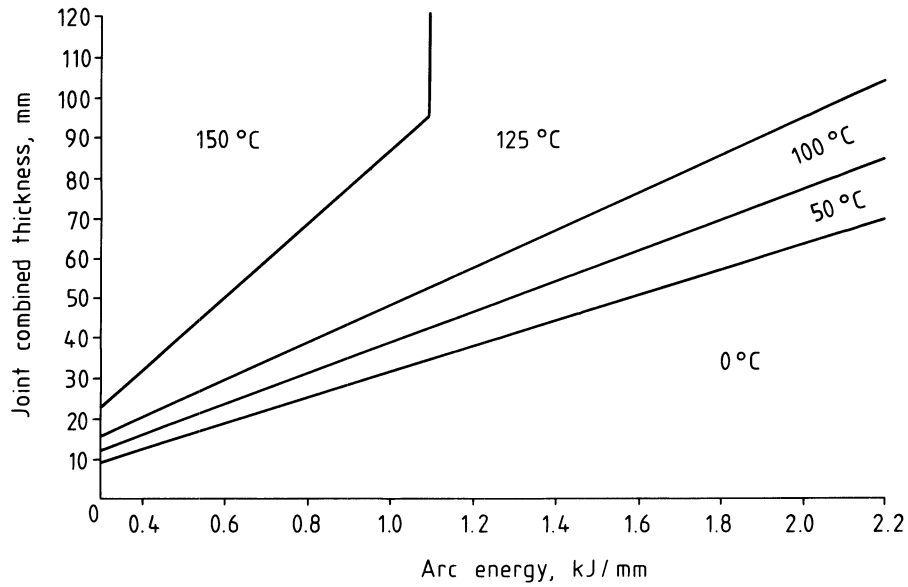
Effective throat thickness = T – 0.2 bar size

For ease of inspection on site, a conservative estimate of the effective throat thickness may be taken to equal W.



For ease of inspection on site, a conservative estimate of the effective throat thickness may be taken as $\frac{W}{2}$.

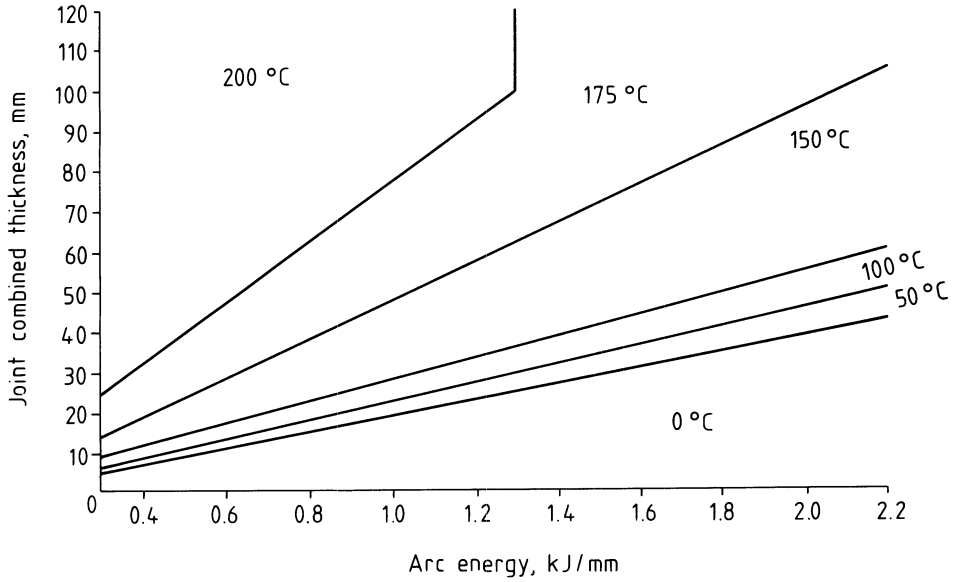
Figure 7 — Effective throat thickness



NOTE This graph applies to hydrogen controlled consumables. For non-hydrogen controlled consumables, preheating to be increased by 50 °C.

NOTE Joint combined thickness is the sum of bar sizes and section thickness.

Figure 8 — Preheating temperatures for lap joints, splice joints and tack welded lap joints in steel bars having a carbon equivalent of 0.42 % or less



NOTE This graph applies to hydrogen controlled consumables. For non-hydrogen controlled consumables, preheating should be increased by 50 °C except in the case of bar sizes greater than 25 mm when welding is not permitted.

NOTE Joint combined thickness is the sum of bar sizes and section thickness.

Figure 9 — Preheating temperatures for lap joints, splice joints and tack welded lap joints in steels having a carbon equivalent of > 0.42 % to 0.51 %

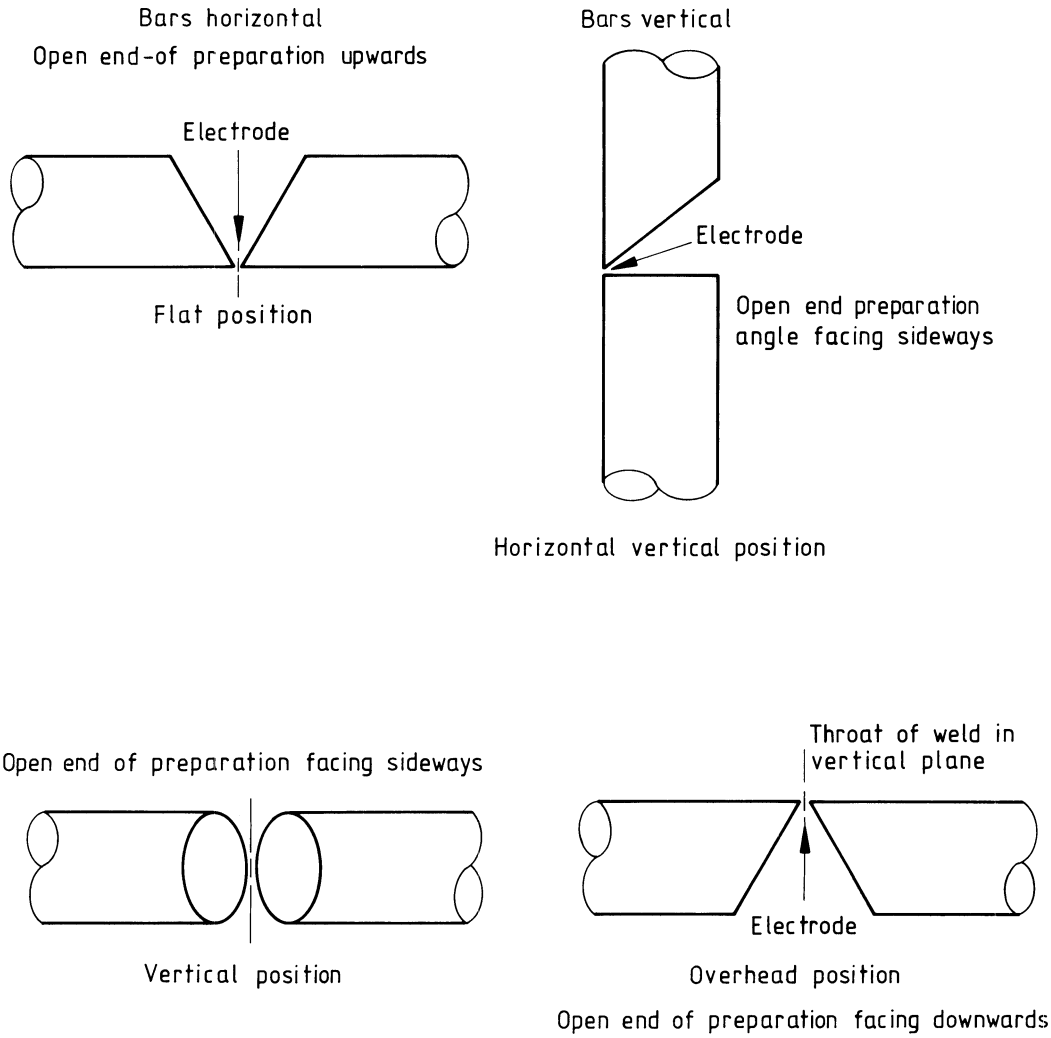


Figure 10 — Welding positions for tests on butt joints

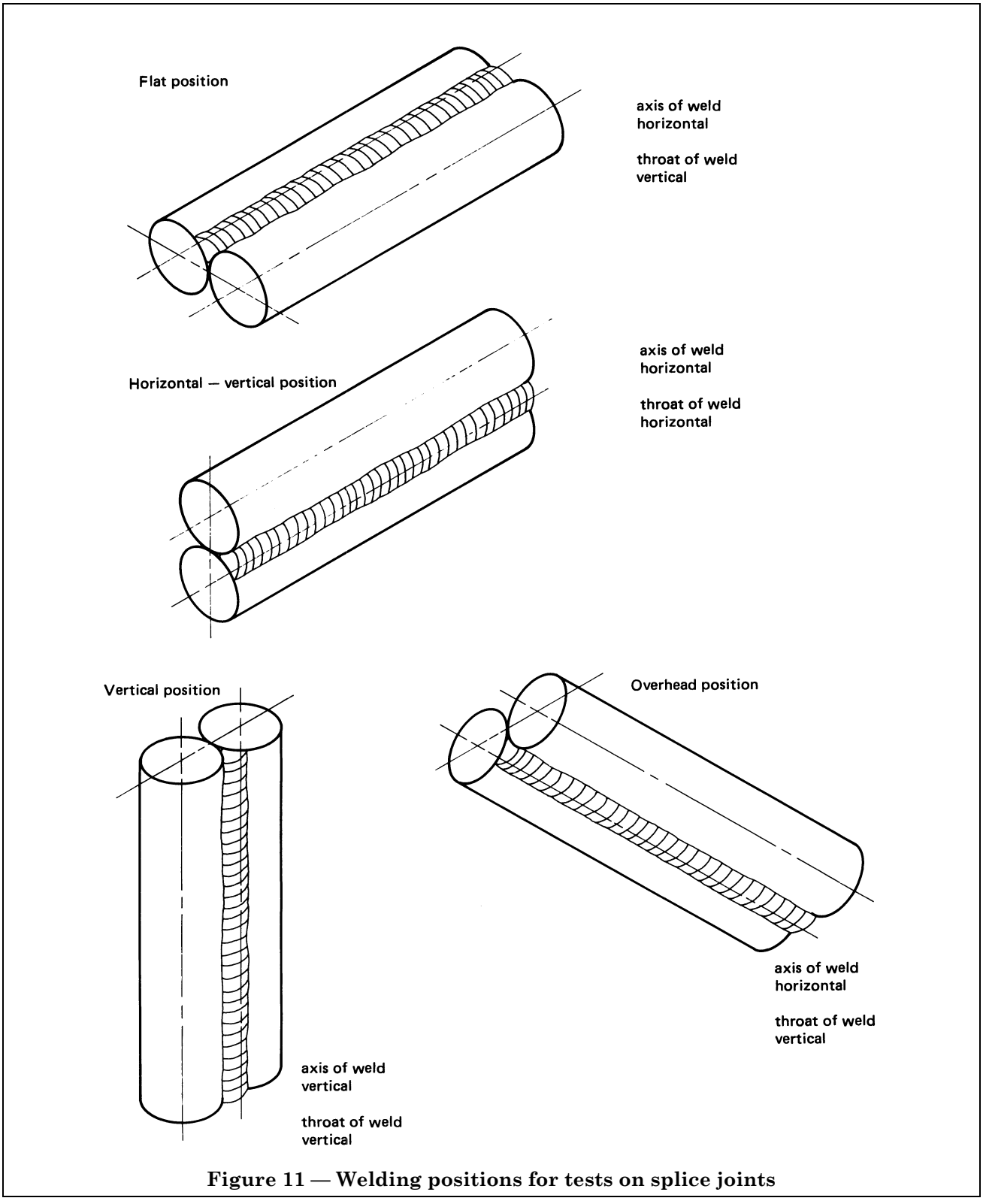
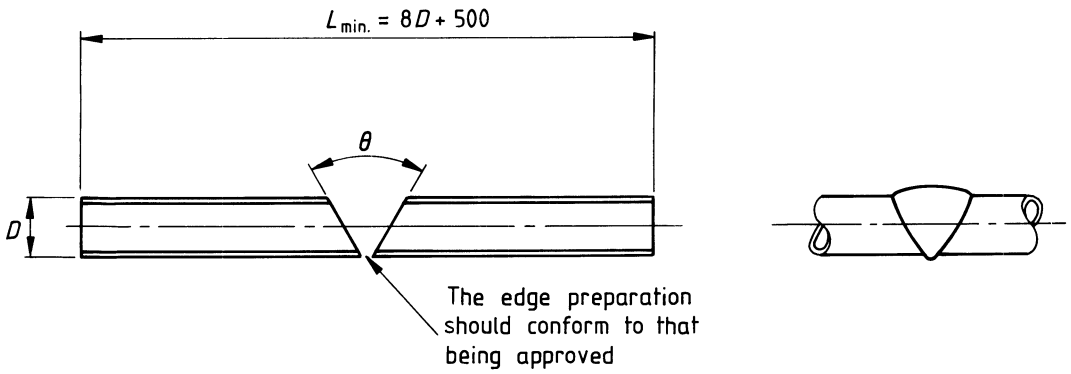
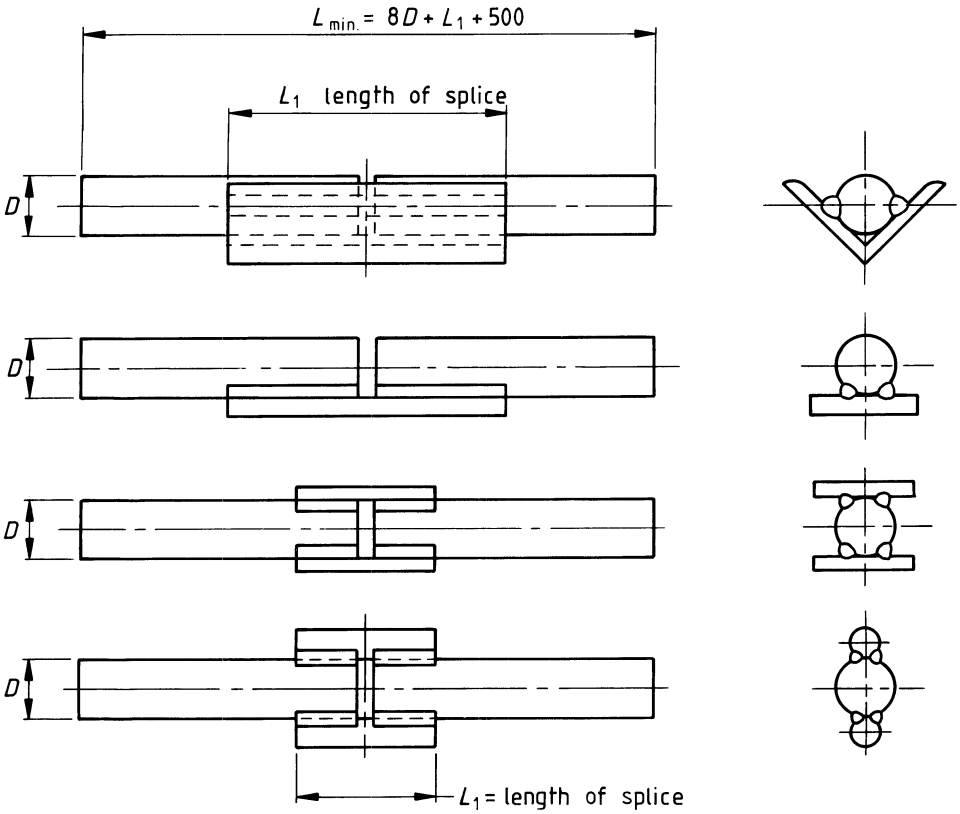


Figure 11 — Welding positions for tests on splice joints



(a) Butt joint



NOTE. The overall length of the tensile test piece should include an allowance for the gripped ends to suit the particular test machine requirements. This would be typically 100 mm at each end, but for test pieces over 25 mm diameter may be greater.

Tensile test pieces

Macro-examination pieces

(b) Splice joints

Figure 12 — Tensile test pieces and macro examination test specimens for procedure approval and welder approval tests

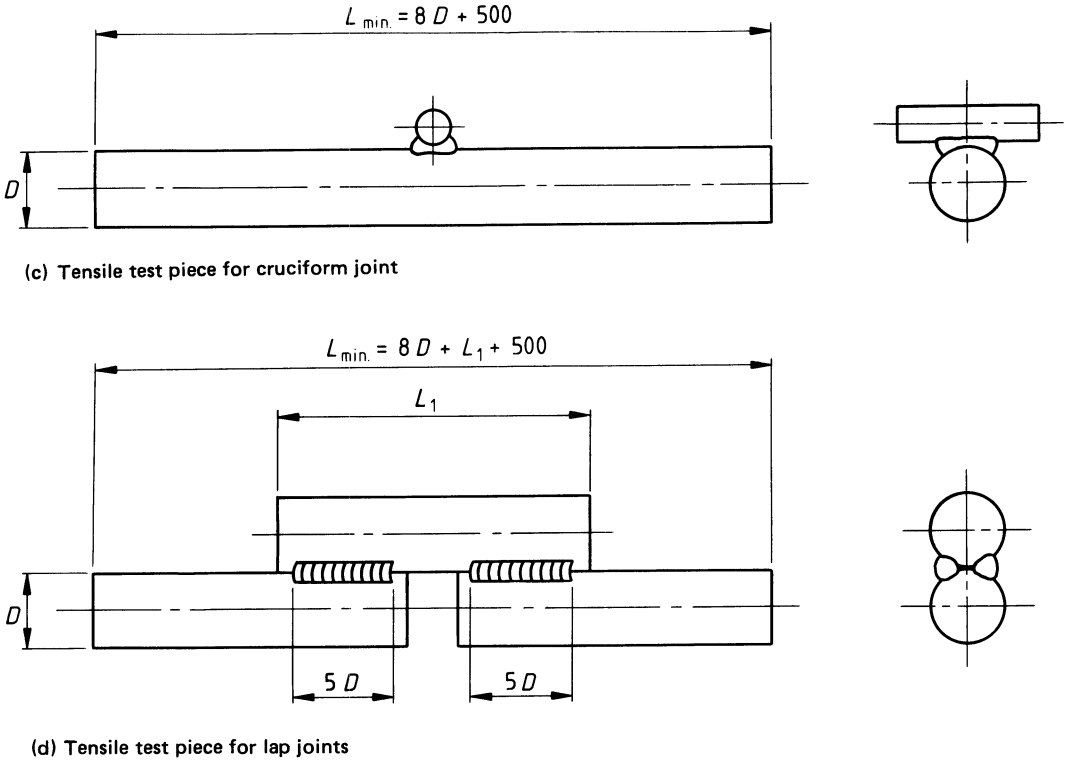


Figure 12 — Tensile test pieces and macro examination test specimens for procedure approval and welder approval tests *(concluded)*

Appendix A Tack welds for locational purposes

A.1 Electrodes

As the purpose of the welding is for location and not for carrying the full tensile strength of the bar, a rutile type electrode shall be used for BS 4449 Grade 250 and a hydrogen-controlled electrode for BS 4449 Grade 460 material. Carbon steel wire shall be used for all grades in the case of the inert-gas shielded processes.

A.2 Joint preparation

The bars to be welded shall be clean of all grease, dirt, excessive scale or rust and shall be dry. Bars at the point of welding shall be clamped or otherwise held in contact, as attempts to "build a bridge" between bars not in contact are not permitted.

A.3 Temperature

Welding shall not be carried out on any surface that is at a temperature of 0 °C or below. In such a case preheating, extending 75 mm each side of the joint shall be carried out to ensure that the temperature in the weld region is at least 25 °C. The minimum preheat temperatures given in Table 1 and Table 2 apply.

A.4 Welding technique

a) The welding current shall be sufficient to ensure complete fusion at the weld root and side walls but not so excessive as to undercut the bar.

b) The arc length shall be short in order to avoid porosity and spatter.

c) If more than one weld run is required to achieve a throat thickness of one third the diameter of the smaller bar or 6 mm, whichever is greater, then all slag shall be removed before the second run is applied.

d) Electrode diameters (for the smaller bar) and welding currents shall be as given in Table 10 for rutile type or hydrogen-controlled electrodes.

Where inert-gas shielded arc welding techniques are employed, filler wire diameters between 0.80 mm and 1.2 mm shall be used together with other welding conditions chosen in order to fulfil the requirements of a) and b).

NOTE Suitable weldment forms are shown in Figure 13.

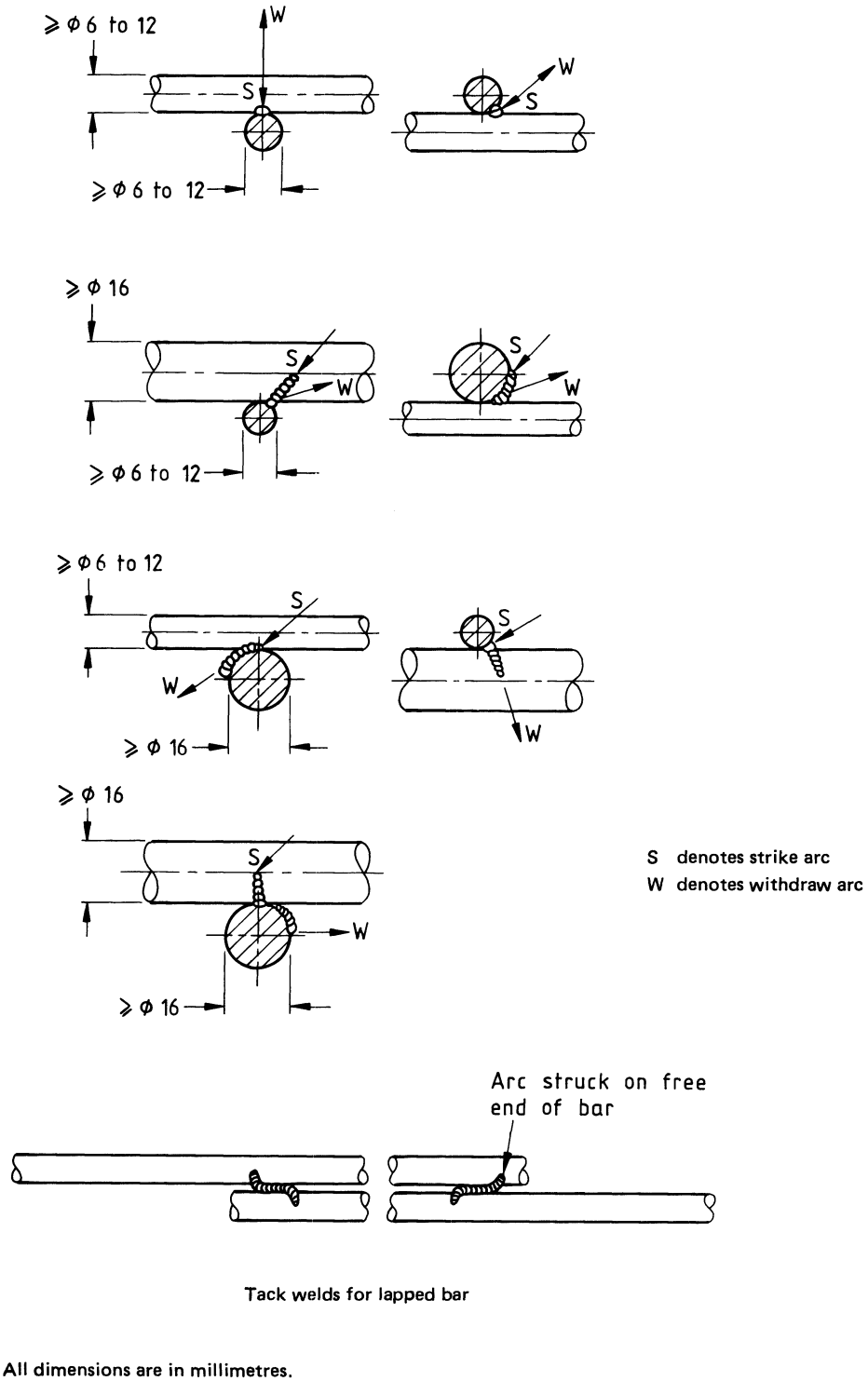
e) Care shall be taken to avoid stray arc strikes and splashes and to avoid rapid cooling of the joint after welding.

A.5 Testing

The testing of trial welds made by the welder shall be carried out.

Table 10 — Electrode diameters and welding currents for tack welds for locational purposes

Bar size (mm)	6	10	16	20
Electrode diameter (mm)	1.5	2.0	2.5	3.25
Welding current (A)	40	60	90	130



All dimensions are in millimetres.

Figure 13 — Suitable weldment forms for tack welds for locational purposes

Appendix B Welding procedure sheet

The welding procedure sheet should give the necessary information clearly and concisely. An example is given as follows:

<table>
<tr><th>WELDING PROCEDURE SHEET</th><th>Procedure No.....</th></tr>
<tr><td>Welding process</td><td rowspan="2">Sketch</td></tr>
<tr><td>Material details

Specification
Composition
Diameter</td></tr>
<tr><td colspan="2">Consumable details

Specification
Trade Name
Diameter
Shielding Gas

Storage Temp.</td></tr>
<tr><td colspan="2">Welding conditions

Preheat
Minimum Open Circuit Voltage
Gas Flow Rate

Run No.
Electrode or Filler dia.
AC/DC +
Current
Voltage

Interpass Temperature
Interrun Cleaning</td></tr>
<tr><td colspan="2">Additional information</td></tr>
</table>

Publications referred to

BS 499, *Welding terms and symbols.*

BS 499-1, *Glossary for welding, brazing and thermal cutting.*

BS 499-2, *Specification for symbols for welding.*

BS 638, *Arc welding power sources, equipment and accessories.*

BS 638-1, *Specification for oil cooled power sources for manual, semi-automatic and automatic metal-arc welding and for TIG welding.*

BS 638-2, *Specification for air cooled power sources for manual metal-arc welding with covered electrodes and for TIG welding.*

BS 638-3, *Specification for air cooled power sources for semi-automatic and automatic metal-arc welding.*

BS 638-4, *Specification for welding cables.*

BS 638-5, *Specification for accessories.*

BS 638-6, *Specification for safety requirements for construction.*

BS 638-7, *Specification for safety requirements for installation and use.*

BS 638-8, *Specification for electrode holders and hand held torches and guns for MIG, MAG and TIG welding.*

BS 639, *Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding.*

BS 709, *Methods of destructive testing fusion welded joints and weld metal in steel.*

BS 2901, *Specification for filler rods and wires for gas-shielded arc welding.*

BS 2901-1, *Ferritic steels.*

BS 4105, *Specification for liquid carbon dioxide, industrial.*

BS 4449, *Specification for carbon steel bars for the reinforcement of concrete.*

BS 4482, *Cold reduced steel wire for the reinforcement of concrete.*

BS 5135, *Specification for arc welding of carbon and carbon manganese steels.*

BS 6693, *Diffusible hydrogen.*

BS 6693-2, *Method for determination of hydrogen in manual metal-arc weld metal.*

BS 7084, *Specification for carbon and carbon manganese steel tubular cored welding electrodes.*

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