British Standard

BRITISH STANDARD

BS 4570:1985

Specification for

Fusion welding of steel castings

UDC 621.791.5:669.14 – 4 – 14

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Welding Standards Committee (WEE/-) to Technical Committee WEE/35, upon which the following bodies were represented:

Associated Offices Technical Committee
BCIRA
British Foundry Association
British Gas Corporation
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users' Association
Institute of British Foundrymen
Institution of Mechanical Engineers
Ministry of Defence
Power Generation Association (BEAMA Ltd)
Steel Casting Research and Trade Association
Welding Institute
Welding Manufacturers' Association (BEAMA Ltd)

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Contents

Foreword

This British Standard has been prepared under the direction of the Welding Standards Committee. It is a combined revision of BS 4570-1:1970 and BS 4570-2:1972 which are withdrawn. There was much common ground between these two Parts and in this revision it was felt preferable to produce a single standard, with attention drawn to where differing requirements apply according to the purpose of welding. This revision incorporates changes resulting from experience in the use of the previous Parts and from technical developments in the welding of steel castings.

Steel castings may require welding to make them satisfactory for their intended service, and this has long been accepted as part of the normal production process. The procedures in this standard can be specified to ensure good welding practice during the production, repair, rectification and fabrication of steel castings. In fabrication, the use of welding has to be taken into account at the design and/or foundry stages.

Fabrication welding principles require that proven welding procedures are used and although full details on procedure testing are included, the requirements have been kept to the minimum necessary to ensure that sound joints can be produced. Where an established fabricator can offer documentary evidence as proof of possessing satisfactory welding procedures without the need for approval, testing need not be carried out. Also, when more comprehensive testing than was done for an already approved procedure has to be carried out, it is necessary to perform only those specific additional tests and not the entire range of tests required by this standard.

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

Care is needed in the interpretation of the results of non-destructive testing, bearing in mind that allowable defects may be present in the castings in the vicinity of the welded joint.

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

At the time of publication of this British Standard, no corresponding International Standard exists.

In the preparation of this revision much assistance has been derived from the information in the document "*Recommended procedure for the fusion welding of steel castings*" published by the Steel Castings Research and Trade Association.

Inspecting authority. The term "inspecting authority" refers to that competent independent body or association which verifies compliance with this standard.

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 and ii, pages 1 to 30, 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.

1 Scope

This British Standard specifies requirements for the fusion welding of steel castings when it is used:

a) to rectify a casting as part of the normal production process;

b) to rectify a casting that has been in service;

c) for the joining together of steel castings by fusion welding, where the sub-sections of the final fabrication are designed for that purpose or when welding is introduced at the foundry planning stage.

This standard covers the manual metal-arc, gas-shielded, self-shielded and submerged-arc welding of the materials given in Table 1, but additional guidance for other processes has been given in some clauses.

Although this standard does not directly cover the welding of steel castings to wrought steels, nor the surface deposition of weld metal for applications such as corrosion resistance and hard facing, it may be used as a guide for the fabrication by joining of these forms of steel involving similar and dissimilar metals.

In addition to the definitive requirements, it also requires the items detailed in clause **2** to be documented. For compliance with this standard, both the definitive requirements and the documented items have to be satisfied.

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

2 Information and requirements to be agreed and to be documented

2.1 Information to be supplied by the purchaser

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

a) whether details of the welding procedure are to be supplied for approval by the purchaser (see **3.2**);

b) whether weld metal of a particular chemical composition is to be used and if so the details (see **4.1.3**);

c) when a welding procedure test is to be carried out, whether a separate procedure test for the particular steel is required (see **20.1.2**);

d) the type of joint or weld for welding procedure approval purposes when this is not to be agreed between the contracting parties [**20.4.2** a)].

2.2 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 following documented items shall be satisfied before a claim of compliance with the standard can be made and verified:

a) the pre-heating temperature, welding consumables and post-weld heat treatment for joining steels of widely different chemical composition in fabrication welding (see **3.3**);

b) requirements for weld metal when creep resisting properties in service are not important and when an alternative to the requirements in **4.1.1** a) or **4.1.1** b) is to be used [see **4.1.1** c)];

c) weld metal mechanical properties when these do not have to match those of the steel casting [see **4.1.2** b)];

d) weld metal chemical composition for submerged-arc welding when it is not similar to that of the parent metal [see **4.1.4** b)];

e) the use of permanent backing material (see **7.1**);

f) the use of carbon steel for temporary backing [see **7.2** b)];

g) the method and frequency of inspection and the standard of acceptance for completed welds (see clause **17**);

h) whether records showing the location of welds are to be supplied (see clause **19**);

i) the need for welding procedure tests when the other requirements in **20.1.1** do not apply [see **20.1.1** b)];

j) the material for a welding procedure test piece when an alternative to the requirements of **20.4.1** a) is to be used [see **20.4.1** b)];

k) the type of joint or weld for welding procedure approval purposes when this is not stated by the purchaser [see **20.4.2** b)];

l) the length of weld to be ignored in non-destructive testing if other than the first and last 25 mm [see **20.7.1** b)];

m) whether transverse tensile or round proportional test specimens are to be used for welding procedure approval purposes (see **20.8.2.1**);

n) whether supplementary tests are required for welding procedure approval purposes and if so the details of the tests and the requirements to be satisfied (see **20.9.1**);

o) when impact tests are used for welding procedure approval purposes, the number of specimens, position of notches and impact values to be obtained (see **20.9.2**).

3 Castings and welding procedures

3.1 The steel castings to be welded shall have been made to the appropriate British Standard and type of steel given in Table 1.

3.2 The manufacturer shall maintain written details of the welding procedures he proposes to use. When required by the purchaser, the manufacturer shall supply the details of the welding procedure for approval by the purchaser before welding commences. [See **2.1** a) and also clause **20**.]

3.3 When it is necessary, in fabrication welding, to join steel castings of widely different chemical composition, the pre-heating temperature, welding consumables and post-weld heat treatment shall be agreed between the contracting parties [see **2.2** a)].

4 Welding consumables

4.1 Weld metal

4.1.1 *General.* Electrodes, filler wire, filler wire/flux combinations, filler rods and fusible inserts[1)] shall be of a type that complies with one of the following, as appropriate:

a) the relevant British Standard listed in Table 1; or

b) when no British Standard is listed in Table 1, the requirements of **4.1.2**, **4.1.3** and **4.1.4**; or

c) when creep resisting properties in service are not important, requirements for the weld metal agreed between the contracting parties [see **2.2** b)].

4.1.2 *Mechanical properties.* The mechanical properties of the weld metal shall be either:

a) at least equal to the minimum in the British Standard for the type of steel casting being welded; or

b) when it is not necessary to have matching mechanical properties, subject to agreement between the contracting parties [see **2.2** c)].

4.1.3 *Chemical composition.* Except in those cases where it is not essential for design purposes, nor always desirable for reasons of weldability or behaviour in service, weld metal shall be of similar chemical composition to that of the parent metal. Weld metal having a different chemical composition from that of the parent metal shall only be used provided that the manufacturer can demonstrate its suitability for the service intended or, alternatively, it is specified by the purchaser. [See **2.1** b)].

NOTE Flux-cored filler wires are available although there is no British Standard for them. They may be used provided that the chemical composition of the weld metal is similar to that of the parent metal or is otherwise agreed between the contracting parties.

4.1.4 *Submerged-arc welding consumables.* Electrode wire/flux combinations shall be such that the weld metal chemical composition is either:

a) similar to that of the parent metal; or

b) as agreed between the contracting parties [see **2.2** d)].

Since welding conditions have a significant effect on the chemical composition of the weld metal, the required composition shall be established by testing under conditions similar to those to be used on the actual fabrication. Particular care shall be taken in controlling welding conditions to ensure consistent weld metal composition, especially where the alloying elements are contained in the flux.

4.2 Storage and handling

Electrodes, filler wires, rods and fluxes shall be stored at a temperature of not less than 20 °C. Handling and use of welding consumables shall be in accordance with the manufacturer's recommendations. Covered electrodes shall be dried before use in accordance with the electrode manufacturer's recommendations that are intended to give a hydrogen level of not more than 10 mL of hydrogen per 100 g of weld metal. (See BS 639 for hydrogen level classification.) Electrodes, filler wires, rods and fluxes that show signs of damage or deterioration shall not be used.

4.3 Shielding and purging gases

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

a) argon complying with BS 4365;

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

c) gas mixtures that have been proved to be satisfactory as a result of procedure approval tests.

1) "A pre-placed filler material which is fused to aid the formation of a weld made from one side only." (This definition is taken from BS 499-1.

When a gas mixture is used which has specified additions, the variation of such additions shall be within ± 10 % of the specified levels.

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

5 Equipment

Welding plant, instruments, cables and accessories shall comply with the requirements of the appropriate British Standard, where one exists. Their capacity shall be adequate for the welding procedure proposed. The contractor shall maintain all welding plant and ancillary equipment in good working order.

NOTE 1 BS 638 and BS 679 are applicable.

NOTE 2 The attention of the contractor is drawn to the advice on safety precautions contained in the Health and Safety at Work Booklet No. 38 "Electric Arc Welding" issued by the Health and Safety Executive and published by HM Stationery Office.

All electrical plant used in connection with the welding operation shall be adequately earthed.

Adequate means of measuring current shall be available either as part of the welding plant or by the provision of a portable ammeter. In the case of mechanized, automatic and semi-automatic welding, means shall be provided for measuring accurately the arc voltage since this exerts considerable influence on the form, composition and soundness (e.g. porosity) of the weld.

When using a gas-shielded welding process, means of measuring the gas flow shall be provided.

NOTE 3 Manufacturers' recommendations should be followed with respect to gas pressure and/or flow rate.

All measuring equipment used in welding and heat treatment shall be suitably calibrated.

Where necessary, staging and protection from the weather shall be provided to enable the welding operation to be performed properly, particularly when using a gas-shielded welding process.

6 Preparation for welding

6.1 Types of weld preparation

For fabrication welding, weld preparations shall be based on thickness and access for welding as for wrought materials. Typical preparations for castings are shown in Figure 1 and Figure 2. However, for a casting repair, a different form of weld preparation shall be used consisting of a contained, profiled cavity, typical shapes being given in Figure 3.

Fabricated joints shall take the form of butt welds between equal thickness sections where possible, in order to facilitate welding and inspection.

6.2 Methods of preparation

The following methods of preparation shall be used, but the final method of preparation shall be determined by the configuration required:

a) mechanical methods, including machining;

b) flame gouging;

c) carbon-arc or metal-arc gouging in combination with air or oxygen or other suitable gases;

d) powder washing.

The use of these methods for specific steels shall be as given in Table 1 and pre-heating requirements for thermal methods shall be as specified in clause **12**. Grinding wheels for use on austenitic stainless steels shall be of the "iron free" type and shall have been used only on such steels.

NOTE Sound welding is more likely to be achieved if preparation for welding is taken into account at the design and foundry stages. In some instances the casting can be provided with a preparation without the need for further mechanical or thermal preparation, other than shot blasting.

6.3 Fusion faces

The foundation for welding and the exposed material shall be sound and free from all deleterious matter.

NOTE When the service conditions demand, it may be necessary to apply suitable non-destructive examination to prove that the fusion faces and adjacent areas are acceptable to the contracting parties. In certain cases, filamentary shrinkage may be sealed-off by suitable means, subject to agreement between contracting parties.

7 Backing materials

7.1 Permanent backing

Permanent backing, either separate or integral, shall only be used by agreement between the contracting parties [see **2.2** e)].

7.2 Temporary steel backing

When temporary steel backing is used it shall be either:

a) of a chemical composition similar to that of the casting; or

b) where it is agreed between the contracting parties that carbon steel can be used this shall be of up to 0.25 % carbon, provided that neither the sulphur nor the phosphorus contents exceed 0.04 % [see **2.2** f)].

NOTE Carbon steel "buttered" with an adequate thickness of austenitic weld metal may be used with austenitic steel castings.

Temporary backing shall not be welded all round its perimeter, as this would increase the risk of basal cracking. Temporary steel backing shall be completely removed after completion of welding.

7.3 Temporary non-metal backing

Temporary non-metal backing shall be completely removed after completion of welding.

Table 1 — Steels, weld preparation, electrodes and filler wires, pre-heating and post-weld heat treatment

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

Steel type	British Standard		Method of weld preparation (see **6.2**)	Electrodes and filler wires (see clause **4**)			Minimum pre-heating temperature (see clause **12**) °C	Post-weld heat treatment temperature (see clause **14**) (note 2) °C
	BS 3100	BS 1504 and others		Manual metal-arc welding	Gas-shielded processes (note 1)	Submerged-arc welding		
0.25 % C max.	A1	161, grade 430	a), b), c) or d)	BS 639: E51 XXB	BS 2901-1: A15, A17, A18	BS 4165: M300 or T300	None	580 to 650 (note 3)
0.30 % C max.	—	161, grade 480	a), b), c) or d)	BS 639: E51 XXB	BS 2901-1: A16, A17, A18	BS 4165: M350 or T350	(note 4)	600 to 650
0.35 % C max.	A2	161, grade 540	a), b), c) or d)	BS 639: E51 XXB	BS 2901-1: A16, A17, A18	BS 4165: M350 or T350	(note 4)	600 to 650
0.45 % C max.	A3	—	a), b), c) or d)	BS 639: E51 XXB (notes 5 and 6)	BS 2901-1: A16, A17, A18 (note 5)	BS 4165: M350 or T350 (note 5)	150 (note 7)	600 to 650 (note 8)
1½ % Mn	A4	BS 2772-3	a), b), c) or d)	BS 639: E51 XXB (note 5)	BS 2901-1: A18 (note 5)	BS 4165: M350 or T350 (note 5)	(note 4)	600 to 650 (note 9)
1½ % Mn	A5 A6	—	a), b), c) or d)	BS 639: E51 XXB (note 5)	BS 2901-1: A18 (note 5)	BS 4165: M350 or T350 (note 5)	150 (note 7)	600 to 650 (note 9)
0.20 % C max. (low temperature)	AL1	430, grade LT40	a), b), c) or d)	BS 639: E51 54B	(note 10)	(note 10)	None	600 to 680
0.15 % C max. (magnetic permeability)	AM1	—	a), b), c) or d)	BS 639: E51 21B	BS 2901-1: A17, A18	BS 4165: M300 or T300	None	600 to 680 (note 3)
0.25 % C max. (magnetic permeability)	AM2	—						
0.10 % C to 0.18 % C (case hardening)	AW1	—	a), b), c) or d)	BS 639: E51 21B	BS 2901-1: A17, A18	BS 4165: M300 or T300	None	None (note 11)
0.40 % C to 0.50 % C	AW2	—	a), b), c) or d) (note 12)	BS 639: E51 56B (note 6)	BS 2901-1: A16, A18 (note 6)	BS 4165: M450 or T450 (note 6)	200	600 to 650 (note 13)
0.50 % C to 0.60 % C	AW3	—	a) or c) (note 12)	BS 639: E51 56B (note 6)	BS 2901-1: A16, A18 (note 6)	BS 4165: M450 or T450 (note 6)	250	600 to 650 (note 13)
C-½ % Mo	B1	245	a), b), c) or d)	BS 2493: MoB	BS 2901-1: A30	(note 10)	150 (note 7)	600 to 680
1¼ % Cr-Mo	B2	621	a), b), c) or d) (note 12)	BS 2493:1 CrMoB	BS 2901-1: A32	(note 10)	200	630 to 680
2¼ % Cr-Mo	B3	622	a), b), c) or d) (note 12)	BS 2493: 2 CrMoB	BS 2901-1: A33	(note 10)	250	680 to 720 (note 14)
3 % Cr-Mo	B4	623						

Table 1 — Steels, weld preparation, electrodes and filler wires, pre-heating and post-weld heat treatment

Steel type	British Standard		Method of weld preparation (see **6.2**)	Electrodes and filler wires (see clause 4)			Minimum pre-heating temperature (see clause **12**) °C	Post-weld heat treatment temperature (see clause **14**) (note 2) °C
	BS 3100	BS 1504 and others		Manual metal-arc welding	Gas-shielded processes (note 1)	Submerged-arc welding		
5 % Cr-Mo	B5	625	a), c) or d) (note 12)	BS 2493: 5 CrMoB	BS 2901-1A 34	(note 10)	250	670 to 720 (note 13)
9 % Cr-Mo	B6	629	a), c) or d) (note 12)	BS 2493: 9 CrMoB	BS 2901-1: A35	(note 10)	250	670 to 720 (note 13)
Cr-Mo-V	B7	660	a), b), c) or d) (note 12)	BS 2493: 2 CrMoB (note 15)	BS 2901-1: A33 (note 15)	(note 10)	250	690 to 720 (notes 13 and 16)
C-Mo (low temperature)	BL1	245 grade LT50	a), b), c) or d) (note 12)	(note 10)	(note 10)	(note 10)	150 (note 7)	630 to 680
3½ % Ni (low temperature)	BL2	503 grade LT60	a), b), c) or d) (note 12)	BS 2493: 3 NiB	(note 10)	(note 10)	200 (note 7)	600 to 680
High tensile	BT1 BT2 BT3	—	a), b), c) or d) (note 12)	(note 17)	(note 17)	(note 10)	200 (note 18)	600 to 650 (notes 5, 9 and 14)
3 % Ni-Cr-Mo (case hardening)	BW1	—	a), b), c) or d) (note 12)	(note 10)	(note 10)	(note 10)	250	600 to 680
C-1 % Cr	BW2 BW3	—	a), c) or d) (note 12)	(note 10)	(note 10)	(note 10)	250	600 to 650 (notes 9 and 13)
C-1 % Cr-Mo	BW4	—	a) (note 12)	(note 10)	(note 10)	(note 10)	300	600 to 650 (notes 9 and 13)
Austenitic manganese	BW10	—	a), c) or d)	BS 2926: 19.9.3, 23.12 or any suitable austenitic manganese deposit (notes 19 and 20)	BS 2901-2: 347S96 or any suitable austenitic manganese deposit (note 19)	(note 10)	(note 21)	None
13 % Cr	420C21 420C24 420C29	420C29	a), c) or d) (note 12)	BS 2926: 19.9, 19.12.3, 13 (notes 13, 15 and 22)	BS 2901-2: 316S96 (notes 13, 15 and 22)	(note 10)	250	680 to 750 (note 23)
13 % Cr-4 % Ni	425C11	425C11	a), c) or d)	(note 10)	(note 10)	(note 10)	100	590 to 630 (note 24)

Table 1 — Steels, weld preparation, electrodes and filler wires, pre-heating and post-weld heat treatment

Steel type	British Standard		Method of weld preparation (see **6.2**)	Electrodes and filler wires (see clause 4)			Minimum pre-heating temperature (see clause **12**) °C	Post-weld heat treatment temperature (see clause **14**) (note 2) °C
	BS 3100	BS 1504 and others		Manual metal-arc welding	Gas-shielded processes (note 1)	Submerged-arc welding		
18 % Cr-8 % Ni	304C15 302C25 304C12	304C15 304C12	a), c) or d) (note 25)	BS 2926: 19.9, 19.9 Nb (notes 15 and 26) BS 2926:19.9 L (note 26)	BS 2901-2: 308S96, 308S92 (note 26)	BS 5465: S19.9, S19.9Nb (notes 15 and 26) BS 5465: S19.9L (note 26)	None (note 27)	1 000 to 1 100 (note 28)
18 % Cr-8 % Ni-Nb	347C17	347C17	a), c) or d) (note 25)	BS 2926: 19.9 Nb	BS 2901-2: 347S96	BS 5465: S19.9Nb	None	(note 16)
18 % Cr-8 % Ni-Mo	316C71 315C16	316C71 315C16		BS 2926: 19.12.3	BS 2901-2: 316S96	BS 5465: S19.12.3		
18 % Cr-10 % Ni-2½ % Mo	316C16 316C12	316C16 316C12	a), c) or d) (note 25)	BS 2926: 19.12.3, 19.12.3 L	BS 2901-2: 316S96, 316S92	BS 5465: S19.12.3, S19.12.3 L	None (note 27)	(note 16)
18 % Cr-10 % Ni-2½ % Mo-Nb	318C17	318C17		BS 2926: 19.12.3 Nb	BS 2901-2: 318S96	BS 5465: S19.12.3Nb		
18 % Cr-10 % Ni-3½ Mo	317C16	317C16 317C12		BS 2926: 19.13.4	BS 2901-2: 317S96	BS 5465: S19.13.4		
Austenitic Cr-Ni-Mo-Cu	—	364C11 332C11	a) or c) (note 12)	(note 10)	(note 10)	(note 10)	None	1 000 to 1 150 Rapid cool
27 % Cr	452C11 452C12	—	a)	(note 10)	(note 29)	(note 29)	300	650 to 700 (note 13)
20 % Cr-10 % Ni	302C35	—	a), c) or d) (note 25)	(note 10)	(note 10)	(note 10)	None	None
25 % Cr-12 % Ni	309C40 309C30 309C32 309C35	—	a), c) or d) (note 25)	(note 10)	BS 2901-2: 309S92	(note 10)	None	None
25 % Cr-20 % Ni	310C45 310C40	310C40	a), c) or d) (note 25)	BS 2926: 25.20 H	BS 2901-2: 310S98	BS 5465: S25.20 H	None	None
25 % Ni-18 % Cr	311C11	—	a), c) or d) (note 25)	BS 2926: 25.20 H	BS 2901-2: 310S98	BS 5465: S25.20 H	None	None
35 % Ni-18 % Cr	330C12 330C11	330C11	a), c) or d) (note 25)	(note 10)	(note 10)	(note 10)	None	None
40 % Ni-20 % Cr	331C60 331C40	—						
60 % Ni-15 % Cr	334C11	—						

Table 1 — Steels, weld preparation, electrodes and filler wires, pre-heating and post-weld heat treatment

Notes to Table 1

NOTE 1 Although there is no British Standard for flux-cored wires, they are available for welding some of the steels given in Table 1.

NOTE 2 In certain cases it may be necessary to carry out full heat treatment to develop the specified mechanical properties of the steel casting.

NOTE 3 Due to the excellent weldability of these steels, while stress relieving after welding is desirable, it is not always essential.

NOTE 4 If the section thickness or configuration is such that pre-heating is necessary, the pre-heating temperature shall be 100 °C minimum.

NOTE 5 The tensile strength of these electrodes and filler wires is rather low compared with that of the cast steel, but the yield stress is satisfactory.

NOTE 6 This should not be used for surfaces subject to abrasion. When surface hardening is to be carried out, a suitable welding electrode should be used.

NOTE 7 Thin section castings may not require pre-heating.

NOTE 8 In special cases, e.g. if the carbon exceeds 0.35 % with castings having rapid changes in section and subject to a high degree of internal stress, it is recommended that immediate post-weld heat treatment at 600 °C to 650 °C, followed by air cooling, be applied.

NOTE 9 A lower post-weld heat treatment temperature may be necessary for certain hardened and tempered castings in order to maintain the specified tensile strength, but, if this is done, the time at that temperature may have to be extended to ensure adequate stress relief.

NOTE 10 No suitable electrode or filler wire complying with a British Standard is available, although suitable types are manufactured and marketed under various trade names.

NOTE 11 Stress relief is not required; this is effected by subsequent case hardening heat treatment.

NOTE 12 If any method except a) is used, the casting shall be pre-heated and the preparation may be followed by grinding.

NOTE 13 Care is needed when welding these steels which may include the need for immediate post-weld heat treatment to minimize the risk of cracking.

NOTE 14 For heavy sections and steels of certain compositions, note 13 may apply.

NOTE 15 These electrodes have non-matching composition and/or properties to the steel casting.

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

NOTE 17 The electrode used should be compatible with the mechanical properties of the steel casting.

NOTE 18 Depending on the composition of the steel, a higher temperature may be necessary.

NOTE 19 A BS 2901-2 347S96 or BS 2926: 23.12 deposit is not suitable for wearing surfaces unless a facing of austenitic manganese steel is applied.

NOTE 20 For major welds, buttering using any suitable Cr-Ni electrode, e.g. 23 Cr-12 Ni should precede the austenitic manganese weld.

NOTE 21 This steel shall not be pre-heated and the interpass temperature shall not be allowed to exceed 200 °C.

NOTE 22 In the case of steel castings to 420C24 and 420C29, the electrodes specified are not suitable for those parts of castings subject to abrasion. In the case of steel castings to 420C21, 420C29 and 420C24, the following considerations also apply:

a) In all cases, particularly when it is intended to use austenitic electrodes (BS 2926: 19.9 or 19.12.3) to minimize the risk of cracking, reference should first be made to the service requirements of the casting for hardness, corrosion and abrasion resistance, fatigue and tensile properties and appearance. In certain corrosive environments, it may be advisable to use electrodes BS 2926: 19.9 Nb and 10.12.3 Nb in place of BS 2926: 19.9 and 19.12.3.

b) A 13 % Cr or 13 % Cr/Ni electrode may be used.

NOTE 23 Extreme care is needed when welding this steel which preferably should have immediate post-weld heat treatment to avoid cracking. If this is not possible, slow cooling to below 50 °C after welding is required, with post-weld heat treatment applied later.

NOTE 24 Cool to room temperature prior to stress relief.

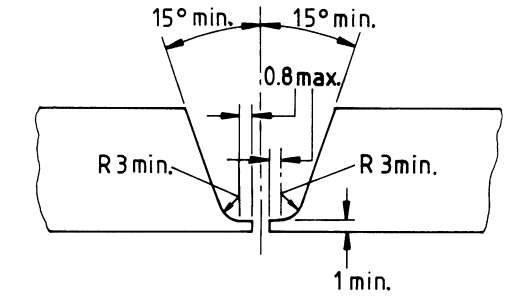
NOTE 25 If any method except a) is used, it may be followed by grinding.

NOTE 26 Welding before final heat treatment is recommended.

NOTE 27 Castings in the fully heat treated condition should be welded with an interpass temperature control of 175 °C maximum.

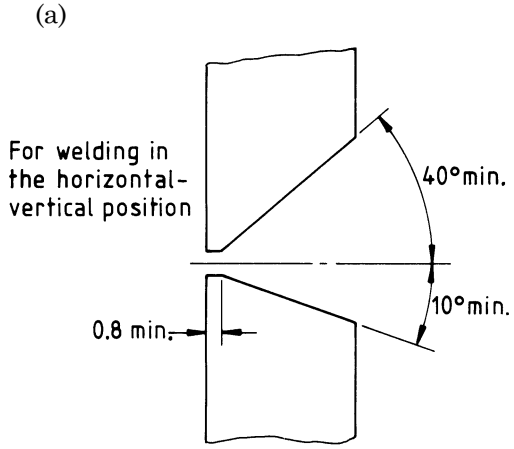
NOTE 28 Cool rapidly. If carbon is below 0.03 %, the post-weld heat treatment may be omitted.

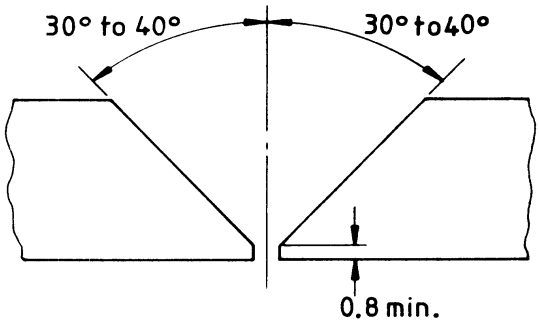
NOTE 29 Not a suitable welding process for this type of steel.



NOTE The dimension for the gap depends on the welding process being used and whether a fusible is insert is to be employed.

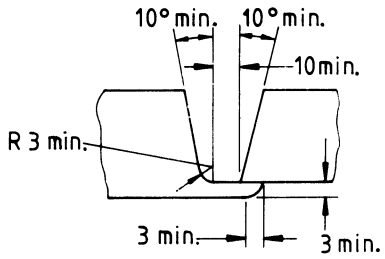
(a)



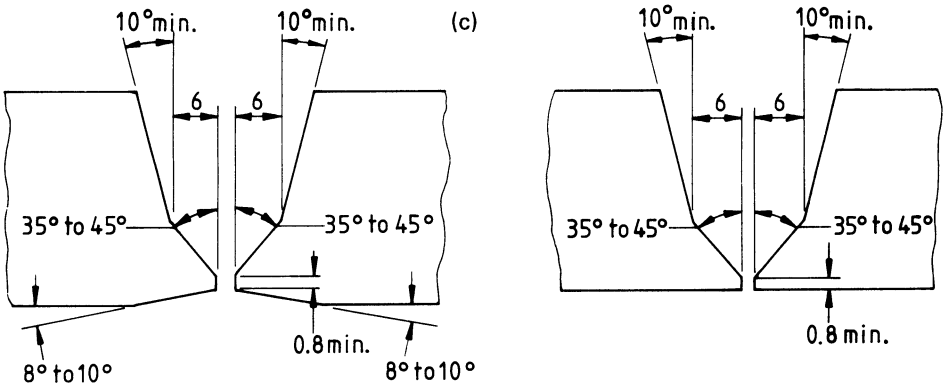


NOTE The dimension for the gap depends on the welding process being used and whether a fusible insert is to be employed.

(b)



(c)

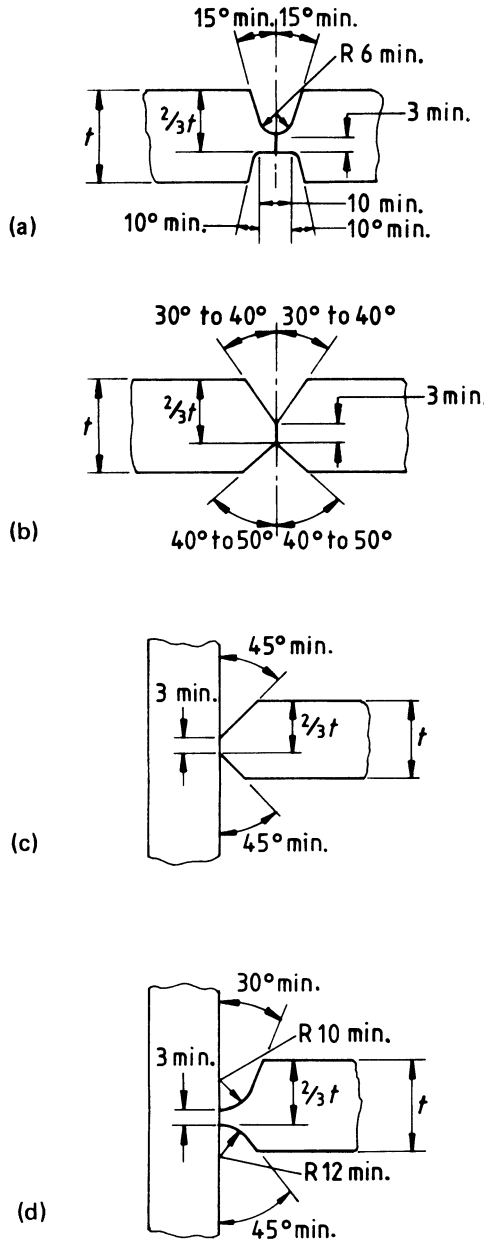


NOTE Each preparation may be used with or without backing. The dimension for the gap depends on the welding process being used.

(d)

All dimensions are in millimetres.

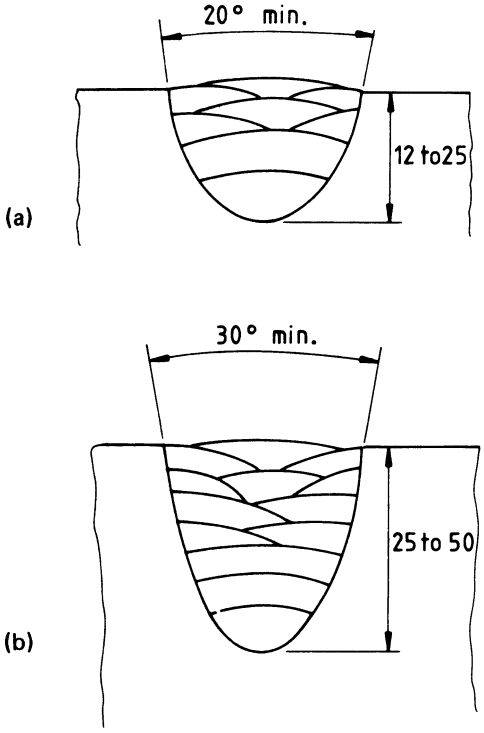
Figure 1 — Typical joint preparation for welding from one side



All dimensions are in millimetres.

NOTE Certain welding procedures achieve full penetration without back gouging, but where this cannot be proved, the back of the first run should be gouged out by suitable means to clean sound metal before welding is started on the gouged out side.

Figure 2 — Typical joint preparations for welding from both sides



All dimensions are in millimetres.

Figure 3 — Typical gouged cavities

8 Assembly (fabrication welding)

To maintain the required alignment and gap, where used, during welding, the parts to be welded shall be securely held in position by mechanical means, welded-on bridge pieces, or by tack welding.

NOTE When sufficient weld metal has been deposited to make the fabrication self-supporting, bridge pieces or mechanical clamps may be removed and potential distortion controlled by welding sequence rather than by mechanical restraint. Cracking can result if bridge pieces or mechanical clamps remain in position during completion of the weld.

Pre-heating, as required by clause **12**, shall be applied and maintained during tack welding and the welding-on of bridge pieces or other attachments.

Electrodes, filler rods or filler wires used for tack welding shall be of the same type and class and of a size not larger than those used for completing the first run of weld metal.

Particular attention shall be paid to the quality of tack welds which shall be made by approved welders (see clause **21**). The throat thickness of tack welds made with filler metal shall be similar to that of the initial root run. Where necessary, the extremities of these tack welds shall be dressed by grinding or chipping to facilitate proper fusion when they are incorporated in the root run. Any cracked tack weld shall be completely removed and re-made satisfactorily.

Care shall be taken when removing welded-on bridge pieces. Under no circumstances shall they be knocked off; they shall be removed by pneumatic chisel or disc grinder at a point close to the surface of the casting, except that for low carbon steels thermal cutting followed by grinding shall be permitted. Any remnants of the bridge pieces and attaching weld shall be removed by grinding or filing until the surface contour of the casting is restored. The area embracing that exposed by the welds attaching the bridge pieces shall be examined by surface non-destructive means to determine whether rectification is required by grinding or by welding. All welded-on bridge pieces shall be removed before applying any post-weld heat treatment, which shall embrace the area occupied by the bridge pieces.

9 Distortion

The welding procedure and production sequence shall be chosen so that distortion is minimized.

NOTE This is particularly important when finished machined castings are to be welded.

10 Arc strikes

Contact of the electrode or of the non-insulated parts of electrode holders with the casting shall be avoided. A striking plate shall be used for cleaning the tip of an electrode.

NOTE It is recommended that electrode holders be of the fully insulated type.

Welding return leads shall be firmly fixed to the work in order to provide good electrical conductivity and to prevent damage by arcing.

11 Inter-run cleaning

Each run of weld metal shall be clean before a further run is applied, particular attention being paid to the junctions between the weld metal and the fusion faces. Visible defects such as cracks, cavities and other deposition faults shall be removed before deposition of further weld metal. Grinding wheels for use on austenitic stainless steels shall be of the "iron free" type and shall have been used only on such steels.

12 Pre-heating

The actual pre-heating temperature[2)] during cutting and welding shall be as given in the welding procedure, based on the requirements for minimum pre-heating temperature given in Table 1, and shall be maintained in the region of the weld. When no pre-heating is specified in Table 1, no thermal gouging, cutting or welding shall be carried out when the temperature of the casting is below 10 °C.

If it is not possible to pre-heat the entire casting or fabrication, either because of its size or because the extent of the welding required is such that the casting or fabrication will fall below the appropriate temperature specified in Table 1 before the completion of welding, then local pre-heating shall be used over an area on each side of the weld having a width of at least three times the thickness of the material.

NOTE Whichever method is used, it is preferable to pre-heat the casting or fabrication to a temperature slightly higher than the minimum so that either the weld is completed before the temperature falls below the value stated or the number of re-heatings required is kept to a minimum.

13 Cooling after welding

Low carbon steel and austenitic steel castings or fabrications shall be cooled naturally.

NOTE Normally, precautions are not necessary.

High carbon steels and alloy steels which may be sensitive to cracking shall be cooled gradually from the welding temperature, primarily to give greater safeguards against cold cracking.

14 Post-weld heat treatment

Post-weld heat treatment conditions shall be as given in the welding procedure, based on the requirements given in Table 1.

[2)] The pre-heating temperature is the temperature of the parent metal in the welding region resulting from heating of the parent metal immediately prior to the absorption of any heat from the welding process and is applicable to the first and all subsequent runs.

NOTE 1 The object of post-weld heat treatment is to reduce the stresses due to welding, to reduce hardness in the heat-affected zone or to achieve specified properties. In all cases, the heat treatment should be considered in relation to any general heat treatment to be applied to the component to provide specific properties. When such general heat treatment has been applied before welding is done, it may be necessary to repeat the treatment after welding to restore these properties. A high temperature treatment may reduce the strength of the weld metal.

The heat treatment shall be of one of the following forms:

a) an immediate stress relief, where the casting or fabrication is stress relieved before its temperature falls below the minimum pre-heating temperature;

b) a final heat treatment of the casting or fabrication carried out before its temperature falls below the minimum pre-heating temperature;

c) a stress relieving, annealing, normalizing or quench and tempering heat treatment carried out some time after the casting or fabrication has cooled to the ambient temperature.

NOTE 2 In general, the temperature of the furnace should not be above 300 °C at the time of inserting a cold casting or fabrication.

Heat treatment shall be carried out by one of the following methods, care being taken to ensure that the minimum temperature is achieved uniformly through the thickness of the casting or fabrication:

1) heating in a stationary industrial furnace;

2) local heating using:

i) gas burners;

ii) a portable muffle furnace;

iii) induction coils;

iv) resistance heaters.

Manually operated gas torches shall not be used.

NOTE 3 Where other methods of heating are the accepted practice in certain industries these may be used by agreement between the contracting parties but consideration should be given to the metallurgical effects of such methods. The foregoing methods are, however, preferable.

The heating and cooling rates and soaking times shall be appropriate to the material geometry, thickness and the requirements for the type of steel casting specified in the appropriate British Standard. In the case of fabrication welding these shall be stated in the welding procedure.

15 Temperature measurement

15.1 General

Pre-heating, interpass and post-weld heat treatment temperatures, where applicable, shall be checked during the period of their application. All post-weld heat treatment conditions shall be noted in the form of records for subsequent inspection when necessary.

15.2 Pre-heating and interpass temperatures[3)]

Pre-heating and interpass temperatures shall be checked by using thermocouples, surface pyrometers or, when they are compatible with the casting material, by temperature indicating paints or crayons.

NOTE Temperature indicating paints will not indicate by how much the minimum temperature is exceeded. Some types of paint will not show, once the temperature has been reached, that this temperature is being maintained. In these cases the paint has to be re-applied if continued temperature observations are to be made.

When pre-heating is being applied by flame to the surface of the casting being welded, the flame shall be removed for at least 2 min before the temperature is checked.

15.3 Post-weld heat treatment

Calibrated thermocouples and recorders shall be used for measuring temperatures when carrying out post-weld furnace heat treatment.

For local treatment, separately attached thermocouples shall be used.

NOTE Thermocouple junctions and wires should be protected from flame impingement. To prevent direct radiation from the heating elements on the hot junction when electrical resistance heating is used, thermocouples should be covered with a protective wrapping.

16 Dressing

Dressing of the completed weld area shall be applied, when considered necessary, for any of the following reasons:

a) to facilitate non-destructive testing;

b) to remove notches or similar flaws that would impair fatigue properties;

c) to improve service in corrosive environments;

d) to minimize the risk of stress relief cracking;

e) to restore the casting contour and/or dimensions.

The method of dressing shall be one of those given as a) or c) in **6.2**. When a thermal process is used, the requirements and precautions in clauses **6** and **12** shall apply. In such cases careful grinding shall follow the thermal dressing.

[3)] The interpass temperature, in a multi-run weld, is the temperature of a section of deposited weld metal and adjacent parent metal immediately prior to welding again at that section.

17 Inspection of completed welds

The method or combination of methods and frequency of inspection together with the standard of acceptance for completed welds shall be as agreed between the contracting parties at the time of the enquiry and order [see **2.2** g)].

18 Rectification of faulty welds

When welds fail to comply wholly or partly with the standard of acceptance derived in accordance with clause **17**, all unacceptable defects shall be removed.

All repaired welds shall be subjected to the same requirements as the original welds.

19 Record of location of welds

By agreement between the contracting parties, records showing the location of welds shall be supplied [see **2.2** h)].

20 Procedure approval

20.1 General

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

NOTE For example, evidence of a welding procedure having been approved to BS 4870-1 could be submitted for exemption purposes.

In other cases, when required either

a) by the application standard, or

b) by agreement between the contracting parties [see **2.2** i)],

welding procedure tests shall be carried out before a manufacturer can be permitted to weld castings in accordance with this standard.

20.1.2 For the purpose of procedure tests, the steels listed in Table 1 shall be grouped as given in Table 2. The approval of a welding procedure for a particular type of steel shall include approval for all the other steels in the same group and between steels in the same group in Table 2, unless the purchaser has stated in the enquiry and/or order that a separate procedure test for the particular steel is required. Approval between groups of steels shall not be permitted.

If fabrication welds between steels in different groups are to be made, a separate procedure test for the particular combination of materials shall be carried out [see **2.1** c)].

NOTE 1 It is recommended that the form given in Appendix A be used to record details of the welding procedure and the test results, in order to facilitate uniform presentation and assessment of the data.

NOTE 2 It is recommended that welding procedure tests carried out in accordance with the requirements of this standard and witnessed by an independent inspecting authority should be accepted by other inspecting authorities, provided that all the provisions have been fulfilled.

20.2 Items in a welding procedure test

20.2.1 *General.* The items listed in **20.2.2** and the items in **20.2.3** relevant to the particular welding process shall be recorded for each welding procedure test.

NOTE Not all of these items need be included in the approved welding procedure documentation.

20.2.2 *Items for all welding processes.* Details relating to the following items shall be recorded for all welding processes:

a) welding process;

b) parent metal specification and steel group (see Table 2);

c) method of preparation and joint configuration;

d) welding position;

e) pre-heating and interpass temperatures;

f) welding technique and sequence;

g) electrode, filler material, flux and shielding gas; make, trade name, type and size;

h) electrode or filler material chemical composition;

i) post-weld heat treatment;

j) test results;

k) identification of inspecting authority if any;

l) when applied, the temperature and time adopted for drying/baking of welding consumables before use.

Table 2 — Grouping of steels for welding procedure approval

Group	British Standard		Type of steel	Remarks
	BS 3100	BS 1504 and others		
1	A1	161 grade 430	0.25 % C max.	See note 1 and **20.9**
	—	161 grade 480	0.30 % C max.	
			0.35 % C max.	
	AL1	430 grade LT40	0.20 % C max. (low temperature)	
	AM1	—	0.15 % C max. (magnetic permeability)	
	AM2	—	0.25 % C max. (magnetic permeability)	
	AW1	—	0.10 % C to 0.18 % C (case hardening)	
2	B1	245	C-½ % Mo	See note 1 and **20.9**
	BL1	245 grade LT50	C-Mo (low temperature)	
3	A2	161 grade 540		
	A4	BS 2772-3	1½ % Mn	
	A5	—	1½ % Mn	
	A6	—	1½ % Mn	
4	A3	—	0.45 % C max.	
	AW2	—	0.40 % C to 0.50 % C	
	AW3	—	0.50 % C to 0.60 % C	
5	BT1	—	High tensile	
	BT2	—	High tensile	
	BT3	—	High tensile	
6	B2	621	1¼ % Cr-Mo	
7	B3	622	2¼ % Cr-Mo	See note 2
	B4	623	3 % Cr-Mo	
	B7	660	Cr-Mo-V	
8	B5	625	5 % Cr-Mo	
	B6	629	9 % Cr-Mo	
9	BW2	—	C-1 % Cr	
	BW3	—	C-1 % Cr	
	BW4	—	C-1 % Cr-Mo	
10	BL2	503 grade LT60	3½ % Ni (low temperature)	
11	BW1	—	3½ % Ni-Cr-Mo (case hardening)	See **20.9**
12	BW10	—	Austenitic manganese	
13	420C21	—	13 % Cr	
	420C29	420C29	13 % Cr	
	420C24	—	12 % Cr to 16 % Cr	
14	425C11	425C11	13 % Cr-4 % Ni	

Table 2 — Grouping of steels for welding procedure approval

Group	British Standard		Type of steel	Remarks
	BS 3100	BS 1504 and others		
15	304C15 302C25 304C12	304C15 — 304C12	18 % Cr-8 % Ni	
	347C17	347C17	18 % Cr-8 % Ni-Nb	
	316C71 315C16	316C71 315C16	18 % Cr-8 % Ni-Mo	
	316C16 316C12	316C16 316C12	18 % Cr-10 % Ni-2½ Mo	
	318C17	318C17	18 % Cr-10 % Ni-2½ % Mo-Nb	
	317C16 —	317C16 317C12	18 % Cr-10 % Ni-3½ % Mo	
16	— —	364C11 332C11	Austenitic Cr-Ni-Mo-Cu	
	452C11 452C12	—	27 % Cr	
	302C35	—	20 % Cr-10 % Ni	
	309C40 309C30 309C32 309C35	—	25 % Cr-12 % Ni	
	310C45 310C40	310C40	25 % Cr-20 % Ni	
17	311C11	—	25 % Ni-18 % Cr	
	330C12 330C11	330C11	35 % Ni-18 % Cr	
	331C60 331C40	—	40 % Ni-20 % Cr	
	334C11	—	60 % Ni-15 % Cr	

NOTE 1 Where a type of steel is intended for low temperature service, the procedure test should be carried out on this steel in preference to the others within that group.
NOTE 2 If a foundry produces Cr-Mo-V castings, the procedure test should be carried out on this steel in preference to the others within that group.

20.2.3 *Items for particular welding processes.* Details relating to the items given in **20.2.3** a) to **20.2.3** e) shall be recorded for these particular processes in addition to the items in **20.2.2**. For pipe welding, where back purging is used, the purge gas, flow rate of purge gas, and period shall be recorded.

a) *Manual metal-arc welding*

1) a.c. or d.c. and polarity;

2) current.

b) *MIG* and *MAG welding, solid or cored-wire, including cored-wire CO_2 and gasless welding*

1) shielding gas and flow rate;

2) nozzle diameter;

3) arc voltage;

4) wire feed speed or current.

Additional for dip transfer technique:

5) electrode extension (mechanized welding);

6) circuit inductance or setting;

7) for pulsed welding, the pulse time, pulse current, background current and background voltage.

c) *TIG welding*

1) tungsten electrode diameter and type;

2) shielding gas and flow rate;

3) nozzle diameter;

4) a.c. or d.c. and polarity;

5) current;

6) arc length or voltage for mechanized welding;

7) for pulsed welding, the pulse time, pulse current, background current and background voltage.

d) *Submerged-arc welding and continuous covered electrode arc welding with or without CO_2 or flux shielding*

1) number and configuration of electrode wires and electrical connections;

2) shielding gas and flow rate;

3) electrode extension;

4) a.c. or d.c. and polarity;

5) current;

6) voltage;

7) power source characteristic.

e) *Electroslag and consumable guide welding*

1) number of electrodes;

2) guide configuration;

3) oscillation width and dwell periods;

4) current (wire feed speed);

5) a.c. or d.c. and polarity;

6) voltage and vertical lift rate;

7) slag depth.

20.3 Changes affecting approval

A new procedure approval test shall be carried out consequent upon a change in any of the following:

a) For repair welding:

1) Any change in welding process[4].

2) Any change in parent metal, type of joint and thickness subject to the extent of approval given in **20.1**, **20.4** and **20.5**, respectively.

3) Any change in type[5] of electrode, filler material, flux or shielding gas.

4) A decrease of more than 50 °C in the specified pre-heating temperature (or interpass temperature) or an increase in pre-heating temperature of more than 100 °C.

5) Any change in post-weld heat treatment temperature range.

b) For fabrication welding:

1) Any change in welding process[6].

2) Any change in parent metal, type of joint, thickness or pipe outside diameter subject to the extent of approval given in **20.1**, **20.4**, **20.5** and **20.6**, respectively.

3) Any change in type[7] of electrode, filler material, flux or shielding gas.

4) A decrease of more than 50 °C in the specified pre-heating temperature (or interpass temperature) or an increase in pre-heating temperature of more than 100 °C.

5) Any change in post-weld heat treatment temperature range.

6) Any change in root detail which affects the welding procedure (gap, root face or backing). Where joints welded from both sides involve a back gouging operation, changes in gap or root face shall not necessitate re-approval.

7) When impact tests are not required, a change to or from vertical-down.

8) When impact tests are required, any change in fundamental welding position (flat, horizontal/vertical, vertical, overhead; see BS 499-1 for definitions). Each fundamental welding position shall be separately approved, except that a welding procedure approved using vertical-up shall include approval for all other welding positions other than when using vertical-down.

For plate these positions are directly applicable to the test weld. Approval on welds made in all four fundamental positions includes approval for all intermediate positions.

[4] This includes consideration of changes in the mode of transfer, number of electrodes and arc characteristics.
[5] In respect of an electrode or filler material, "type" means the designation according to the standard with which it complies, but a change to an electrode or filler material with a different designation does not necessitate re-approval of the welding procedure if the change results in improved weld metal properties.
[6] This includes consideration of changes in the mode of transfer, number of electrodes and arc characteristics.
[7] In respect of an electrode or filler material, "type" means the designation according to the standard with which it complies, but a change to an electrode or filler material with a different designation does not necessitate re-approval of the welding procedure if the change results in improved weld metal properties.

For pipe it is more convenient to define the pipe position and movement during the test as given below.

Pipe position during test	Pipe movement during test	Welding position for which approval is given
Horizontal	Rotated	Flat
Vertical	Rotated or fixed	Horizontal/vertical
Horizontal	Fixed	All

9) Any change in welding technique.

10) Any change in the size of a manual metal-arc welding electrode used for the root run of a weld made from one side only.

11) Any change of more than one-third in the size of a manual metal-arc welding electrode used for the root run of a backed weld.

In the absence of a change in any of the above items, the approval of a procedure shall remain in force indefinitely.

20.4 Types of test piece

20.4.1 A procedure approval test shall be carried out in a position that simulates an actual repair or a fabrication joint.

NOTE As it is normally impracticable to use actual production castings for a fabrication welding test, the test piece may be made between two cast plates or two cast pipes.

The material for the test piece shall be either:

a) made by the same production process and be from the same group of steel (see Table 2) as that to be used for production work; or

b) agreed between the contracting parties [see **2.2** j)].

20.4.2 For procedure approval purposes a gouged cavity shall be welded or a test joint shall be made either:

a) as stated by the purchaser in the enquiry [see **2.1** d)]; or

b) as agreed between the contracting parties at the time of the order [see **2.2** k)];

for one or more of the following types of joint or weld:

1) a fillet weld;

2) a gouged cavity;

3) a butt joint (plate or pipe);

4) a branch connection.

Approval on test joint 3) shall include approval for 2) and 1), and approval on test weld 2) shall include approval for 1).

There shall be no repair welding of a completed test piece.

20.5 Thickness

Approval of a welding procedure for thickness "t" shall include approval for thicknesses in the ranges given in Table 3.

Table 3 — Procedure approval thickness ranges

Thickness "t" of deposited weld metal on test piece (see **20.4.2**)	Range of thickness of deposited weld metal approved	
	min.[a]	max.
	mm	mm
Up to and including 10 mm	0	$2t$
Over 10 mm up to and including 20 mm	5	$2t$
Over 20 mm up to and including 40 mm	10	$2t$
Over 40 mm	15	200

[a] For repair welding the minimum thickness requirements do not apply.

20.6 Pipe diameter for butt joints or branch connections

Approval on pipe or branch pipe of outside diameter D shall give approval for diameters in the range $0.5D$ to $2D$.

NOTE By agreement between the contracting parties, cast plate may be used instead of pipe over 500 mm diameter.

20.7 Visual examination and non-destructive testing

20.7.1 *General*. Visual examination shall be carried out before any dressing of the weld. For a welding procedure to be approved, the test piece(s) representing the welding procedure test shall comply with the requirements for both non-destructive and destructive testing (see **20.8** and **20.9**).

The length of a gouged cavity or a butt joint to be ignored in both non-destructive and destructive testing shall be either:

a) the first and last 25 mm; or

b) some other distance agreed between the contracting parties [see **2.2** l)].

If the test piece fails to comply with any of the requirements for visual examination or non-destructive testing specified in **20.7.3**, one further test piece shall be welded and subjected to the same examination. If this additional test piece does not comply with the relevant requirements, the procedure shall be regarded as not capable of complying with the requirements of this standard without modification.

20.7.2 *Non-destructive testing*. After any post-weld heat treatment and prior to the cutting of test specimens, all test pieces shall be examined visually, followed by:

a) magnetic particle testing (see BS 6072) or penetrant testing (see BS 6443) and

b) radiographic examination (see BS 2600-1 and BS 2600-2 and BS 2910) and/or ultrasonic examination (see BS 3923-1 and BS 3923-3).

20.7.3 *Acceptance levels*. Defects that are detected by visual examination and non-destructive testing shall be assessed in accordance with the details given in Table 5. The existence of any defect greater than the maximum permitted by Table 5 shall be sufficient cause for rejection.

Minor local defects, except cracks, which can be established as being due solely to the welder's workmanship shall not be sufficient cause for rejection.

NOTE 1 Multiple type faults contained within the same weld, either superimposed or interposed, which are individually acceptable as isolated imperfections may be considered acceptable provided that investigation shows that there is nothing fundamentally wrong with the welding procedure.

NOTE 2 In the case of penetrant testing, the degree of "bleed-out" is related to the volume of the defect and not its cross-sectional dimensions.

NOTE 3 It should be appreciated that the details given in Table 5 are being used for the approval testing of welding procedures and welders and as such may be different from those specified for a particular application.

20.8 Mechanical tests

20.8.1 *Tests required*. The type and number of specimens to be tested shall be as given in Table 4 and they shall be taken from the locations shown in Figure 5 and Figure 6.

20.8.2 *Tensile test for butt joints and gouged plates*

20.8.2.1 The tensile test shall be made on either transverse tensile test specimens in accordance with **20.8.2.2** or round proportional test specimens in accordance with **20.8.2.3**, as agreed between the contracting parties [see **2.2** m)].

20.8.2.2 When used, transverse tensile test specimens shall be machine cut from each test joint to the dimensions given in BS 709. If permanent backing has been used, it shall be removed prior to testing.

Specimens shall be taken in the following way, according to thickness.

a) A single specimen of full material thickness shall be used for thicknesses up to and including 40 mm.

b) For thicknesses greater than 40 mm, there shall be either a single specimen or multiple specimens, provided there is compliance with c) and d).

c) When multiple specimens are used, each set shall represent a single required tensile test. Collectively, all of the specimens required to represent the full thickness of the joint at one location shall comprise a set.

Table 4 — Test specimens from procedure approval test joints[a]

Test	Butt joint in plate or gouged cavity of thickness		Butt joint in pipe	Fillet weld	Branch connection
	Up to and including 40 mm	Over 40 mm			
Tensile (see **20.8.2**)	1	2	2	—	—
Bend (see **20.8.3**)	1	2	2	—	—
Macro-examination	1	1	2	2	4
Hardness survey	1	1	1	1	1

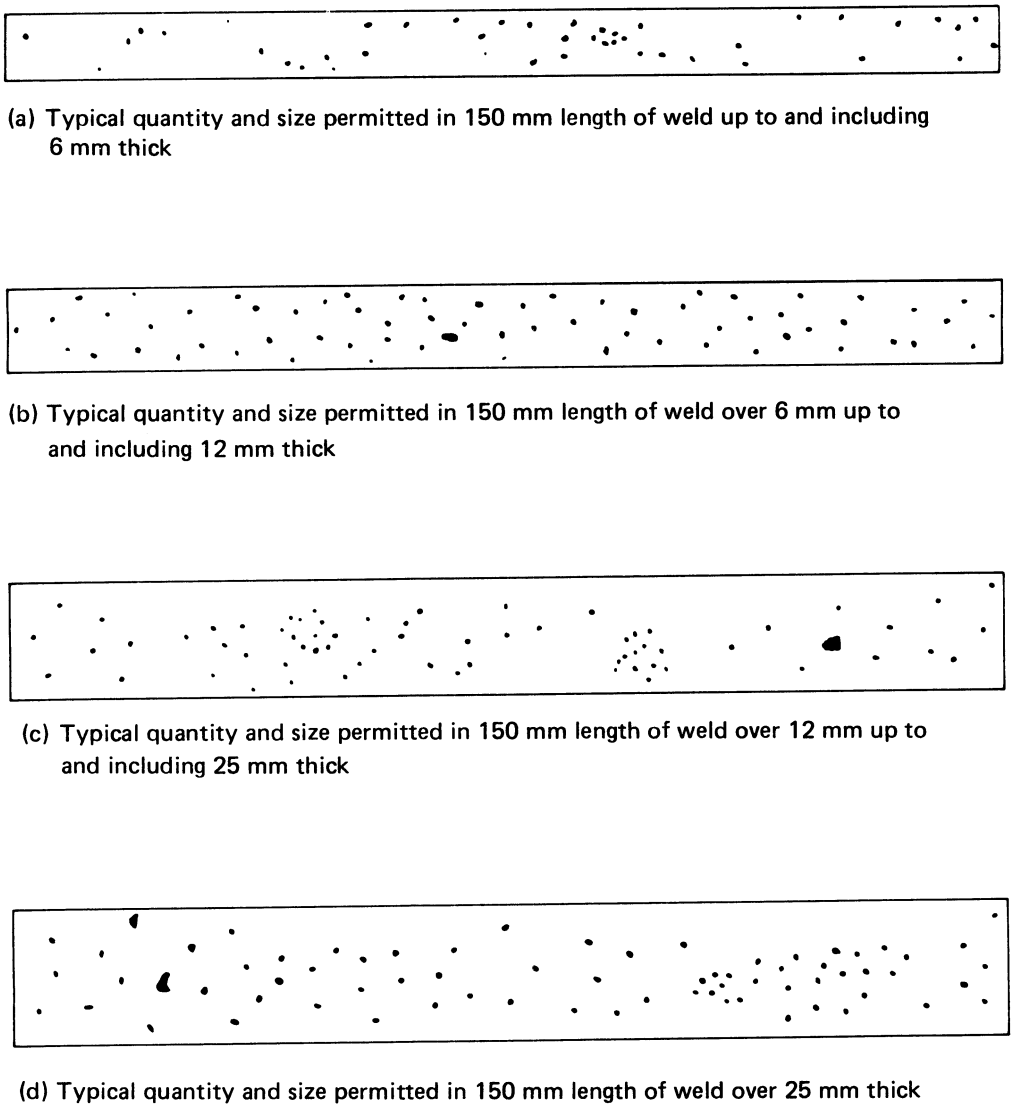
[a] For supplementary requirements see **20.9**.

Table 5 — Acceptance levels for welding procedure and welder approval tests

Notation:
t is the thickness of the test joint or test weld
L is the length of the longest defect in a group
h is the height of defect

Defect type[a]			Permitted maximum
Planar defects		a) Cracks	Not permitted
		b) Lack of root fusion[b] Lack of side fusion Lack of inter-run fusion	Not permitted
		c) Lack of penetration	Not permitted
Cavities and inclusions		a) Isolated pores or rounded inclusions	Greatest dimension 3 mm
		b) Distributed porosity or inclusions	2 % by area[c] (as seen in a radiograph) for $t \leqslant 50$ mm and pro rata for greater thicknesses
		c) Elongated slag inclusions	Length 1/3 t
		d) Linear group of slag inclusions	Aggregate length not to exceed t in a length of $12t$ except when distance between successive defects exceeds 6 L
Profile defects		a) Undercut	Slight intermittent undercut permitted, depth not to exceed approximately 0.5 mm
	Additional for fabrication welding only	b) Shrinkage grooves and root concavity	As for undercut, but depth not to exceed 1.5 mm
		c) Excess penetration	$h \leqslant 3$ mm. Occasional local slight excess is allowable
		d) Reinforcement shape	The reinforcement is to blend smoothly with the parent metal; dressing is not normally required provided the shape does not interfere with the specified non-destructive testing techniques
		e) Overlap	Not permitted
		f) Linear misalignment	$h \leqslant t/10$, 3 mm maximum

[a] For definitions of defect types, see BS 499-1.
[b] Not all types of preparation have a root, e.g. air-arc gouged cavity.
[c] The area of radiograph to be considered is the length of weld affected by the porosity or inclusions times the maximum width of the weld. Guidance on how the acceptance level would appear in a radiograph for typical distributions is obtainable from Figure 4.



(a) Typical quantity and size permitted in 150 mm length of weld up to and including 6 mm thick

(b) Typical quantity and size permitted in 150 mm length of weld over 6 mm up to and including 12 mm thick

(c) Typical quantity and size permitted in 150 mm length of weld over 12 mm up to and including 25 mm thick

(d) Typical quantity and size permitted in 150 mm length of weld over 25 mm thick

Figure 4 — Guidance on distributed porosity or inclusions as seen in radiograph

d) When multiple specimens are necessary, the entire thickness shall be mechanically cut into a minimum number of approximately equal strips of a size that can be tested in the available equipment.

Each specimen shall be tested and meet the requirements of **20.8.2.4**.

20.8.2.3 When used, round proportional test specimens shall be machine cut from each test piece to the dimensions given in BS 709 for the all-weld tensile test specimen.

Specimens shall be taken in the following way, according to thickness.

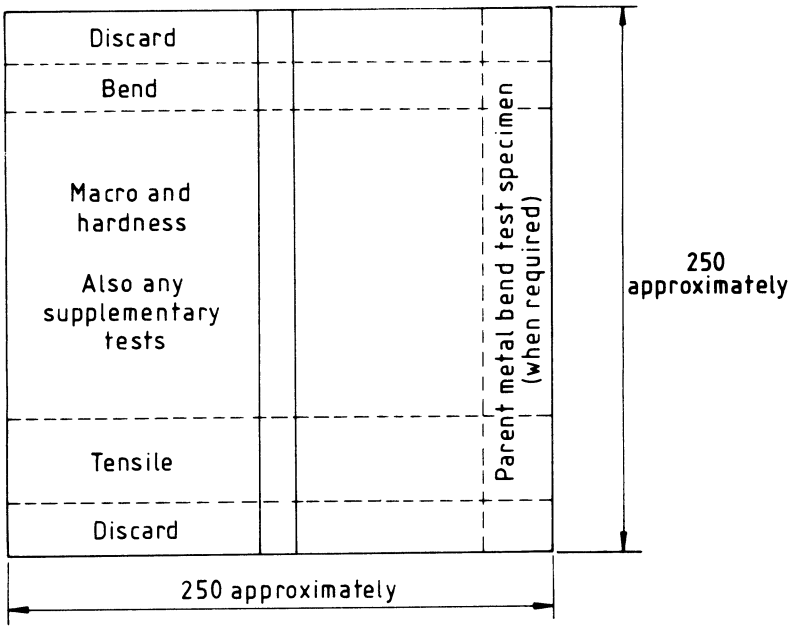
a) For thicknesses up to and including 40 mm, a single specimen shall be used.

b) For thicknesses over 40 mm, multiple specimens shall be cut through the full thickness of the weld with their centres parallel to the metal surface and not over 25 mm apart. The centres of the specimens adjacent to the metal surfaces shall not exceed 16 mm from the surface.

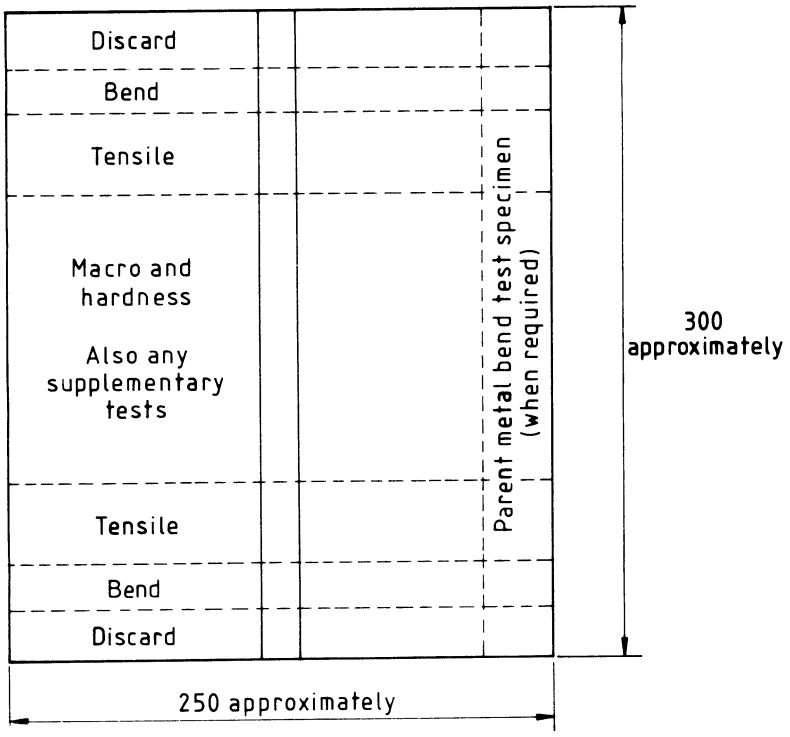
Each specimen shall be tested and meet the requirements of **20.8.2.4**.

20.8.2.4 All specimens shall be tested in tension in accordance with the methods described in BS 18-2.

The tensile strength obtained shall be at least equal to the specified minimum tensile strength for the casting material unless, in accordance with **4.1.2**, an alternative value is to apply.



(a) For thicknesses up to and including 40 mm



(b) For thicknesses over 40 mm

All dimensions are in millimetres.

Figure 5 — Location of test specimens for welds in plate for procedure approval

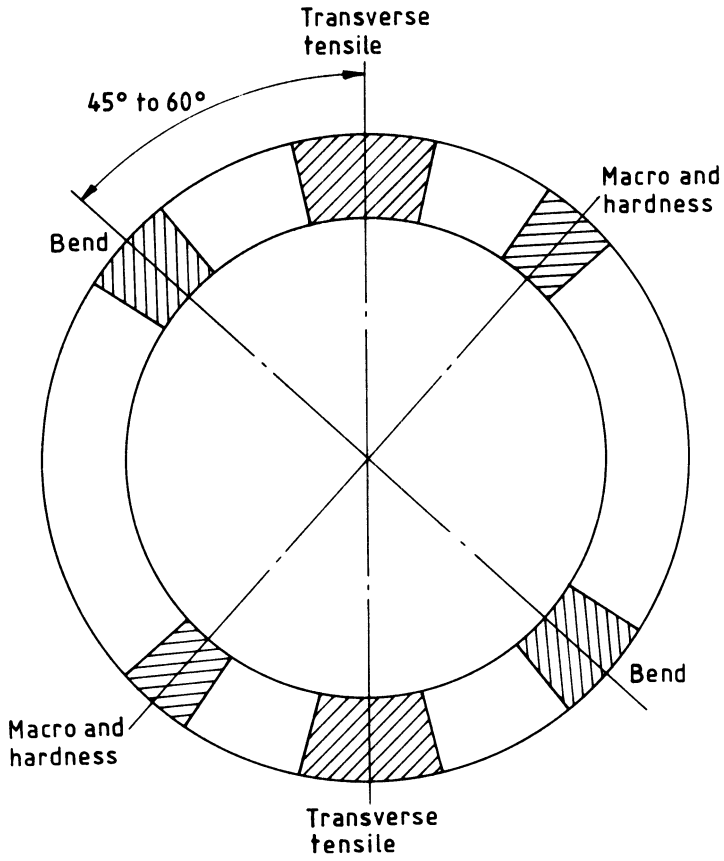


Figure 6 — Location of test specimens for welds in pipe for procedure approval

20.8.3 *Bend test for butt joints*. Each bend test specimen shall be machine cut from the test joint to the dimensions given in BS 709. If permanent backing has been used, it shall be removed prior to testing.

For thicknesses up to and including 10 mm, the specimen shall be a face bend for a gouged cavity and a root bend for a butt joint in plate or pipe. For thicknesses over 10 mm, only side bend specimens shall be used.

The specimen shall be tested in accordance with BS 709 by bending it through at least 90 ° round a former of a diameter equal to four times the thickness of the specimen. For materials exhibiting lack of ductility, the minimum degree of bending shall be the same as that shown by a separate specimen taken from the parent metal.

NOTE For a gouged cavity or a butt joint in plate when the weld metal and parent metal differ markedly in bending properties, either between weld metal and parent metal or between dissimilar parent metals, one longitudinal bend test specimen may be used instead of face, root or side bend test specimens, in which case the side to be placed in tension should be agreed and recorded.

After bending, each specimen shall show no signs of failure, although slight tearing at the edges of the specimen need not be considered as cause for rejection.

20.8.4 *Macro-examination for all test joints*. Each macro-examination test specimen shall be prepared for macro-etching and etched (see Appendix A of BS 709:1983) to give a clear indication of the weld structure. The etched face shall be assessed in accordance with **20.7.3**.

20.8.5 *Hardness survey for all test joints.* A hardness survey shall be conducted in accordance with BS 709 across a cross section of the test weld and the results shall be recorded. The method of hardness testing shall be in accordance with either BS 427 or BS 891.

20.8.6 *Repeat tests*. If any of the tests given in **20.8.2** to **20.8.4** show that the welds do not meet the required standard, two further test joints shall be made and the tests repeated. If either of these additional test joints does not meet the required standard, the welding procedure shall not be regarded as being capable of meeting the requirements of this standard without modification.

20.9 Supplementary requirements

20.9.1 Supplementary tests shall be carried out as agreed between the contracting parties [see **2.2** n)].

20.9.2 When relevant from the point of view of service conditions, impact tests shall be included in the assessment of the welding procedure. The number of test specimens, position of notches and impact values to be obtained shall be agreed between the contracting parties [see **2.2** o)]. The method of testing shall be in accordance with BS 709.

NOTE It may be useful and advantageous, or even necessary for compliance with other standards, to carry out more comprehensive testing than is required by **20.8** and **20.9** (e.g. impact tests, chemical analysis, micro-examination, delta ferrite determination in austenitic stainless steels) in order to gain more information and to avoid having to repeat the welding procedure approval test at a later date just to obtain additional test data. The dimensions of the test piece would probably have to be increased if additional tests were made.

21 Welder approval

21.1 General

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

NOTE 1 Evidence of a welder having been approved to BS 4871-1 may be submitted for consideration as satisfying the requirements of this standard.

NOTE 2 The welder's employer should hold and regularly maintain adequate records of all approval tests for each welder. It is recommended that the form given in Appendix B be used to record details of the approval test and the results in order to facilitate uniform presentation and assessment of the data.

NOTE 3 It is recommended that welder approval tests carried out in accordance with this standard and witnessed by an independent inspecting authority should be accepted by other inspecting authorities provided that all the provisions have been fulfilled.

The welder who satisfactorily completes the welding procedure approval test shall thereby be exempt from undergoing a separate welder approval test involving the same extent of procedure approval.

For the purpose of welder approval tests, the steels listed in Table 1 shall be grouped as shown in Table 6. The approval of a welder to weld a particular type of steel shall include approval for all other steels in the same group. Approval between groups of steel shall not be permitted.

A welder shall only be approved for the welding process used in the approval test.

A welder's approval shall remain valid provided that it can be shown, as signified at intervals of six months by a senior responsible person in the firm that employs the welder, that the welder has, subsequent to the test, been employed with reasonable continuity on work within the extent of his approval and has continued to produce satisfactory welds as verified by means appropriate to the type of production work. Reapproval shall be required if any of the following apply:

a) the welder is employed on work outside the extent of his current approval;

b) the welder changes his employer without transfer of his approval records;

c) six months or more have elapsed since the welder was engaged in welding with the approved process;

d) there is some specific reason to question the welder's ability.

21.2 Test weld

The test weld shall be made between plates or pipes or a gouged plate. The material for the test pieces shall be cast or wrought steel of any type from the same group in Table 6 as that to which the steel to be used in production belongs.

For welder approval purposes, a test weld shall be made for one or more of the following types of weld for a repair or fabrication:

a) a gouged cavity (typical cavities are shown in Figure 3);

b) a butt joint (cast or wrought plate and/or pipe);

c) a fillet weld (plate);

d) a branch connection (pipe).

Approval under b) shall include approval under a) and c).

21.3 Thickness

A test made on material 20 mm thick or over shall give approval for fabrication weld thicknesses of 15 mm and above and for repair welds of any thickness. If material less than 15 mm thick is to be used in production for fabrication welding, a test made on material of thickness t shall give approval for thicknesses in the range $0.75t$ to $2t$.

21.4 Position

The approval of a welder on a test joint welded in one of the positions given in Table 7 shall give approval for welding in the positions and the types of weld stated in Table 7 (see also Figure 7).

Table 6 — Grouping of steels for welder approval

Group	Grouping of steel by nominal composition	British Standard		Electrodes and filler wires to be used for welder approval test		
		BS 3100	BS 1504 and others	Manual metal-arc welding	Gas-shielded processes	
					Solid wire	Flux-cored wire
A1	Carbon steels and low alloy steels with less than 6 % total alloy	A1 — A2 A3 AL1 AM1, AM2 AW1, AW2, AW3 A4 A5, A6 B1 BL1 B2 B3 B4 B5 B7 BT1, BT2, BT3 BL2 BW1, BW2, BW3, BW4	161 grade 430 161 grade 480 161 grade 540 — 430 grade LT40 — — BS 2772-3 — 245 245 grade LT50 621 622 623 625 660 — 503 grade LT60 —	Any electrode of a basic low hydrogen type having a total alloy content of not more than 6 %	Any wire having a total alloy content of more than 6 %	Any wire having a total alloy content of not more than 6 %
A2	High alloy steels, non-austenitic	B6 420C21, 420C29 425C11 420C24 452C11, 452C12	629 420C29 425C11 — —	Any electrode from Table 1 specified for these steels	Wires complying with BS 2901-2	Wires of a suitable chemical composition
A3	High alloy steels, austenitic	BW10 304C15, 302C25, 304C12 347C17 316C71, 315C16 316C16, 316C12 318C17 317C16 302C35 309C40, 309C30 309C32, 309C35 310C45, 310C40 311C11 330C12, 330C11 331C60, 331C40 334C11 —	304C15, 304C12 347C17 316C71, 315C16 316C16, 316C12 318C17 317C16, 317C12 — — — 310C40 — 330C11 — — 364C11, 332C11	Electrode complying with BS 2926	Solid wire of an austenitic type complying with BS 2901-2	Wires of a suitable chemical composition

21.5 Pipe diameter for butt joints or branch connections

A test on pipe or branch pipe of outside diameter D shall give approval for diameters in the range $0.5D$ to $2D$ except that a test on pipe 165 mm or larger shall give approval for diameters of 80 mm and larger.

21.6 Inspection

21.6.1 *Visual examination*. All test pieces shall be examined visually before any dressing of the weld, and assessed in accordance with the requirements of **21.6.4**.

21.6.2 *Radiographic examination*. If acceptable on visual examination, groove welds and gouged cavities shall then be dressed smooth prior to radiographic examination by one of the techniques given in BS 2600-1 or BS 2600-2 or BS 2910 as appropriate. A radiographic sensitivity of 2 % or better, as shown by an image quality indicator complying with the requirements of BS 3971, shall be obtained on all radiographs. Assessment shall be in accordance with the requirements of **21.6.4**.

Table 7 — Welder approval: positions approved (see Figure 7)

Approval test		Position and type of weld approved		
		Plate		Pipe
Weld	Position	Groove or cavity	Fillet weld	Groove weld
Plate: groove or gouged cavity	1G	1G	1F	1G
	2G	1G 2G	1F 2F	1G 2G
	3G	1G 3G	1F 2F 3F	1G
	4G	1G 4G	1F 2F 4F	1G
	3G and 4G	1G 3G 4G	All	1G
Plate: fillet	1F	—	1F	—
	2F	—	1F 2F	—
	3F	—	1F 2F 3F	—
	4F	—	1F 2F 4F	—
	3F and 4F	—	All	—
Pipe: groove	1G	1G	1F	1G
	2G	1G 2G	1F 2F	1G 2G
	5G	1G 3G 4G	1F 2F 3F 4F	1G 5G
	6G	All	All	All
	2G and 5G	All	All	All

21.6.3 *Macro-examination*. Fillet welds shall be sectioned at three places for macro-examination. The sections shall be prepared for macro-etching and etched (see Appendix A of BS 709:1983) to give a clear indication of the weld structure. The etched face shall be assessed in accordance with **21.6.4**.

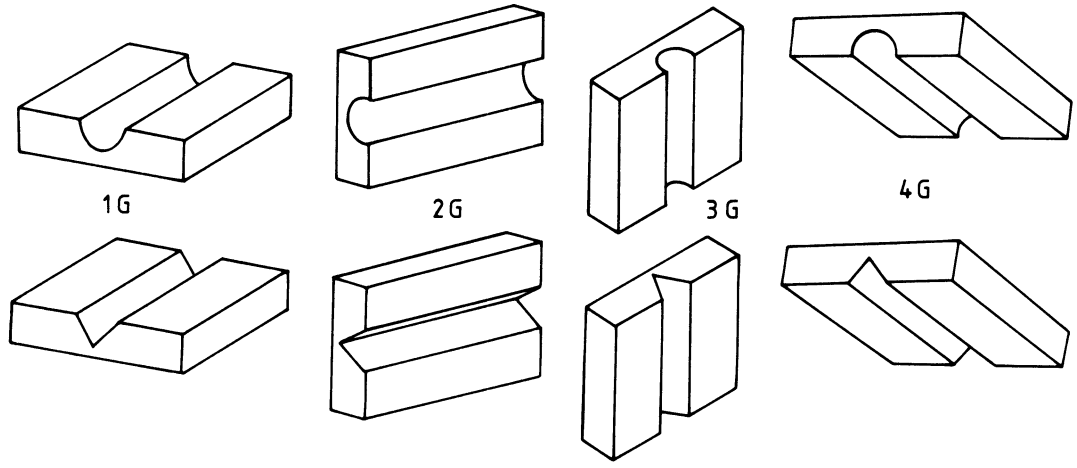
21.6.4 *Acceptance levels*. Defects that are detected by visual examination, radiographic examination or macro-examination shall be assessed in accordance with the details given in Table 4. The existence of any defect greater than the maximum permitted by Table 4 shall be sufficient cause for rejection.

NOTE 1 Multiple type faults contained within the same weld, either superimposed or interposed, which are individually acceptable as isolated imperfections may be considered acceptable provided that investigation shows that there is nothing fundamentally wrong with the welding procedure.

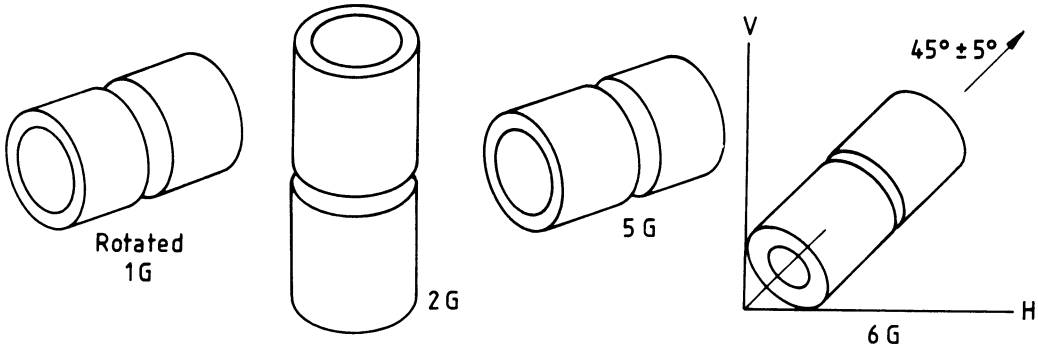
NOTE 2 It should be appreciated that the details given in Table 4 are being used for the approval testing of welders and welding procedures and as such may be different from those specified for a particular application.

21.7 Repeat tests

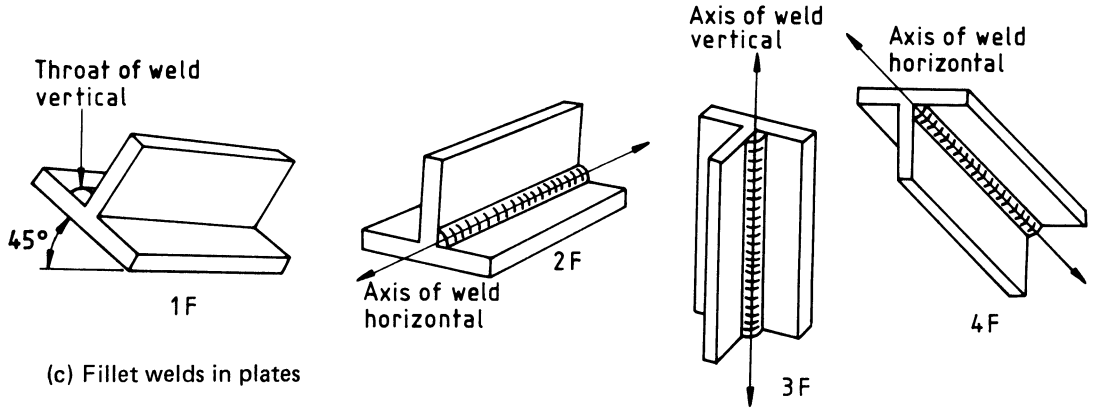
If any of the tests given in **21.6.1** to **21.6.3** show that the welds do not meet the required standard specified in **21.6.4**, two further test pieces shall be made and the tests repeated. If either of these additional test pieces does not meet the required standard, the welder shall not be regarded as being capable of welding steel castings to the requirements of this standard without further training.



(a) Groove welds in cast or wrought plates



(b) Groove welds in pipes



(c) Fillet welds in plates

Figure 7 — Welding positions

Appendix A Record of approval for welding procedure

The recommended form is as follows.

(Organization's symbol or logo)	Record of approval test of welding procedure (BS 4570:1985) 1. Procedure details	Test record no.

Manufacturer's name	Location of test Shop or site	Manufacturer's procedure no. (and revision no.)

Welding process(es)	**Parent material(s)** Specification(s) Grade Material group(s) no. (see Table 2) to no. Dimensions of test piece Thickness Diameter
Joint type	
Welding position(s)	
Test piece position	
Weld preparation (dimensioned sketch) **Groove design used**	**Run sequence and completed weld dimensions** (sketch)
Welding consumables *Filler material* Make and type Composition *Shielding gas/flux* Make and type Composition *Baking treatment*	**Welding conditions** Run no. Size(s) Current Voltage Polarity Travel speed — R.O.L. Wire feed speed Gas flow rate: Shield Purge Stringer or weave bead

Second side treatment			
	Temperature	Method	Control
Preheat			
Interpass			

Post-weld heat treatment
Specification
Method
Control
Heating rate
Soak temperature
Soak time
Cooling rate

Other information

Originator	Date	Welder's identity
		Name Mark

Extent of approval	Remarks (if any)
Range of materials Range of thickness(es) Range of diameters	

(Organization's symbol or logo)	Record of approval test of welding procedure (BS 4570:1985) 2. Test results	Test record no.

State "acceptable", "non-acceptable" (with reasons) or give numerical results.

Non-destructive tests

Visual	*Radiography*
Magnetic particle or penetrant	*Ultrasonics*

Destructive tests

Test	Tensile strength	Test temperature	Macro-examination
Units			
Transverse tensile			
All weld tensile			

Bend tests

Orientation	Former diameter	Results
Root/side		
Root/side		
Root/side		
Root/side		

Hardness survey	Type	Load	Location of hardness measurements (sketch)
	Hardness range		
Parent material			
H.A.Z.			
Weld			

Impact tests Application standard

Specimen location and size	Notch location	Test temperature	Results (with units)

Additional test(s) and result(s), e.g. chemical analysis, micro examination, ferrite measurement

The statements in this record are correct. The test welds were prepared, welded and tested in accordance with the requirements of BS 4570:1985

Manufacturer's representative	Inspecting authority
Position	Witnessed by
Date	Date

Appendix B Manufacturer's record of welder approval test

<table>
<tr><td colspan="4">Welder approval test certificate to procedure no.</td></tr>
<tr><td colspan="2">Welder's name
Welder's identity mark
Location</td><td colspan="2">Date of welding

Date of testing</td></tr>
<tr><td>Welding process</td><td>Voltage</td><td>Current</td><td>Polarity</td></tr>
<tr><td colspan="2">Parent material specification

Type

Thickness

Pipe diameter or dimensions</td><td colspan="2">Group to Group
Welding consumables
Electrode or filler material specification
Type of flux or electrode covering
Shielding gas composition</td></tr>
<tr><td>Welding position</td><td>Position of plate or pipe</td><td colspan="2">Fixed or moved</td></tr>
<tr><td colspan="4">Type of weld (sketch of preparation)</td></tr>
<tr><td colspan="4">Test results
State "acceptable" or "non-acceptable" (with reasons)
Visual
Radiography
Macro-examination</td></tr>
<tr><td colspan="4">Extent of approval
Range of materials covered by test
Range of thicknesses covered by test
Range of diameters covered by test (pipes)
Remarks (if any)</td></tr>
<tr><td colspan="4">The results of the above welder test are in accordance with the requirements of BS 4570:1985.

Name of employer

Employer's certifying signature

and status of signatory

For limits of validity see overleaf

Inspecting authority

Engineer-surveyor for inspecting authority</td></tr>
</table>

This certificate remains in force whilst the welder continues to weld products which are tested in accordance with the appropriate requirements of BS 4570:1985 otherwise re-approval is required after a lapse of six months. Compliance with the requirement for continuance of validity of this certificate has to be authenticated in the manner indicated below.

NOTE This test certificate is to be available for perusal by the surveyor concerned, who will check the entries, which later have to include the authenticating personal signature of a senior responsible official of the welder's employing company or organization.

DECLARATION

I, the undersigned, declare that the welder named overleaf has been regularly employed on the class of work covered by this test certificate during the ..... months preceding the date of my signature.

Date	Personal signature	Position or title

Publications referred to

BS 18, *Methods for tensile testing of metals.*
BS 18-2, *Steel (general).*
BS 427, *Method for Vickers hardness test.*
BS 499, *Welding terms and symbols.*
BS 499-1, *Glossary for welding, brazing and thermal cutting.*
BS 638, *Arc welding power sources, equipment and accessories.*
BS 639, *Covered electrodes for the manual metal-arc welding of carbon and carbon manganese steels.*
BS 679, *Filters for use during welding and similar industrial operations.*
BS 709, *Methods of destructive testing fusion welded joints and weld metal in steel.*
BS 891, *Method for Rockwell hardness test.*
BS 1504, *Specification for steel castings for pressure purposes.*
BS 2493, *Low alloy steel electrodes for manual metal-arc welding.*
BS 2600, *Radiographic examination of fusion welded butt joints in steel.*
BS 2600-1, *Methods for steel 2 mm up to and including 50 mm thick.*
BS 2600-2, *Over 50 mm up to and including 200 mm thick.*
BS 2772, *Iron and steel for colliery haulage and winding equipment.*
BS 2772-3, *1.5 per cent manganese steel castings for mine car couplers.*
BS 2901, *Filler rods and wires for gas-shielded arc welding.*
BS 2901-1, *Ferritic steels.*
BS 2901-2, *Austenitic stainless steels.*
BS 2910, *Methods for radiographic examination of fusion welded circumferential butt-joints in steel pipes.*
BS 2926, *Specification for chromium and chromium-nickel steel electrodes for manual metal-arc welding.*
BS 3100, *Specification for steel castings for general engineering purposes.*
BS 3923, *Methods for ultrasonic examination of welds.*
BS 3923-1, *Manual examination of fusion welds in ferritic steels.*
BS 3923-3, *Manual examination of nozzle welds.*
BS 3971, *Specification for image quality indicators for industrial radiography (including guidance on their use).*
BS 4105, *Liquid carbon dioxide, industrial.*
BS 4165, *Electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel.*
BS 4365, *Industrial argon.*
BS 4870, *Approval testing of welding procedures.*
BS 4870-1, *Fusion welding of steel.*
BS 4871, *Approval testing of welders working to approved welding procedures.*
BS 4871-1, *Fusion welding of steel.*
BS 5465, *Specification for electrode wires and fluxes for the submerged-arc welding of austenitic stainless steel based on weld metal composition.*
BS 6072, *Method for magnetic particle flaw detection.*
BS 6443, *Method for penetrant flaw detection.*
Health and Safety Executive *Electric Arc Welding* (Health and Safety at Work, Booklet No. 38). HMSO.

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