



BS 3019:Part 1:1984

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British Standard

TIG welding

Part 1. Specification for TIG welding of aluminium, magnesium and their alloys

Soudage à l'arc en atmosphère inerte avec électrode de tungstène
Partie 1. Soudage à l'arc en atmosphère inerte avec électrode de tungstène
de l'aluminium, du magnésium et de leurs alliages — Spécifications

Wolfram-Schutzgasschweißen (WIG-Schweißen)
Teil 1. WIG-Schweißen von Aluminium, Magnesium und deren Legierungen

British Standards Institution

Foreword

This British Standard, which was prepared under the direction of the Welding Standards Committee, is a revision of BS 3019 : Part 1 : 1958, which is withdrawn. The standard was first published in 1958 as general recommendations for manual inert-gas tungsten arc welding, Part 1, 'Wrought aluminium, aluminium alloys and magnesium alloys'. This revision takes account of development and greater usage of this process and sets out requirements for manual and mechanized inert-gas tungsten-arc welding of wrought and cast aluminium and aluminium alloys and magnesium alloys.

Weld acceptance levels are not specified since this British Standard would normally be used in conjunction with other standards. Where no such other standard is available, this British Standard can itself be used, provided that such additional requirements as are necessary are agreed between the contracting parties.

For wrought aluminium and aluminium alloys the material designations used are those in the International Alloy Designation System for Wrought Aluminium and Wrought Aluminium Alloys, which has been adopted in the United Kingdom and is now used in other British Standards.

This system is administered by the Aluminum Association Inc., who issue the 'Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminum Alloys'.

For magnesium alloys the material designations used are those now used in other British Standards.

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

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

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Specification

1 Scope

This British Standard specifies requirements for the manual and mechanized inert-gas tungsten-arc (TIG) welding of the wrought and cast forms of aluminium and aluminium alloys listed in table 1 and magnesium alloys listed in table 2 (clause 6).

They are intended to apply primarily, but not exclusively, to material not exceeding 12.5 mm in thickness.

In addition to the definitive requirements, this standard 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.

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

2 Definitions

For the purposes of this Part of BS 3019, the definitions given in BS 499 : Part 1 apply.

3 Information and requirements to be agreed and documented

3.1 Information to be supplied by the purchaser

The following information to be supplied by the purchaser shall be 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) whether written welding procedures are required (see clause 4);
- (b) whether welding procedure approval tests are required (see clause 19);
- (c) the application standard or code of practice to be applied together with any supplementary requirements;
- (d) locations, dimensions and details, i.e. form and size of joint, angle between fusion faces, gaps between parts, etc., of all welds. Symbols conforming to BS 499 : Part 2 shall be used for standard weld forms, but details shall be given for any non-standard welds;
- (e) whether the welds are to be made on the manufacturer's premises or in situ;
- (f) whether means of identification is required to enable welds to be traced to the welder who made them (see clause 21);
- (g) surface finish of weld profile;
- (h) surface treatment;
- (j) quality control arrangements.

3.2 Requirements to be agreed

The following items to be agreed between the contracting

parties, which are specified in the clauses referred to, shall be 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) specifications of the parent metal and filler metal (see clauses 5 and 6);
- (b) the procedure to be used for the d.c. welding of aluminium with helium or argon-helium mixtures (see 6.3.2);
- (c) the use of other than run-on/run-off plates to obtain full section thickness (see 8.1.2);
- (d) when dressing is not to be carried out, the permissible weld profile if it is not specified in the application standard (see 8.1.3.2);
- (e) the use of a special method to achieve full penetration without the use of backing where access to the reverse side is not possible (see 8.1.6(b));
- (f) the material for permanently backing butt welds when this is not part of the structure (see 8.1.6(2));
- (g) the material for permanently backing welds in hollow sections when this is not of similar composition to the parent metal (see 8.3.3);
- (h) the dressing of material prepared by grinding (see 9.2);
- (j) the use of a chemical treatment to remove surface oxide (see 9.6(b));
- (k) the tolerances on fit-up of parts joined by fillet welds (see 12.2);
- (l) the action to be taken on any areas of stray arcing (see 17.2);
- (m) the peening of welds (see clause 22);
- (n) the method and extent of inspection and testing in the absence of a relevant application standard (see clause 24);
- (p) the acceptance requirements for welded joints in the absence of a relevant application standard (see clause 25);
- (q) the use of local repair welding (see clause 26);
- (r) the use of stress-relieving heat treatment for aluminium alloys (see 27.1);
- (s) when post-weld heat treatment is required to improve properties but there is no application standard, the details of the heat treatment to be applied (see 27.2).

4 Details of welding procedure

When written welding procedures are required by the purchaser (see 3.1(a)), they shall include such of the following items as are relevant:

- (a) welder's identification;
- (b) welding procedure serial number;

- (c) welding process or processes when more than one is used in making a complete joint;
- (d) parent metal specification, thickness and for pipe* the outside diameter or dimension;
- (e) whether shop or in situ welding;
- (f) weld preparation (sketch);
- (g) pre-weld cleaning, degreasing;
- (h) fit-up (sketch);
- (i) jiggling or tacking;
- (k) permanent or temporary backing with details of groove;
- (l) welding position (including direction for vertical position);
- (m) filler metal specification and size;
- (n) tungsten electrode diameter and type;
- (p) pre-heating and interpass temperature, if required, including method and control;
- (q) welding speed (mechanized welding);
- (r) shielding gas composition and flow rate;
- (s) nozzle diameter;
- (t) power source type and special features, e.g. use of d.c. suppressors, h.f. initiation or arc stabilization etc.;
- (u) current range;
- (v) for mechanized welding, arc length or voltage;
- (w) a.c. or d.c. and polarity;
- (y) for pulsed welding, the pulse and background times, currents and voltages;
- (z) welding head position and torch angle (mechanized welding);
- (aa) approximate number and arrangement of runs and weld dimensions (sketch);
- (bb) single or double welder technique;
- (cc) welding sequence;
- (dd) details of oscillation or weaving, if any;
- (ee) back gouging;
- (ff) post-weld heat treatment if required, including method of control;
- (gg) any special features.

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

5 Parent metal

The parent metal shall be as specified in either (a) or (b):

- (a) one of the materials listed in table 1 or table 2;
- (b) when agreed between the contracting parties, materials made from the use of alloys of similar types to those listed in tables 1 and 2 (see 3.2(a)).

Table 1. Parent metals (aluminium)

British Standard	Material designation
<i>Wrought products</i>	
BS 1470-75	1080A 1050A 1200 3103 5251 5154A 5083 6061 6063 6082
BS 2898	1350 6101A
BS 4300/6-15	3105 5005 5454 7020
<i>Cast products</i> (Sand and permanent mould castings)	
BS 1490	LM2 LM4 LM5 LM6 LM9 LM10 LM20 LM25 LM27
NOTE. A cross-reference table between the new and the old BS designations and the nearest equivalent ISO designations is given in appendix A.	

*In this standard the word 'pipe', alone or in combination, is used to mean 'pipe' or 'tube' or 'structural hollow section' (circular or rectangular), although these terms are often used for different categories of product by different industries.

Table 2. Parent metals (magnesium)

British Standard	Material designation	Nominal composition
%		
<i>Wrought products</i>		
BS 3370, BS 3372, BS 3373	MAG 111	Mg-3 Al-1 Zn-Mn
	MAG 121	Mg-6 Al-1 Zn-Mn
	MAG 151	Mg-3 Zn-0.5 Zr
<i>Cast products</i>		
BS 2970	MAG 1	Mg-8 Al-0.5 Zn-Mn
	MAG 2	Mg-8 Al-0.5 Zn-Mn
	MAG 3	Mg-10 Al-0.5 Zn-Mn
	MAG 5	Mg-4 Zn-1 RE-0.5 Zr
	MAG 6	Mg-3 RE-2 Zn-0.5 Zr
	MAG 7	Mg-8.5 Al-1 Zn-0.5 Mn
	MAG 8	Mg-3 Th-2 Zn-0.5 Zr
	MAG 9	Mg-5.5 Zn-2 Th-0.5 Zr
RE = Rare earth metals		

NOTE. Guidance on the selection of filler metals is given in B.2 which should be followed unless otherwise agreed between the contracting parties (see 3.2(a)).

Table 4. Filler rods and wires (magnesium)

Type	Nominal composition %
MAG 1	Mg-8.2 Al-0.6 Zn-0.3 Mn
MAG 3	Mg-9.8 Al-0.6 Zn-0.3 Mn
MAG 5	Mg-4.2 Zn-1.2 RE*-0.7 Zr
MAG 6	Mg-3.2 RE-1.9 Zn-0.7 Zr
MAG 8	Mg-3.2 Th-2.1 Zn-0.7 Zr
MAG 9	Mg-5.5 Zn-1.9 Th-0.7 Zr
MAG 111	Mg-3 Al-1 Zn-0.3 Mn
MAG 141	Mg-1.1 Zn-0.6 Zr
*RE = Rare earths	
NOTE. Where MAG 2 or MAG 7 have to be welded, the choice of filler metal is the same as that for MAG 1.	

6 Welding consumables

6.1 Filler rods and wires

6.1.1 Aluminium. The type of filler rod and wire given in table 3 and complying with the requirements of BS 2901 : Part 4 shall be used.

NOTE. Guidance on the selection of filler metals is given in B.1 which should be followed unless otherwise agreed between the contracting parties (see 3.2(a)).

Table 3. Filler rods and wires (aluminium)

Type	Nominal composition %
1050A	99.5 Al
1080A	99.8 Al
3103	Al-1.2 Mn
4043A	Al-5.2 Si
4047A	Al-12 Si
5154A	Al-3.5 Mg-0.3 Mn
5554	Al-2.7 Mg-0.8 Mn-0.1 Cr-0.1 Ti
5056A	Al-5 Mg-0.4 Mn
5356	Al-5 Mg-0.1 Mn-0.1 Cr-0.1 Ti
5556A	Al-5.2 Mg-0.8 Mn-0.1 Cr-0.1 Ti
5183	Al-4.8 Mg-0.8 Mn-0.1 Cr

6.1.2 Magnesium. The type of filler rod and wire given in table 4 and complying with the requirements of BS 2901 : Part 4 shall be used.

6.2 Tungsten electrodes

The type and diameter of tungsten electrodes shall be appropriate to the welding current used.

NOTE. Guidance on the use of tungsten electrodes is given in appendix C.

6.3 Shielding gas

6.3.1 For a.c. welding, only argon complying with the requirements of BS 4365 shall be used. The rate of flow of argon shall be sufficient to ensure stable arc conditions and clean welds.

NOTE 1. A general relationship between argon flow and welding currents for manual welding under workshop conditions is shown in figure 1 but other factors, e.g. the choice of nozzle size, access, also affect the flow rate.

6.3.2 Helium and argon-helium mixtures shall be used for d.c. welding of aluminium. The procedures to be used for the d.c. welding of aluminium with helium or argon-helium mixtures shall be agreed between the contracting parties (see 3.2(b)).

NOTE 2. Argon only may be used for d.c. welding in certain specialized applications.

6.4 Storage and handling

Filler rods and wires shall be stored and handled with care and in accordance with the material supplier's recommendations. They shall be stored in their original packaging, in a dry store room. Filler rods and wires that show signs of deterioration, e.g. dirtiness or corrosion, or are supplied without protective packing, shall be cleaned by suitable chemical or mechanical means or if this is impractical, shall not be used.

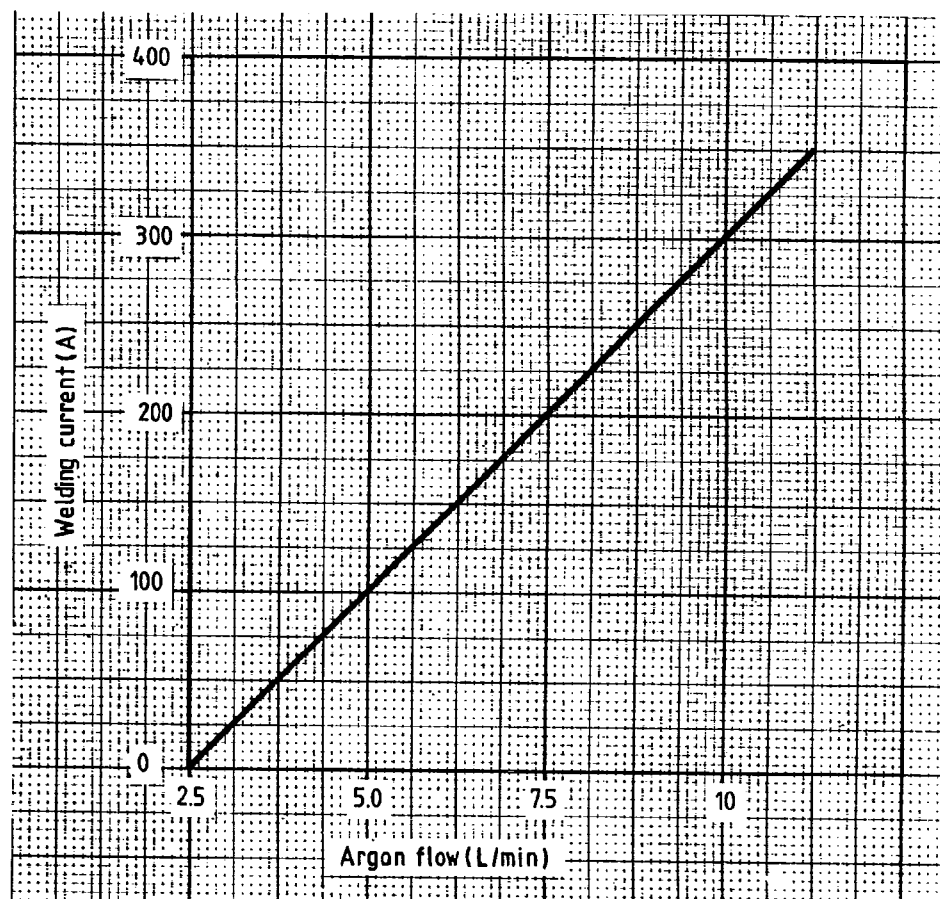


Figure 1. Typical argon consumption for manual a.c. welding in workshop conditions

7 Equipment

7.1 Plant

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

NOTE 1. Guidance on the use and maintenance of welding equipment is given in appendix D.

NOTE 2. Attention 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.

7.2 Earthing

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

NOTE. The welding return lead should be of the same or greater current rating than the welding lead.

7.3 Instrumentation

Adequate means of measuring the current and gas flow shall be available either as part of the welding equipment or by the use of portable instruments.

In the case of mechanized welding, means shall be provided for measuring the welding speed and wire feed speed.

8 Welding details

8.1 Butt welds

8.1.1 Joint details and welding conditions differing from those given in E.2 shall be permitted subject to welding procedure approval.

NOTE. Recommended joint details, welding conditions and joint preparation are given in appendix E.

8.1.2 The ends of butt welds in plate shall be welded so as to provide the full section thickness. This shall be done by either:

- (a) the use of run-on/run-off plates, or
- (b) other means agreed between the contracting parties (see 3.2(c)).

8.1.3 In the as-welded condition, the weld face shall be proud of the surface of the parent metal. Where a flush surface is required, the excess metal shall be dressed off.

8.1.3.1 When no dressing is to be carried out, the weld profile shall be as specified in the application standard, where it exists.

8.1.3.2 When no dressing is to be carried out and no application standard exists, the weld profile shall be agreed between the contracting parties (see 3.2(d)).

8.1.4 Where full penetration butt welds are to be welded from both sides, the back of the first run shall be gouged out to clean weld metal before welding is commenced on the second side, unless in the case of mechanized welding it can be shown by procedure testing that this is unnecessary. NOTE. Guidance on back gouging is given in appendix F.

8.1.5 When temporary backing is specified this may be of freshly clean carbon steel, but for high quantity production stainless steel is preferred. In the case of magnesium, other materials such as copper or graphite may be used. If the temporary backing is ungrooved, the back of the first run shall be gouged out to clean metal before the sealing run is made. Dimensions for temporary backing material shall be as given in figure 2.

8.1.6 Where access to the reverse side is not possible, either:

- (a) permanent backing shall be used, or
- (b) by agreement between the contracting parties, an approved special method of welding that gives full penetration without the use of backing shall be adopted (see 3.2(e)).

When permanent backing material is used, this shall consist of either:

- (1) part of the parent metal structure, or
- (2) a separate component of a material agreed between the contracting parties as having compatible weldability and having a thickness at least that of the parent metal when this is less than 5 mm (see 3.2(f)).

8.1.7 Where permanent backing material is employed it shall be tack, intermittently or fully welded and the joint shall be arranged in such a way as to ensure that complete fusion of the parts to be joined including the backing, is readily obtained.

NOTE. Under certain conditions, e.g. fatigue and corrosion, permanent backing material may be undesirable.

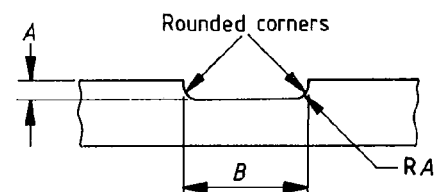
8.1.8 Where a butt joint is made between two members differing in thickness by:

- (a) less than 3 mm, or
- (b) one fifth of the thickness of the thinner of the two members,

whichever is the lesser, a gradual transition shall be obtained by deposition of weld metal (see figures 3(a) and (b)). For greater differences in thicknesses, the thicker shall be tapered on one or both sides (see figures 3(c) to (f)), to a slope of no greater than 1 in 5, so that the weld is made between members of equal thickness.

NOTE. The choice of method may be dictated by the application requirements.

Butt Joints



Corner Joints

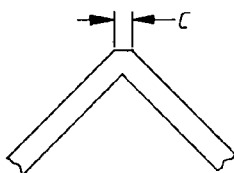


Figure 2. Temporary backing

Parent metal thickness (mm)	Dimension A (mm)	Dimension B (mm)
up to 1.5	0.5	3.0
1.5–5.0	1.0	5.0
over 5.0 to 10.0	2.0	6.5

Parent metal thickness (mm)	Dimension C (mm)
1.5–3.0	Nil
3.0–6.5	3.0

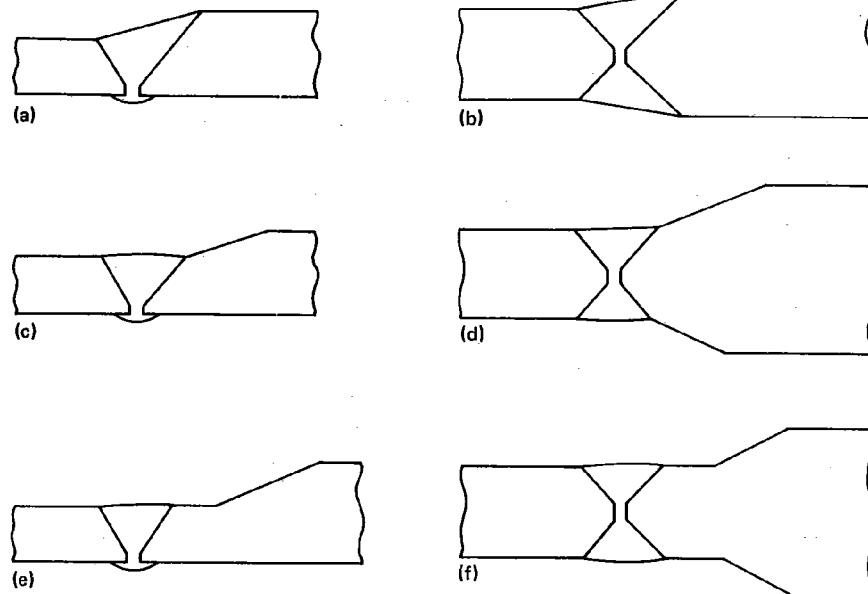


Figure 3. Butt joints of unequal cross-section

8.2 Fillet welds

8.2.1 Joint details and welding conditions differing from those given in E.3 shall be permitted subject to welding procedure approval.

8.2.2 A fillet weld, as deposited, shall be not less than the specified dimensions which shall be clearly indicated as throat thickness and/or leg length as appropriate.

8.2.3 For fillet welds, the actual throat thickness shall be not less than 0.7 times the design leg length.

8.3 Welds in pipe and hollow sections

8.3.1 Joint details differing from those given in E.4 shall be permitted subject to welding procedure approval.

8.3.2 Wherever possible, temporary internal alignment and back-up tools shall be used and should be of stainless steel (see 8.1.5).

8.3.3 Where permanent backing is used it shall be material either:

- (a) of similar composition to the parent metal, or
- (b) agreed between the contracting parties as having compatible weldability (see 3.2(g)).

9 Preparation of joint faces

9.1 Preparation or cutting of the material shall be done by shearing, sawing, grinding, machining or gouging. Preformed edges, e.g. formed or extruded details, shall be acceptable. Plasma arc cutting equipment is also acceptable for thick material.

9.2 Except where otherwise agreed between the contracting parties, material prepared by grinding shall be dressed with a file to smooth the surface and to remove any debris which may have become embedded in the metal surface (see 3.2(h)).

9.3 The preparation of fusion faces, angle of bevel, root radius and root face shall be such that the limits of accuracy required by the appropriate application standard can be achieved.

When, however, no appropriate application standard exists and this standard is itself to be used, the tolerances for manual welding on the limits of gap, root face and the included angle shall be as recommended in tables 9 to 13.

NOTE. For mechanized welding, closer limits may be necessary and particular requirements depend on the characteristics of the process and the joint configuration.

9.4 Fusion faces and adjacent surfaces shall be smooth and free from cracks, notches or other irregularities, e.g. overlap which might be the cause of defects or would interfere with the deposition of the weld.

NOTE. Removal of sharp corners and burrs on the root faces of single-sided butt welds is recommended.

9.5 Fusion faces and the surrounding surfaces shall be free from heavy oxide (including anodic film), oil, grease, paint, moisture or any other substance which might affect the quality of the weld or impede the progress of welding.

NOTE. Failure to free faces and surfaces from these substances will result in weld porosity and other inclusions.

Heavily oiled materials shall be degreased either chemically or with a solvent.

9.6 Degreasing shall be followed by removal of surface oxide by one of the following methods, (a), (b) or (c), as appropriate.

(a) Mechanical means, by either:

- (1) scratch brushing the surface to be welded, preferably with a power-driven rotary scratch brush of stainless steel, or
- (2) scraping to ensure that all the heavy oxide which was formed on the aluminium during manufacture or storage is removed.

(b) Chemical treatment, as agreed between the contracting parties, when the nature of the work dictates (see 3.2(j)).

(c) For thin sheets, where mechanical brushes are not suitable, hand brushing or rubbing with stainless steel wire wool or scraping.

When scratch brushing is used, brushes or alumina-impregnated nylon scourers, which shall be used exclusively for aluminium and kept clean, shall be selected to abrade rather than to burnish the surface.

NOTE. With magnesium and its alloys, a more usual procedure is to remove the chromate from the upper surfaces and to leave the chromate film on the undersurface to support the weld bead, especially if no backing material is used.

The interval between cleaning and welding shall be as short as possible and preferably not exceed six hours. If accidental contamination with dirt or moisture occurs after cleaning and prior to welding, the joint shall be re-cleaned.

During assembly of prefabricated units, some delays may be inevitable and when prepared joints awaiting welding are kept clean by applying a temporary cellulose masking tape over the joint, which is only removed immediately prior to welding. Such tapes shall have the adhesive confined to two narrow strips at the tape edges, so that the weld area is not contaminated by the adhesive when the tape is applied.

10 Assembly for welding

Parts to be welded shall be assembled in such a manner as to permit easy access to the joint. Where practicable, jigs and manipulators should be used to enable welding to be carried out in the most favourable position (flat). When used, jigs,

including any backing material or chills, shall be clean and dry and made from materials which will not contaminate the weld, e.g. stainless steel.

NOTE. In the butt welding of sheet materials, the fixture or jig should preferably be capable of clamping the sheet with an adequate and uniform force to apply a compressive force across the joint to counteract shrinkage stresses and to minimize distortion of the edges. For the butt welding of pipes, the use of internal or external alignment clamps is recommended; the former may be fitted with temporary stainless steel expanding backing rings which assist in the control of root penetration.

11 Alignment of butt joints

The butting faces shall not be out of alignment by more than 25 % of the root face or parent metal thickness, whichever is the less.

NOTE. Closer tolerances may be required for special applications.

12 Fit-up of parts joined by fillet welds

12.1 The edges and surfaces to be joined by fillet welds shall be in as close contact as possible, since any gap creates a risk of solidification cracking.

12.2 Tolerances on fit-up, if other than those recommended in tables 12 and 13, shall be subject to agreement between the contracting parties (see 3.2(k)).

13 Tack welds

When employed to align component parts for welding, tack welds shall be suitably spaced along the joint. When they are to be included in the final weld, their throat thickness or leg length shall be not less than those of the root run to be used in the joint and shall be subject to the same welding conditions as those specified for the initial root run. Additionally, their ends shall be tapered by gouging to blend with the parent metal surface to ensure adequate fusion to the subsequent runs. Cracked tack welds shall be completely removed and remade prior to welding.

14 Temporary attachments

Welded temporary attachments shall be avoided as far as possible and particularly with the heat-treatable alloys, but when used the welds shall be, as far as practicable, remote from principal joints and areas which may be highly stressed, and shall be made in accordance with clause 13.

NOTE. For removal of attachments, see clause 23.

15 Protection from the weather

Surfaces to be welded, including temporary backing, shall be dry.

NOTE 1. At low ambient temperatures where there is a tendency for condensation to occur, it may be necessary to heat the metal evenly to not more than 100 °C.

The welding area and the work shall be screened against draughts, otherwise the gas shield could be broken, resulting in porous or oxidized welds.

NOTE 2. It is also customary under these circumstances to increase the gas flow until a stable arc condition is achieved.

Furthermore, precautions shall be taken to avoid condensation in the inert gas passages of the welding equipment, since this can lead to porous welds. If such condensation is observed, this shall be removed by thoroughly purging the equipment with inert gas before welding.

For welding out of doors, adequate shelter shall be provided in order that the welding area be isolated from the outside environment.

NOTE 3. Omission of such precautions may result in porous or oxidized welds.

16 Preheating

Where it is necessary to preheat to avoid cold-start defects, the maximum temperature shall be 150 °C for wrought aluminium and 250 °C for wrought magnesium.

In the welding or repair of castings, it shall be determined whether preheating is necessary to prevent stress cracking and if so, at what temperature.

NOTE 1. The fabricator should seek specialist advice in such cases.

Special care shall be taken to ensure close temperature control, especially when welding the heat-treatable alloys.

NOTE 2. The use of temperature recording instruments or temperature indicating paints or crayons is recommended.

17 Stray arcing on work

17.1 Precautions shall be taken to avoid stray arcing which can occur between the work and

- (a) the tungsten electrode;
- (b) the welding earth return lead connection;
- (c) any part at earth potential;
- (d) the electrode holder, if the insulated body of the TIG torch is damaged.

Item (a) can give rise to tungsten inclusions in the work-piece. This contamination is not so serious as copper contamination, but where the inclusions are large and angular, and/or numerous, or where a corrosion hazard exists, they shall be removed by mechanical means.

NOTE 1. Item (a) can be avoided by correct torch manipulation and the avoidance of touch-down.

NOTE 2. Items (b), (c) and (d) can result in localized contamination with copper or iron. The contaminated area may be brittle and/or cracked due to local penetration of copper and poses a corrosion hazard. These areas should be removed by mechanical means, as above. Items (b) and (c) can be avoided by ensuring a firm earth connection (see 7.2).

17.2 Local soft spots, cracking or local corrosion hazards caused by stray arcing shall be either removed by mechanical means or repair welded, as agreed between the contracting parties, after which the areas shall be checked by inspection (see 3.2(i)).

18 Inter-run cleaning

Each run of weld metal including tack welds shall be cleaned by stainless steel wire brushing before it is covered by a further run, particular attention being paid to junctions and to the elimination of crevices between the weld metal and the fusion faces. Visible defects such as cracks, cavities, overlaps and other deposition faults shall be removed before the deposition of further weld metal.

19 Approval and testing of welding procedures

If so required by the purchaser, the manufacturer shall carry out procedure tests to demonstrate by means of a specimen weld of adequate length on parent metal representative of that to be used, that he can make satisfactory welds with the welding procedure to be used on the contract. For aluminium, these shall be in accordance with BS 4870 : Part 2. The test weld shall include weld details from the actual construction and it shall be welded in a manner simulating the anticipated production conditions (see 3.1(b)).

20 Approval and testing of welders

The contractor shall satisfy the purchaser that the welders are suitable for the work upon which they will be employed. For work on aluminium, welders shall have satisfied the relevant requirements of BS 4872 : Part 2 but if the welders are to work to approved welding procedures, they shall have satisfied the relevant requirements of BS 4871 : Part 2.

21 Identification

When specified by the purchaser, adequate means of identification, either by an identification mark or other record, shall be provided to enable each weld to be traced to the welder(s) by whom it was made (see 3.1(f)).

NOTE. Attention is drawn to the danger of hard stamping or electric pencilling in highly stressed areas and the designer should give guidance as to the location of such marks. Indentations used for marking in radiographic examination come into the same category.

22 Peening of weldments

The peening of welds and heat-affected zones is not normally necessary and shall only be carried out by agreement between the contracting parties (see 3.2(m)).

23 Removal of temporary attachments

When welded attachments used to facilitate construction are required to be removed, this shall be done by a clean cutting operation and the surface of the material finished smooth by grinding. Temporary attachments shall not be hammered off.

24 Inspection and testing

The method and extent of inspection and testing shall be either:

- (a) in accordance with the relevant application standard where it exists, or
- (b) by agreement between the contracting parties, in the absence of an application standard (see 3.2(n)).

Where mechanical tests are required, they shall be in accordance with BS 3451.

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

25 Quality of welds

Welded joints shall be free from defects that would impair the service performance of the construction. Such acceptance requirements, covering both surface and sub-surface defects, shall be either:

- (a) as specified in the application standard where it exists, or
- (b) by agreement between the contracting parties, in the absence of an application standard (see 3.2(p)).

26 Correction of faulty welds

When local repair welding is agreed between the contracting parties, the following procedure shall be carried out (see 3.2(q)).

- (a) The full extent of the defective area shall be accurately determined either by visual inspection, radiographic inspection, the use of dye penetrants or ultrasonic techniques.
- (b) The defective area shall be removed by back gouging or machining and the faces of the resultant groove shall have an included angle of not less than 60°, and shall have a generously rounded root so as to encourage the deposition of a sound, properly fused weld. The groove shall be continued for 12 mm to 25 mm beyond each end of the defective area and shall be gently scalloped out at its extremities.
- (c) If dye penetrants have been used, the back-gouged area shall be examined before rewelding to ensure that all traces of penetrant have been removed.
- (d) The repair weld shall fill the back-gouged weld and blend with the original weld surface.

27 Post-weld heat treatment

27.1 Stress-relieving heat treatment is not normally necessary for aluminium alloys and shall only be carried out by agreement between the contracting parties (see 3.2(r)).

27.2 When heat treatment of weldments is required to improve joint properties, the details shall be either:

- (a) in accordance with the application standard where it exists, or
- (b) by agreement between the contracting parties, in the absence of an application standard, taking into account the effect on joint properties and the alloy being used (see 3.2(s)).

Appendices

Appendix A Comparison of aluminium alloy designation systems

As referred to in the note to table 1, the following table gives cross-references between the new and the old BS designations for aluminium alloys, together with the nearest equivalent ISO designations.

Table 5. Aluminium alloy designations		
New BS alloy designation (International)	Old BS alloy designation	ISO designation/ alloy type (nearest equivalent)
1080A	1A	Al 99.8
1050A	1B	Al 99.5
1200	1C	Al 99.0
3103	N3	Al Mn 1
4043A	N21	Al Si 5
4047A	N2	Al Si 12
5251	N4	Al Mg 2
5154A	N5	Al Mg 3.5
5056A	N6	Al Mg 5
5356	—	Al Mg 5
5554	N52	*Al Mg 3 Mn
5556A	N61	Al Mg 5.2 Mn Cr
5083	N8	Al Mg 4.5 Mn
5183	—	Al Mg 4.5 Mn
6061	H20	Al Mg 1 Si 1 Cu
6063	H9	Al Mg Si
6082	H30	Al Si 1 Mg Mn
1350	1E	*Al 99.5
6101A	91E	*Al Mg Si
3105	N31	Al Mn Mg
5005	N41	Al Mg 1
5454	N51	Al Mg 3 Mn
7020	H17	Al Zn 4.5 Mg 1
LM2		*Al Si 10 Cu 2 Fe
LM4		Al Si 5 Cu 3
LM5		*Al Mg 5
LM6		Al Si 12
LM9		*Al Si 12 Mg
LM10		Al Mg 10
LM20		Al Si 12 Cu
LM25		Al Si 7 Mg
LM27		*Al Si 7 Cu 2

*Not covered by ISO.

Appendix B Guidance on selection of filler metal

B.1 Aluminium

Recommendations as to the choice of filler metals are given in table 6. In order to simplify the table, parent metal grouping and filler metal grouping have been used, details of these groupings being given in table 6a. Certain alloys which cannot be grouped have been specifically listed. The recommendations given in table 6b are not mandatory and in some circumstances a different choice of filler metal may be preferable, but this should be subject to agreement between the contracting parties (see 6.1.1).

For some applications, post-weld anodizing may be required. Where there is a choice of filler metals, that nearer in composition to the parent metal will give a better colour match, if other requirements such as weld soundness allow it to be used. Where 6XXX alloys are involved, filler metals containing Mg (5XXX) will give a better colour match than those containing Si (4XXX). Similar comments apply where welds will be exposed to long term weathering.

Table 6a. Groupings used in table 6b

Parent metal grouping	Filler metal grouping	Alloys
1XXX series	—	1080A, 1050A, 1200, 1350
3XXX series	—	3103, 3105
5XXX series	—	5251, 5454, 5154A
6XXX series	—	6063, 6061, 6082, 6101A
—	Type 1	1080A, 1050A
—	Type 3	3103
—	Type 4	4043A, 4047A*
—	Type 5	5056A, 5356, 5556A, 5183

*4047A is specifically used to prevent weld metal cracking in joints involving high dilution and high restraint. In most other cases, 4043A is preferable.

Table 6b. Selection of filler wires and rods (aluminium)

Parent metal combination 2nd part 1st part	Al-Si Castings	Al-Mg Castings	3XXX	1XXX	7020	6XXX	5005	5XXX	5083
5083	NR†	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	5556A Type 5 5556A	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	5556A Type 5 Type 5
5XXX	NR†	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 ‡ Type 5	Type 5 ‡ Type 5	
5005	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 5 Type 4 Type 4	Type 5 Type 4 Type 4	Type 5 Type 5 Type 5	Type 5 Type 4 Type 4	Type 5 ‡ Type 5		
6XXX	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 4 Type 4 Type 4	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 4 or 5 Type 4 Type 4			
7020	NR†	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	Type 5 Type 5 Type 5	5556A Type 5 Type 5				
1XXX	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 4 Type 3 or 4 Type 4	Type 1 § Type 1 Type 1 §					
3XXX	Type 4 Type 4 Type 4	Type 5 Type 5 Type 5	Type 3 § Type 3 Type 3 §						
Al-Mg Castings	NR†	Type 5 Type 5 Type 5							
Al-Si Castings	Type 4 Type 4 Type 4								

*Filler metals for parent metal combination to be welded are shown in one box, which is located at the intersection of the relevant parent metal row and column. In each box, the filler metal for maximum weld metal strength is shown in the top line: in the case of 6XXX and 7020 alloys, this will be below the fully heat-treated parent metal strength. The filler metal for maximum resistance to corrosion is shown in the middle line. The filler metal for freedom from persistent weld cracking is shown in the bottom line.

†NR = not recommended. The welding of alloys containing approximately 2 % or more of Mg with Al-Si filler metal (and vice-versa) is not recommended because sufficient Mg₂Si precipitate is formed at the fusion boundary to embrittle the joint.

‡The corrosion behaviour of weld metal is likely to be better if its alloy content is close to that of the parent metal and not markedly higher. Thus for service in potentially corrosive environments it is preferable to weld 5154A with 5154A filler metal or 5454 with 5554 filler metal. However, in some cases this may only be possible at the expense of weld soundness, so that a compromise will be necessary.

§ If higher strength and/or better crack resistance is essential, type 4 filler metal can be used.

|| For welding 1080A to itself, 1080A filler metal should be used.

B.2 Magnesium

Recommendations as to the choice of filler metals are given in table 7. These recommendations are not mandatory, but any departure from them should be subject to agreement between the contracting parties (see 6.1.2).

Table 7. Selection of filler rods and wires (magnesium)									
2nd Part 1st Part*	MAG 9	MAG 8	MAG 6	MAG 5	MAG 3	MAG 1 MAG 2 or MAG 7	MAG 151	MAG 121	MAG 111
MAG 111	NR	NR	MAG 6 [P]	MAG 6 [P]	MAG 3	MAG 1	NR	MAG 1	MAG 111
MAG 121	NR	NR	MAG 6 [P]	MAG 6 [P]	MAG 3	MAG 1	NR	MAG 1	
MAG 151	MAG 141 [P]	MAG 141 [P]	MAG 141 [P]	MAG 141 [P]	NR	NR	MAG 141 [P]		
MAG 1 MAG 2 or MAG 7	MAG 8 [P]	MAG 8 [P]	MAG 6 [P]	MAG 6 [P]	MAG 3	MAG 1			
MAG 3	MAG 8 [P]	MAG 8 [P]	MAG 6 [P]	MAG 6 [P]	MAG 3				
MAG 5	MAG 8 [P]	MAG 8 [P]	MAG 6	MAG 5					
MAG 6	MAG 8 [P]	MAG 8 [P]	MAG 6						
MAG 8	MAG 8	MAG 8							
MAG 9	MAG 9								

* Filler metals for parent metal combination to be welded are shown at the intersection of the relevant parent metal row and column.

Key

NR: Not recommended

P : Possible but difficult

* Filler metals for parent metal combination to be welded are shown at the intersection of the relevant parent metal row and column.

Key

NR: Not recommended

P : Possible but difficult

Appendix C Guidance on use of tungsten electrodes

Electrodes should be either of the pure tungsten or zirconiated type and chosen according to the welding current used. Suggested current ranges for different electrode diameters are given in table 8.

In some cases other types of tungsten electrodes may be more suitable, e.g. thoriated electrodes for d.c. welding.

Table 8. Electrode sizes and currents

Electrode diameter	Current range for a.c. use	
	Balanced 'squared' wave type	Balanced sine wave type
mm	A	A
1.2	Up to 50	Up to 45
1.6	50–80	Up to 65
2.4	80–160	60–115
3.2	160–225	115–170
4.0	225–330	170–225
4.8	330–400	210–275
6.4	400–550	Over 280

NOTE. Currents in excess of those stated in this table may lead to tungsten inclusions in the welds. Currents below those stated may lead to unstable arcs.

Tungsten electrodes should be free from surface contamination before welding commences and should the electrode be contaminated during welding, the arc can be run for a short while on scrap material to clear the contamination. If this treatment is unsuccessful, the electrode should be withdrawn from the torch and the end re-ground.

Appendix D Guidance on the use and maintenance of welding equipment

Alternating current is used for the argon-shielded inert-gas tungsten arc welding of aluminium and magnesium and their alloys.

Negative electrode d.c. welding, although possible with aluminium when used with a helium shroud, is seldom adopted due to the presence of surface oxides. These have to be removed by the arc for satisfactory welding and this is only achieved when the electrode is positive. Unfortunately, this polarity also results in overheating of the tungsten electrode, making the molten tip unstable with a consequent danger of tungsten inclusion in the weld. A compromise solution to these conflicting requirements is to use a.c. However, the tungsten/aluminium or magnesium a.c. arc has unequal negative and positive half cycles resulting in unstable conditions. This potential imbalance of the current waveform due to inherent rectification, can be compensated by connecting a bank of electrolytic condensers (a suppressor bank) in series with the transformer secondary, or electronically in the more modern solid state systems. The latter may also provide square waveform current outputs with control of the ratio of positive to negative half waves, to optimize welding efficiency.

A system for starting and maintaining the arc without the electrode touching the workpiece is also required. This is done by ionizing the arc gap (and thus producing a conducting path for the welding current) using a train of high frequency high voltage sparks or the injection of a high voltage surge for a short time at the appropriate point in the cycle, but modern solid state systems generally require high frequency for arc starting only.

Equipment for a.c. TIG welding, therefore, may include not only the power transformer but also a suppressor bank and a high frequency or surge generator. A mains contactor and sundry relays and solenoid valves are also included to control cooling water and argon flow.

The electrical equipment requires little maintenance, but the spark points in the high frequency generator may need adjusting and cleaning from time to time; also the torch leads, flow gauges and switches require regular inspection for damage. The equipment manufacturers' maintenance instructions should be observed and their advice sought in cases of doubt. Care has to be taken that leaks do not develop in the gas or water lines due to burns or mechanical damage. All connections in the gas line have to be scrupulously clean and these, as well as the tubes, have to be free from moisture or grease.

Ceramic and water-cooled shielding gas nozzles should be in good condition and there should be no excessive internal spatter deposit.

A positive pressure of argon has always to be maintained in a gas cylinder to prevent atmospheric contamination of the cylinder and for this purpose it is suggested that a minimum of 3 bar* should be observed. Attention is drawn to the fact that the water content of the gas rises as the pressure falls (see BS 4365) and for critical applications, it may be necessary to increase the minimum pressure to 10 bar or even higher to reduce the risk of defects.

For mechanized welding, the traversing device should be capable of achieving a uniform travel speed. When continuous filler rod additions are required, a wire feed mechanism capable of supplying wire at an infinitely variable constant rate over a range suitable for the wire diameter should be used.

Appendix E Recommended joint details, welding conditions and joint preparation

E.1 General

Guidance on welding design and weld dimensions for aluminium is given in CP 118 and application standards such as BS 5500, BS 5222 and BS 5387. The general guidance given throughout this appendix can be applied to magnesium with some adjustments given to the conditions in the tables.

E.2 Butt welds

Recommended joint details and welding conditions are given in tables 9, 10 and 11.

*1 bar = 10^5 N/m² = 10^5 Pa

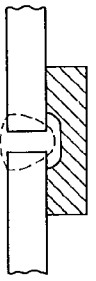
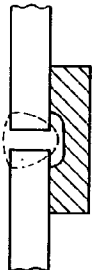
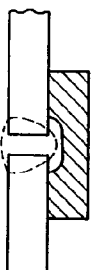
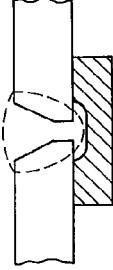
Table 9. Recommended joint details and typical welding conditions for butt joints									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
1.0		Flat	1	55	1.6	1.6	9.5	5	1. Only a small addition of filler will be required. 2. Good fit-up to be achieved. Gap: NIL. 3. Autogenous possible.
1.5		Flat	1	135	2.4	3.2	9.5	5	1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Autogenous: NIL gap
		Flat	1	90	2.4				1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Extra skill needed with no backing.
		Hor.	1	90	2.4	2.4	9.5	5	
		Vert.	1	90	2.4				
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.									

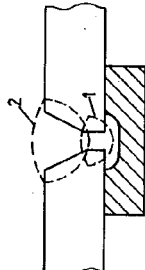
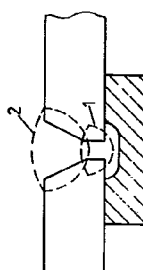
Table 9. Continued

Table 9. Continued									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
2.5		Flat	1	165	2.4 or 3.2	3.2	9.5	6	1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Autogenous: NIL gap
		Flat	1	120	2.4 or 3.2	3.2	9.5	6	1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Extra skill needed with no backing.
		Hor.	1	120	2.4 or 3.2				
		Vert.	1	120	2.4 or 3.2				
3.0		Flat	1	180	3.2	4.0	12.7	6	1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Autogenous: NIL gap
		Flat	1	156	3.2	3.2	12.7	6	1. Nominal gap: NIL Maximum gap: 1.0 mm 2. Penetration control possible with no backing and extra skill.
		Hor.	1	156	3.2				
		Vert.	1	156	3.2				

*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.

Table 9. Continued									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
5.0		Flat	1	250	3.2 or 4.8	4.8	12.7	8	1. Nominal gap: NIL Maximum gap: 1.5 mm
		Flat	2	230	3.2 or 4.8	4.8	12.7	8	1. Nominal gap: NIL Maximum gap: 1.5 mm 2. Back gouge before second run.
		Hor.	2	230	3.2 or 4.8				
		Vert.	2	210	3.2 or 4.8				
6.5		Flat	1	320	3.2 or 4.8	5.6	12.7	9	1. 75° incl. Vee with 1.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm
		Flat	2	240	3.2 or 4.8	4.8	12.7	9	1. 75° incl. Vee with 1.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm
		Hor.	2	240	3.2 or 4.8				
		Vert.	2	225	3.2 or 4.8				

*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.

Table 9. Continued									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
8.0		Flat	2	330	3.2 or 4.8	5.6	12.7	9	1. 75° incl. Vee with 1.5 mm root faces. 2. Nominal gap: NIL Maximum gap: 1.5 mm
		Flat	3	285	3.2 or 4.8	5.6	12.7	9	1. 75° incl. Vee with 1.5 mm root faces. 2. Nominal gap: NIL Maximum gap: 1.5 mm 3. Back gouge before reverse run.
		Hor.	4†	275	3.2 or 4.8				
		Vert.	3	275	4.8				
9.5		Flat	2	350	4.8 or 6.4	6.4	12.7	9	1. 75° incl. Vee with 1.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm
		Flat	3	350	4.8 or 6.4	6.4	12.7	9	1. 75° incl. Vee with 1.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm 3. Back gouge before reverse run.
		Hor.	4†	340	4.8				
		Ver.	3	310	4.8				

* Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.

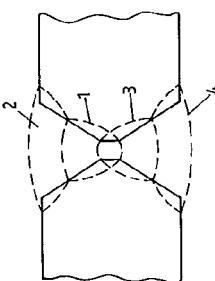
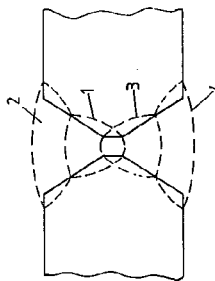
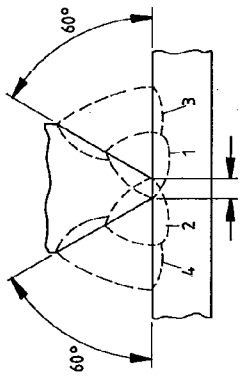
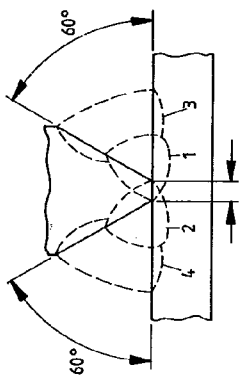
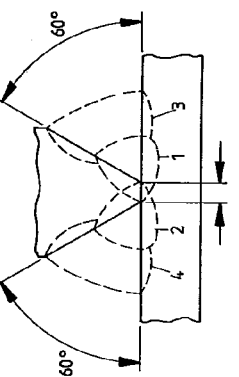
Table 9. Concluded									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
9.5		Flat	4	350	4.8, 6.4	6.4	12.7	9	1. 75° incl. Vee with 2.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm 3. Procedure for minimum distortion 4. Back gouge before reverse run
		Hor.	4	340	4.8				
		Vert.	4	310	4.8				
12.5		Flat	4	350	4.8, 6.4	6.4	12.7	9	1. 75° incl. Vee with 2.5 mm root face. 2. Nominal gap: NIL Maximum gap: 1.5 mm 3. Procedure for minimum distortion 4. Back gouge before reverse run
		Hor.	4	340	4.8				
		Vert.	4	310	4.8				
* Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. † Extra run to fill.									

Table 10. Recommended joint details and typical welding conditions for tee butt joints with butt welds

Thickness mm	Joint detail	Position	Number of runs	Current ^t A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
6.5	 Root face 1.0–1.5 mm	All	4	290 to 320	3.2 or 4.8	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm 2. Back gouge first run before second run.
8.0	 Root face 1.0–1.5 mm	All	4	320 to 345	3.2 or 4.8	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm 2. Back gouge first run before second run.
9.5	 Root face 1.0–1.5 mm	All	4	360 to 380	4.8 or 6.4	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm 2. Back gouge first run before second run.

*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.
^tFor welding in the vertical and overhead positions the current may be reduced by 10 %.

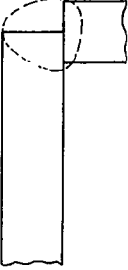
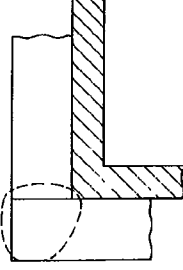
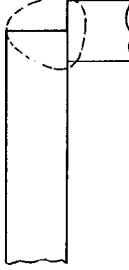
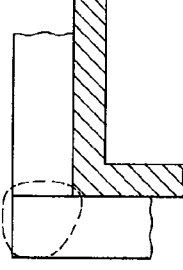
Table 11. Recommended joint details and typical welding conditions for corner joints									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min.	Notes
1.0		All	1	55	1.6	1.6	9.5	8	1. Nominal gap: NIL 2. Autogenous possible.
1.5		All	1	75	1.6	2.4	9.5	8	1. Nominal gap: NIL 2. Autogenous possible.
		All	1	130	—	3.2	12.7	6	1. Nominal gap: NIL 2. Autogenous possible.
2.0		All	1	105	1.6, 2.4	2.4	9.5	8	1. Nominal gap: NIL 2. Autogenous possible.
		All	1	160	1.6, 2.4	3.2	12.7	6	1. Nominal gap: NIL 2. Autogenous possible.
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.									

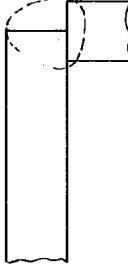
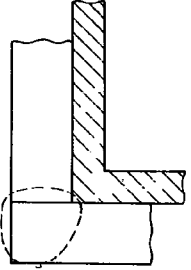
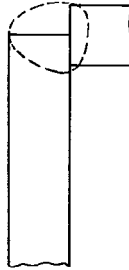
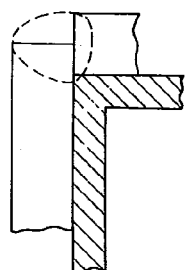
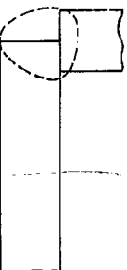
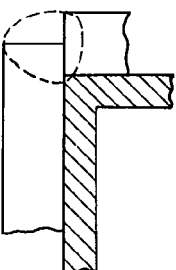
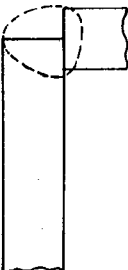
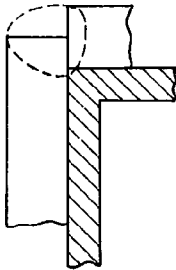
Table 11. Continued									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
2.5		All	1	120	2.4	3.2	12.7	8	1. Nominal gap: NIL 2. Autogenous possible.
		All	1	170	2.4	3.2	12.7	6	1. Nominal gap: NIL 2. Autogenous possible.
3.0		All	1	170	3.2	4.0	12.7	9	1. Nominal gap: NIL
		All	1	180	3.2	4.0	12.7	8	1. Nominal gap: NIL Maximum gap: 1.0 mm
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.									

Table 11. Concluded									
Thickness mm	Joint detail	Position	Number of runs	Current A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
5.0		All	1	260	4.8	4.8	12.7	9	1. Nominal gap: NIL
		All	1	275	4.8	5.6	15.9	9	1. Nominal gap: NIL Maximum gap: 1.0 mm
6.5		All	1	280	4.8	5.6	15.9	9	1. Nominal gap: NIL
		All	1	295	4.8	6.4	15.9	9	1. Nominal gap: NIL Maximum gap: 1.0 mm
* Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. † For welding in the vertical and overhead positions the current may be reduced by 10 %.									

E.3 Fillet welds

Recommended joint details and welding conditions are given in tables 12 and 13.

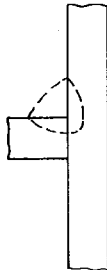
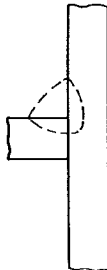
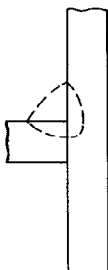
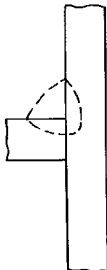
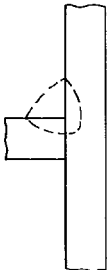
Table 12. Recommended joint details and typical welding conditions for tee joints with fillet welds										
Thickness mm	Joint detail	Position	Number of runs	Current† A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min.	Notes	
1.5		All	1	90	2.4	2.4	6.4	5	1. Nominal gap: NIL	
2.0		All	1	110	2.4	2.4	9.5	6	1. Nominal gap: NIL	
2.5		All	1	140	2.4	3.2	9.5	6	1. Nominal gap: NIL Maximum gap: 1.0 mm	
3.0		All	1	180	3.2	4.0	9.5	6	1. Nominal gap: NIL Maximum gap: 1.0 mm	
5.0		All	1	280	4.8	5.6	9.5	8	1. Nominal gap: NIL Maximum gap: 1.0 mm	
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. †For welding in the vertical and overhead positions the current may be reduced by 10 %.										

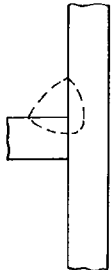
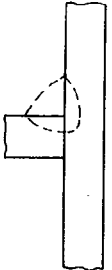
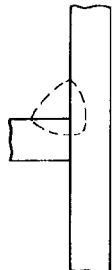
Table 12. Concluded									
Thickness mm	Joint detail	Position	Number of runs	Current† A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
6.5		All	1	320	4.8	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm
8.0		All	1	345	4.8	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm
9.5		All	1	380	4.8, 6.4	6.4	12.7	9	1. Nominal gap: NIL Maximum gap: 1.5 mm
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. †For welding in the vertical and overhead positions the current may be reduced by 10 %.									

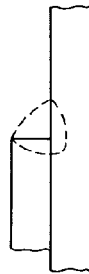
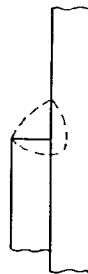
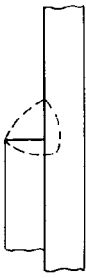
Table 13. Recommended joint details and typical welding conditions for lap joints with fillet welds									
Thickness mm	Joint detail	Position	Number of runs	Current† A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
1.5		All	1	80	2.4	2.4	9.5	5	1. Square edge. Nominal gap: NIL
2.0		All	1	130	2.4	3.2	9.5	6	1. Square edge. Nominal gap: NIL
2.5		All	1	140	3.2	3.2	9.5	6	1. Square edge. Nominal gap: NIL
3.0		All	1	200	3.2	4.0	9.5	6	1. Square edge. Nominal gap: NIL
5.0		All	1	270	4.0	5.6	12.7	8	1. Square edge. Nominal gap: NIL
* Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. † For welding in the vertical and overhead positions the current may be reduced by 10 %.									

Table 13. Concluded									
Thickness mm	Joint detail	Position	Number of runs	Current† A	Filler diameter mm	Electrode diameter mm	Nozzle diameter mm	Argon* flow L/min	Notes
6.5		All	1	320	4.8	6.4	12.7	9	1. Square edge, Nominal gap: NIL
8.0		All	1	345	4.8	6.4	12.7	9	1. Square edge Nominal gap: NIL Maximum gap: 1.5 mm
9.5		All	1	380	4.8, 6.4	6.4	12.7	9	1. Square edge: NIL gap Nominal gap: NIL Maximum gap: 1.5 mm
* Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding. † For welding in the vertical and overhead positions the current may be reduced by 10 %.									

E.4 Welds in pipe and hollow sections

Recommended joint details for butt joints and branch connections in structural hollow sections are given in table 14 and figures 4 to 7. As a general guide, the conditions given in tables 9 and 12 for welding sheet and plate which are accessible from one side only, may be used. Where control of the shape of the penetration bead is important, a J-end preparation is preferred as this presents a uniform root face and land thickness which is easily penetrated and fused. The root run is normally welded at a lower current and with a smaller diameter filler rod than the filling and capping runs. However, for butt joints where

the pipe is fixed with its axis horizontal, the welder may have to adjust the current or torch traverse speed as welding proceeds from the overhead through vertical to the flat position. Typically, the current required for welding in the overhead and vertical positions is about 10 % lower than that required for the flat position. The use of a foot-operated remote current control device for operation by the welder is beneficial for this type of work.

Design details for full penetration butt joints and branch connections for aluminium piping systems for the transmission of fluids under pressure are given in BS 5222 : Part 2.

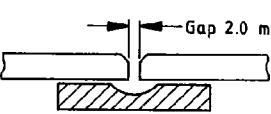
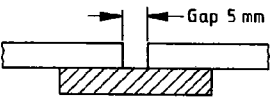
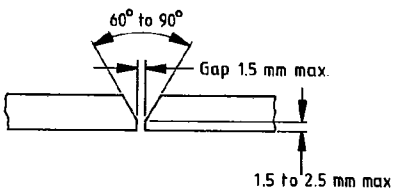
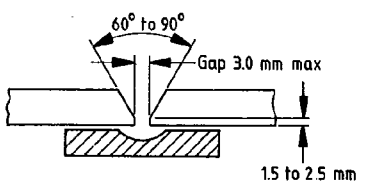
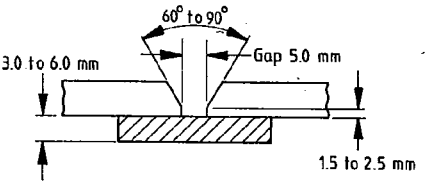
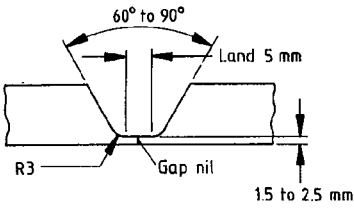
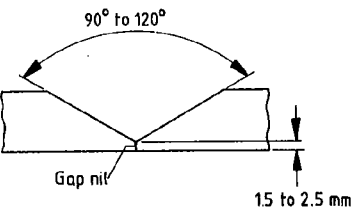
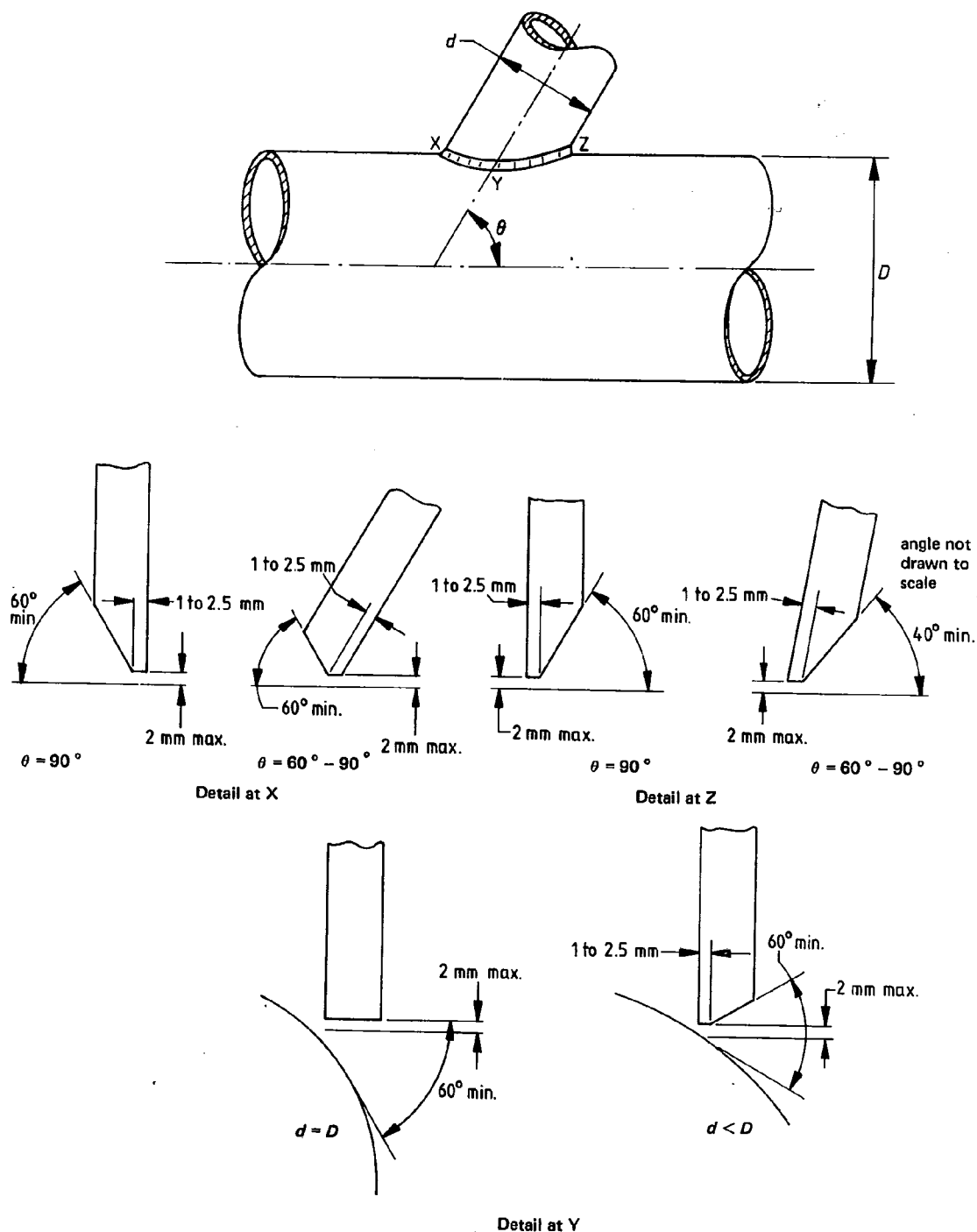
Table 14. Butt welds in hollow sections			
Wall thickness mm	Joint detail	Position	Notes
1.5 to 5.0		Pipe fixed: All	Small sighting vee optional. Unbacked. One run.
		Pipe fixed: All	Small sighting vee optional. Stainless steel temporary backing ring. One run.
		Pipe fixed: All	Permanent aluminium backing ring. 1st run to fuse backing ring. 2nd capping run as required.
5.0 to 9.5		Pipe fixed: All	1st run to fuse root faces. Subsequent filling and capping runs as required.
		Pipe fixed: All	Stainless steel temporary backing ring. 1st run to fuse root faces. Subsequent filling and capping runs as required.
		Pipe fixed: All	Permanent aluminium backing ring. 1st run to penetrate and fuse backing ring. 2nd and subsequent runs to fill and cap as required.

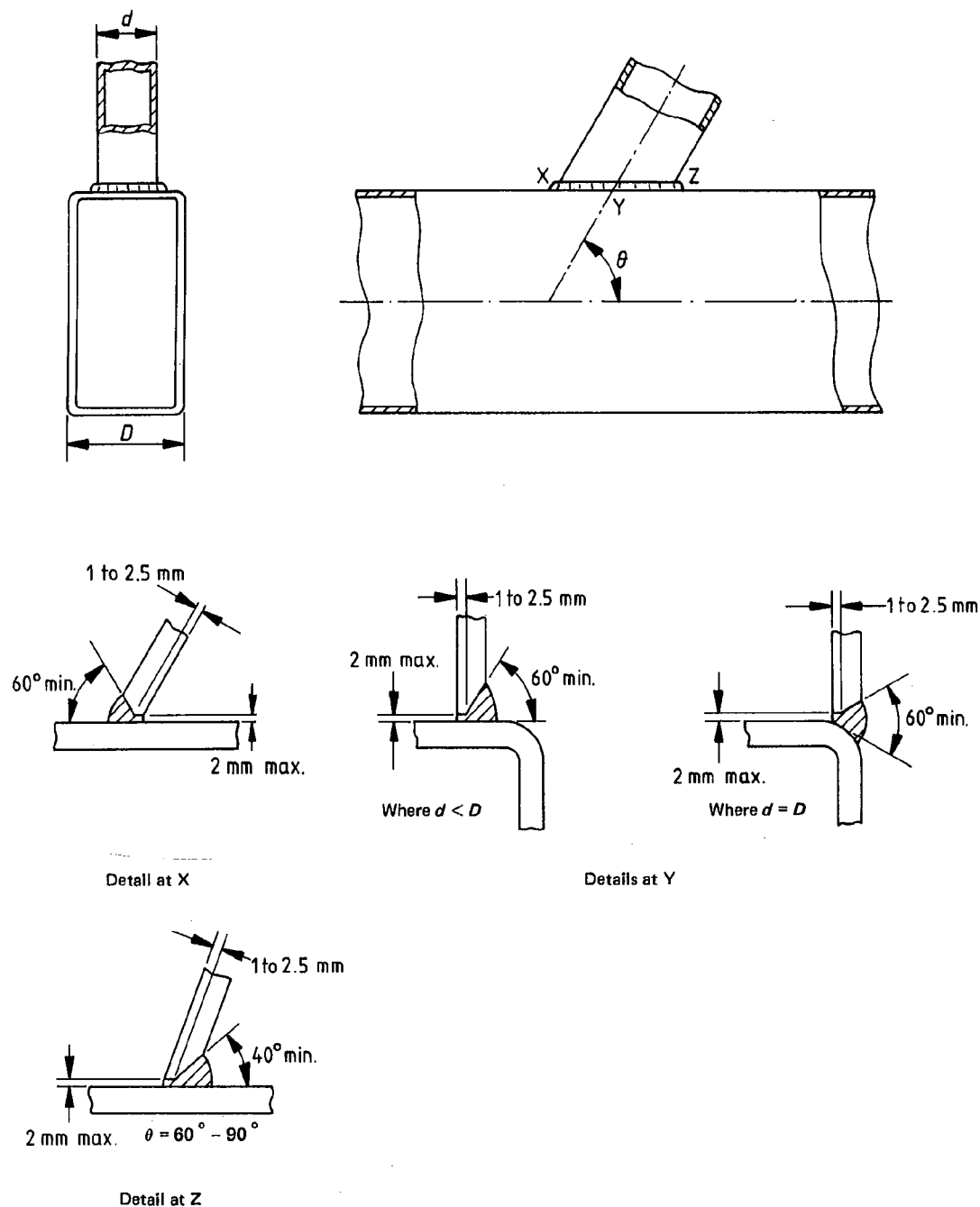
Table 14. *Concluded.*

Wall thickness mm	Joint detail	Position	Notes
6,5 to 12,5		Pipe fixed: All	Preferred preparation for pressure piping system. Unbacked, but may use temporary backing ring. 1st run to fuse root faces. 2nd and subsequent runs to fill and cap as required.
		Pipe fixed: All	Alternative to J preparation above when special tools are not available. Ideal for site work, 1st run to fuse root faces. 2nd and subsequent runs to fill and cap as required. May use temporary backing.



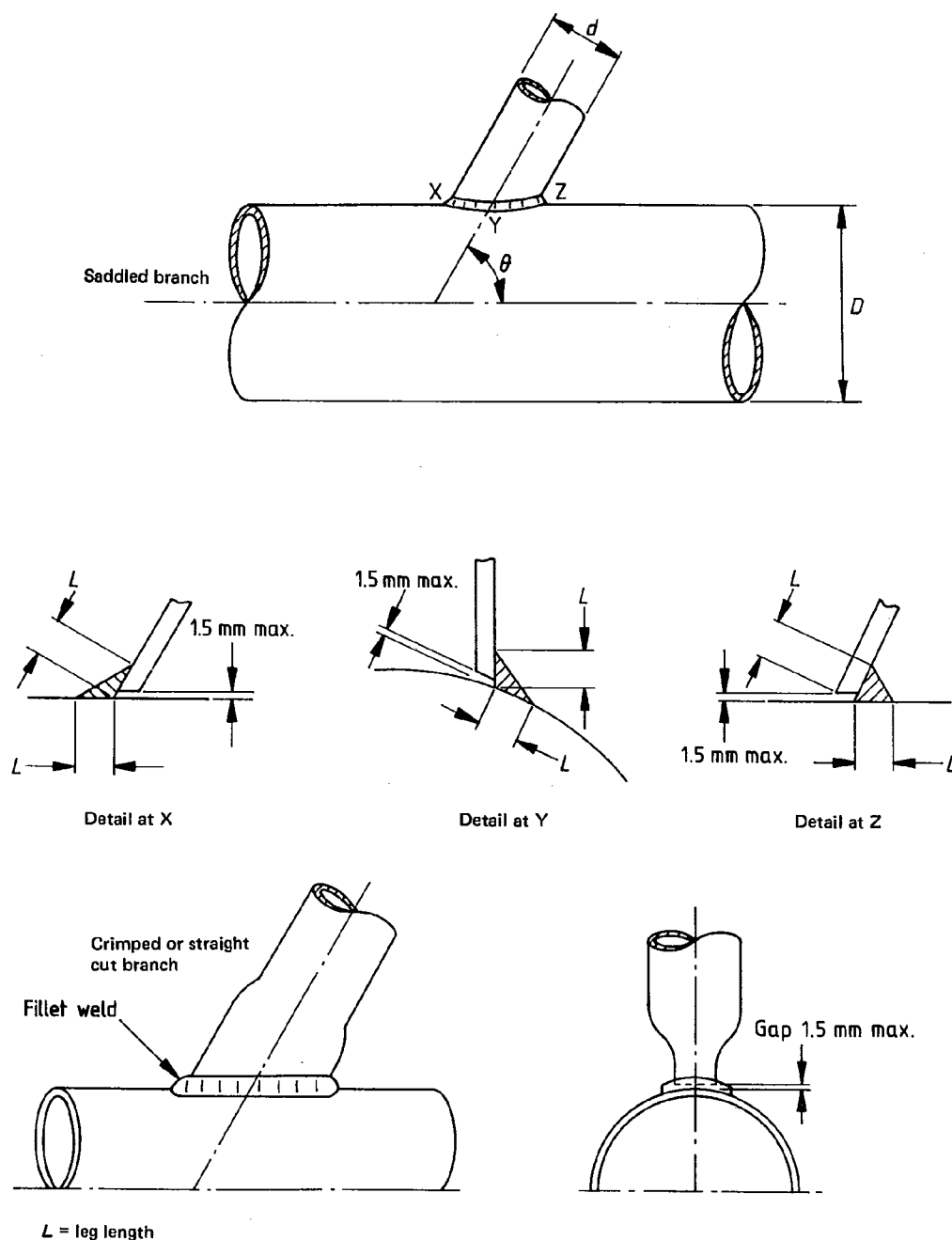
NOTE. The angle of intersection θ of the axes of the circular hollow sections should not be less than 60° unless adequate efficiency of the junction has been demonstrated. For angles θ less than 60° , special consideration should be given to joint detail to permit access for welding.

Figure 4. Typical details for branch connections for circular structural hollow sections: butt welds



NOTE. The angle of intersection θ should not be less than 60° unless adequate efficiency of the junction can be demonstrated. For angles less than 60° , special consideration should be given to joint detail to permit access for welding.

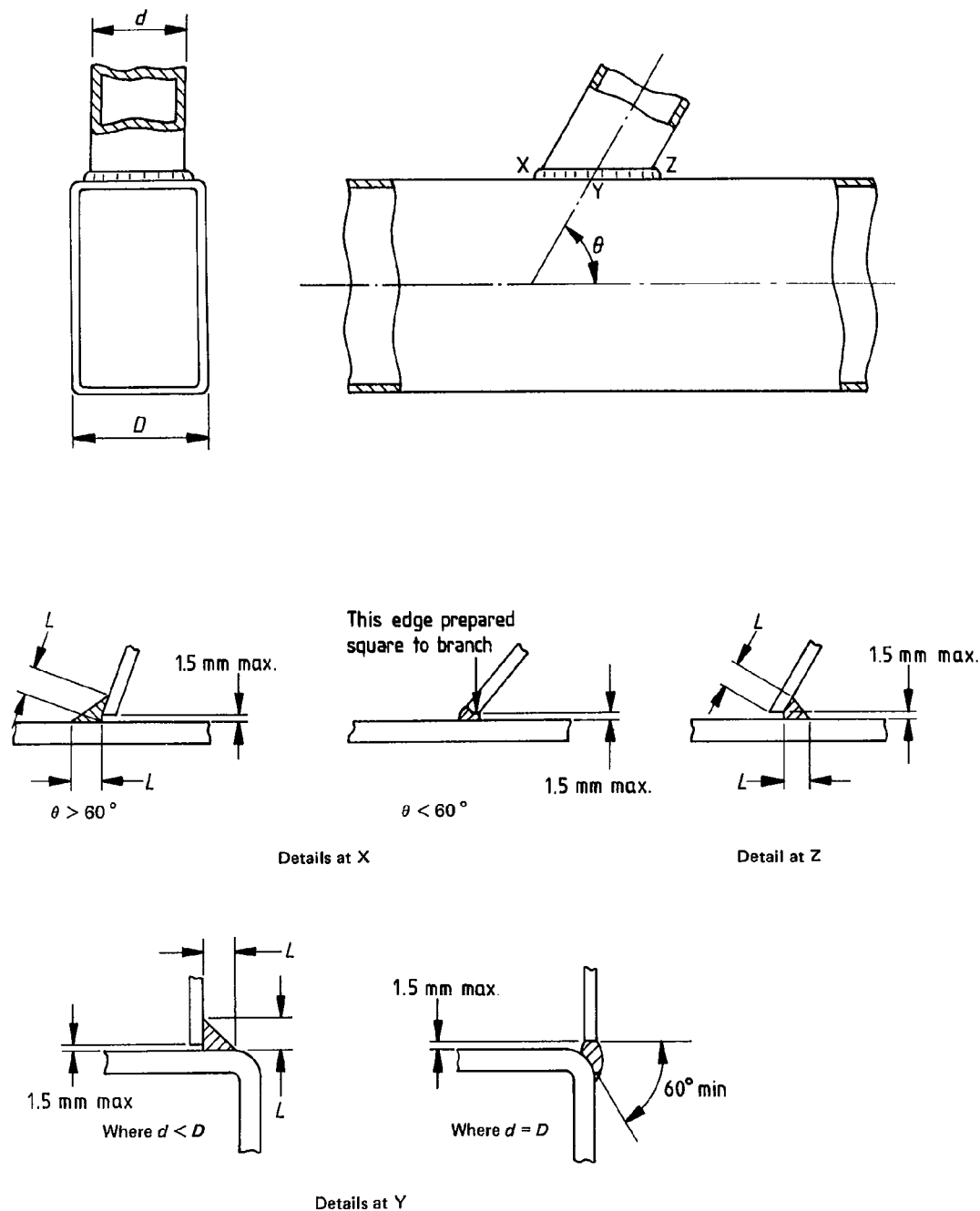
Figure 5. Typical details for branch connections for rectangular structural hollow sections: butt welds



NOTE 1. Leg lengths should be such that the stresses in fillet welds are in accordance with the permissible stresses given in the relevant specification and that the welds will transmit the loads in the member.

NOTE 2. The angle of intersection θ of the axes of the circular hollow sections should not be less than 40° , unless adequate efficiency of the junction has been demonstrated.

Figure 6. Typical details for branch connections for circular structural hollow sections: fillet welds



NOTE 1. Leg lengths should be such that the stresses in fillet welds are in accordance with the permissible stresses given in the relevant specification and that the welds will transmit the loads in the member.

NOTE 2. The angle of intersection θ of the axes of the rectangular hollow sections should not be less than 40° , unless adequate efficiency of the junction has been demonstrated.

Figure 7. Typical details for branch connections for rectangular structural hollow sections: fillet welds

E.5 Joint preparation

The heat-treatable alloys, e.g. 6XXX and 7XXX series aluminium alloys, may suffer edge cracking during plasma cutting and the plasma cut edge should be machined to remove the heat-affected material, i.e. to a depth of 6 mm. Planing machines, milling cutters or routers are preferred as they are capable of giving smooth surfaces, particularly for long edges, and they should be used for producing J and U preparations on thick material.

For short lengths of joint, e.g. the ends of sections etc., surface grinders fitted with suitable discs or hand tools such as coarse files and Surform may be used for V or square preparations.

For circular section pipe end preparations, machine cutting tools which rotate on the axis of the pipe are preferred. These eliminate misalignment due to ovality and produce a truly circular pipe end with a uniform root face thickness, which greatly assists the control of weld penetration.

When suitable chemical degreasing plant is not available, degreasing by swabbing with a non-flammable and low toxicity solvent such as trichloroethane is preferred, although the highly flammable solvents such as petroleum ether, acetone or white spirit are satisfactory. Attention is drawn to the effect of ultraviolet radiation on chlorinated hydrocarbons, which can produce toxic vapours.

Appendix F Guidance on back gouging

Where butt joints in thicker material, say greater than 5 mm, are welded from both sides, it is frequently desirable to

gouge out the root prior to welding from the reverse side to ensure complete penetration and, in joints welded with a gap, the removal of oxide accumulations on the underbead.

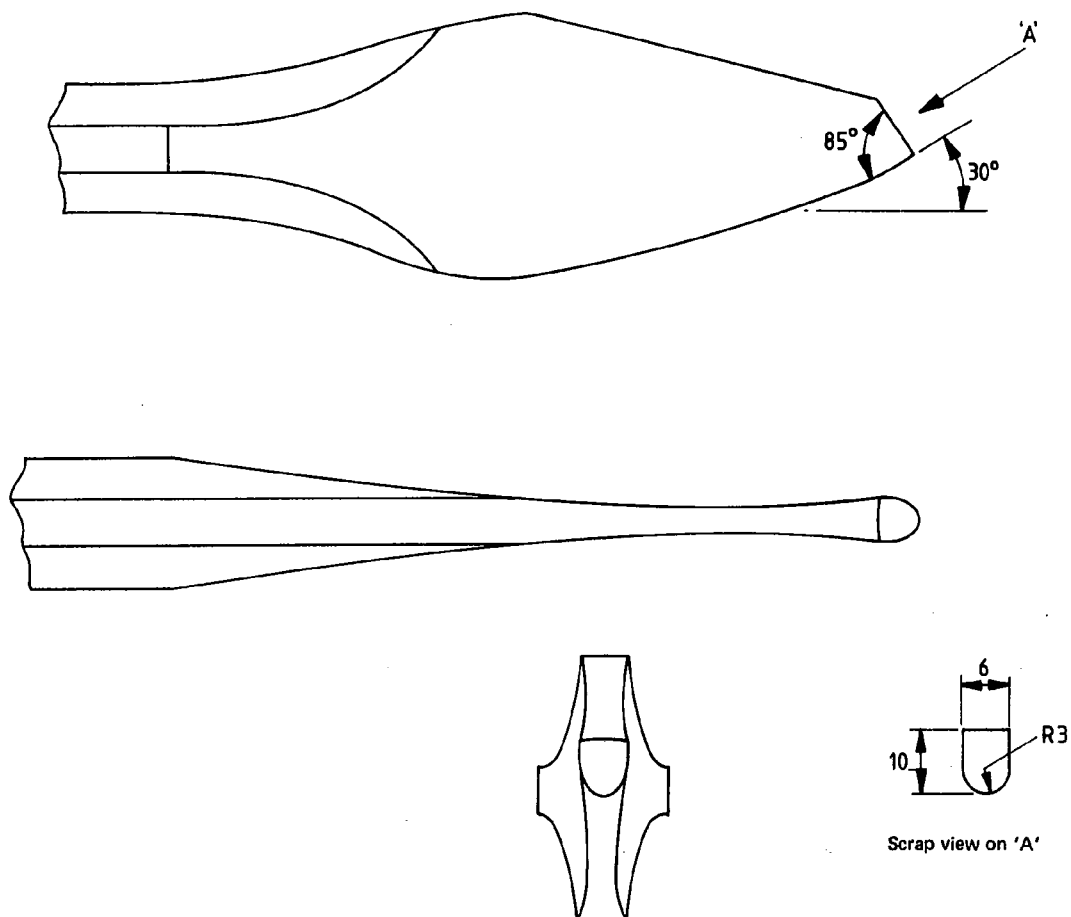
To prevent lack of penetration and fusion, back-gouged grooves should not deviate from the centre-line of the weld and should not be excessively deep or narrow or undercut. Attention to these points will assist the achievement of effective side wall fusion in subsequent welding. The profiles of grooves can best be controlled by using chisels of the type shown in figures 8 to 10.

The narrow chisel (figure 8) should be used to back gouge grooves not deeper than 5.0 mm, as in the case of butt welds in plates up to 9.5 mm thick. For material thicker than 9.5 mm, this chisel should be used to cut down into the root of the first run, followed by the wide chisel (figure 9) to open out the groove. The profiles of both chisels permit a high speed of cutting with little danger of digging in too deeply.

The 'C' chisel (figure 10) should be used finally to skim the sides of the gouged groove in order to remove any steps or undercuts which may have been produced when using the previous tools. This chisel does not cut as quickly as the others and is therefore best suited for dressing the groove, and for reducing the bulk of tack welds which are subsequently to be welded over.

Diamond or V-shaped chisels should be avoided, as they tend to dig in and form a chattered or 'saw-toothed' root to the groove which may not be fully penetrated by welding.

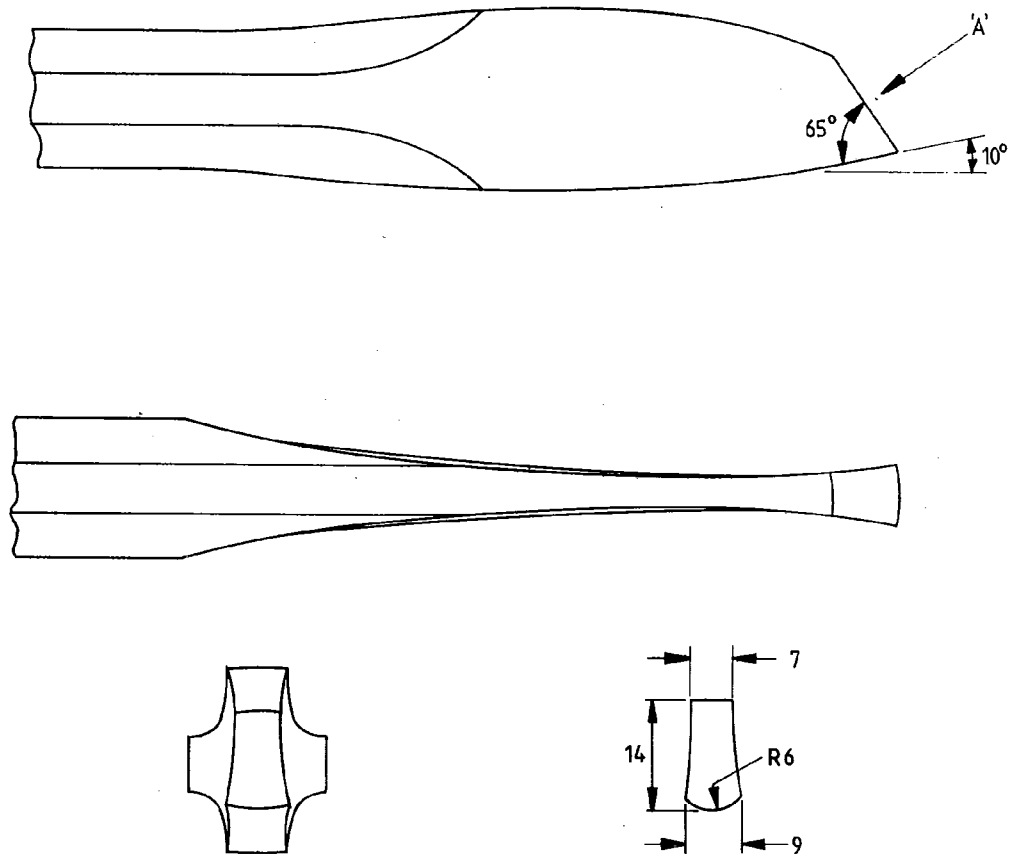
As an alternative to chisels, high speed rotary cutters may be used and are preferable on thin materials.



Dimensions are in millimetres

End tool forged and ground from standard chisel blanks.

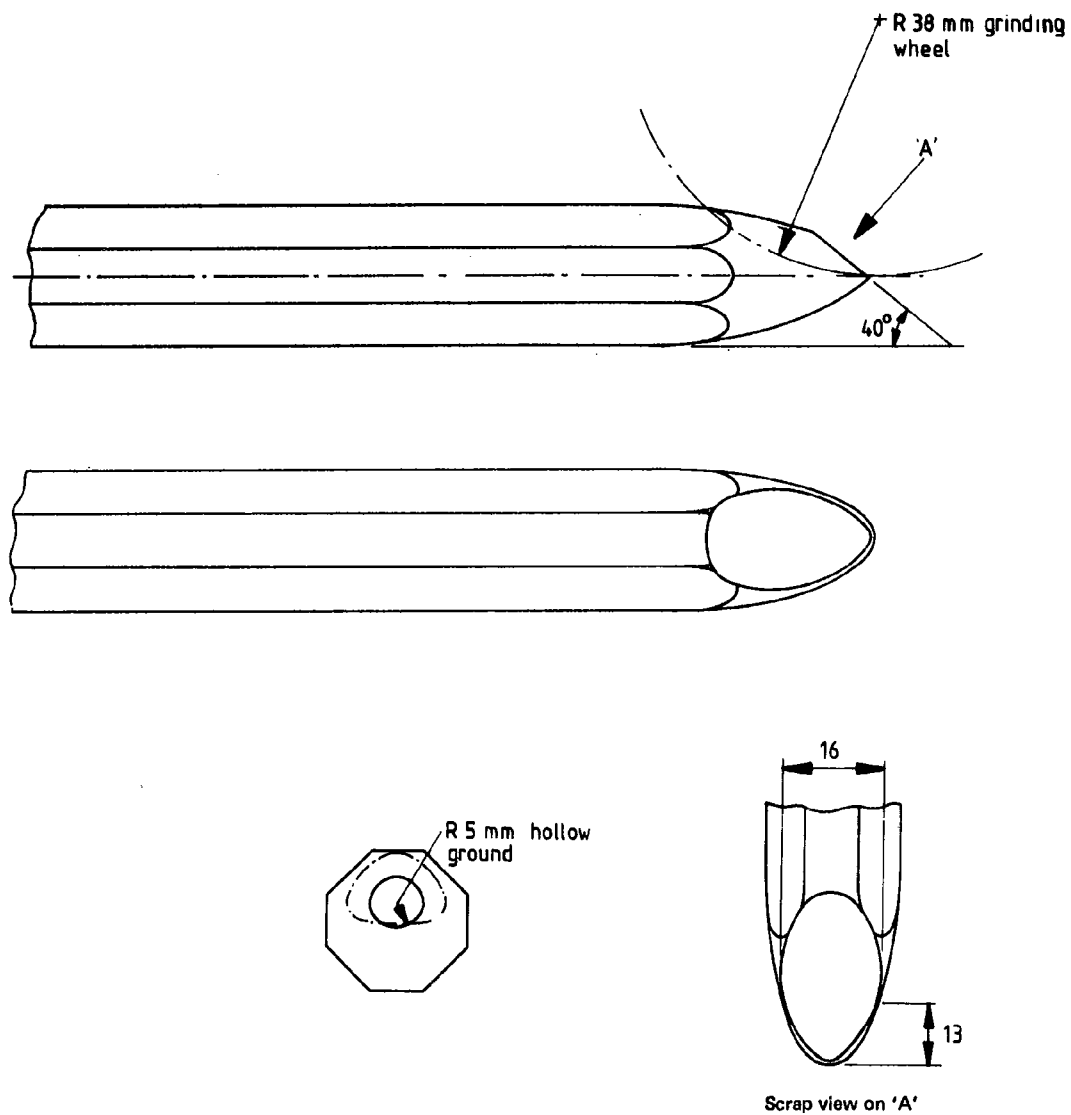
Figure 8. Narrow chisel



Dimensions are in millimetres

End tool forged and ground from standard chisel blanks.

Figure 9. Wide chisel



Dimensions are in millimetres

End tool forged and ground from standard chisel blanks.

Figure 10. 'C' chisel

Publications referred to

This standard makes reference to the following British Standards:

- BS 499 Welding terms and symbols
Part 1. Welding, brazing and thermal cutting glossary
Part 2. Specification for symbols for welding
- BS 1470 Wrought aluminium and aluminium alloys for general engineering purposes — plate, sheet and strip
- BS 1471 Wrought aluminium and aluminium alloys for general engineering purposes — drawn tube
- BS 1472 Wrought aluminium and aluminium alloys for general engineering purposes — forging stock and forgings
- BS 1473 Wrought aluminium and aluminium alloys for general engineering purposes — rivet, bolt and screw stock
- BS 1474 Wrought aluminium and aluminium alloys for general engineering purposes — bars, extruded round tubes and sections
- BS 1475 Wrought aluminium and aluminium alloys for general engineering purposes — wire
- BS 1490 Aluminium and aluminium alloy ingots and castings
- BS 2898 Wrought aluminium and aluminium alloys for electrical purposes. Bars, extruded round tube and sections
- BS 2901 Filler rods and wires for gas-shielded arc welding
Part 4. Aluminium and aluminium alloys and magnesium alloys
- BS 2970 Magnesium alloy ingots and castings
- BS 3370 Wrought magnesium alloys for general engineering purposes. Plate, sheet and strip
- BS 3372 Wrought magnesium alloys for general engineering purposes. Forgings and cast forging stock
- BS 3373 Wrought magnesium alloys for general engineering purposes. Bars, sections and tubes including extruded forging stock
- BS 3451 Methods of testing fusion welds in aluminium and aluminium alloys
- BS 4300 Specification (supplementary series) for wrought aluminium and aluminium alloys for general engineering purposes:
4300/6 3105 Sheet and strip
4300/7 5005 Sheet and strip
4300/8 5454 Plate, sheet and strip
4300/10 5454 Drawn tube
4300/11 5454 Forging stock and forgings
4300/12 5454 Bar, extruded round tube and sections
4300/14 7020 Plate, sheet and strip
4300/15 7020 Bar, extruded round tube and sections
- BS 4365 Industrial argon
- BS 4870 Approval testing of welding procedures
Part 2. TIG or MIG welding of aluminium and its alloys
- BS 4871 Approval testing of welders working to approved welding procedures
Part 2. TIG or MIG welding of aluminium and its alloys
- BS 4872 Approval testing of welders when welding procedure approval is not required
Part 2. TIG or MIG welding of aluminium and its alloys
- BS 5222 Aluminium piping systems
Part 2. Design
- BS 5387 Specification for vertical cylindrical welded storage tanks for low-temperature service: double-wall tanks for temperatures down to -196°C
- BS 5000 Unfired fusion welded pressure vessels
- CP 118 The structural use of aluminium

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