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British Standard

MIG welding

Part 1. Specification for MIG welding of aluminium and aluminium alloys

Soudage à l'arc en atmosphère inerte avec électrode fusible
Partie 1. Soudage à l'arc en atmosphère inerte avec électrode fusible de l'aluminium et des alliages d'aluminium — Spécifications

MIG-Schweißen
Teil 1. MIG-Schweißen von Aluminium und Aluminiumlegierungen

British Standards Institution

Foreword

This British Standard forms one of the process standards in the comprehensive series prepared under the direction of the Welding Standards Committee. It is a revision of BS 3571 : Part 1 : 1962, which is withdrawn. The standard was first published in 1962 as 'General recommendations for manual inert-gas metal-arc welding, Part 1. Aluminium and aluminium alloys'. This revision takes account of development and more widespread use of the process and sets out requirements for manual and mechanized inert-gas metal-arc welding of wrought and cast aluminium and aluminium alloys.

Although only argon is specified as the shielding gas it is not intended that this standard should inhibit development in the use of helium and helium/argon mixtures. Similarly although welding conditions recommended are for spray transfer welding it is not intended to exclude pulsed arc welding.

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'.

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.

Contents

Specification

1 Scope

This Part of BS 3571 specifies requirements for the manual and mechanized MIG welding of the wrought and cast forms of aluminium and aluminium alloys listed in table 1 (clause 5).

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 publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 3571, 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 (see **8.1.3**);

(h) whether full penetration welds are required when access to the reverse side is not possible (see **8.1.6**);

(i) surface treatment;

(j) quality control arrangements.

3.2 Requirements to be agreed

The following items, which are specified in the clauses referred to, to be agreed between the contracting parties, 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) specification of the parent metal (see clause **5**);

(b) specification of the filler wire (see **6.1**);

(c) specification of the inert gas mixture (see **6.2**(b));

(d) welding current to be used (see **6.3**);

(e) the use of other than run-on/run-off plates to obtain full section thickness (see **8.1.2**);

(f) 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**(a));

(g) the use of a special method to achieve full penetration without the use of backing when access to the reverse side is not possible (see **8.1.6**(b));

(h) the material for permanently backing butt welds when this is not part of the structure (see **8.1.6**(2));

(i) the material for permanently backing welds in hollow sections when this is not of similar composition to the parent metal (see **8.3.3**);

(j) the dressing of material prepared by grinding (see **9.2**(b));

(k) the use of chemical treatment to remove surface oxide (see **9.6**(b));

(l) the tolerances on fit-up of parts joined by filled welds (see **12.2**);

(m) the action to be taken on any areas of stray arcing (see **17.2**);

(n) the peening of welds (see clause **22**);

(o) 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 (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) welders' 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) jigging or tacking;

(j) permanent or temporary backing with details of groove;

(k) welding position (including direction for vertical position);

(l) filler metal specification and size;

(m) pre-heating and interpass temperature, if required, including method and control;

(n) welding speed (mechanized welding);

(o) shielding gas composition and flow rate;

(p) nozzle diameter;

(q) power source characteristic, e.g. constant voltage or constant current;

(r) current range or wire feed speed;

(s) arc voltage range;

(t) electrode extension (mechanized welding);

(u) for pulsed welding, the pulse and background times, currents and voltages;

(v) welding head position and gun angle (mechanized welding);

(w) approximate number and arrangement of runs and weld dimensions (sketch);

(x) welding sequence;

(y) details of oscillation or weaving, if any;

(z) back gouging;

(aa) post-weld heat treatment if required, including method and control;

(bb) 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;

(b) when agreed between the contracting parties, materials made from the use of alloys of similar types to those listed in table 1 (see **3.2**(a)).

Table 1. Parent metals

British Standard	Material designation
Wrought products	
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
Cast products (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.

6 Welding consumables

6.1 Filler wires

The types of filler wire given in table 2 and complying with the requirements of BS 2901 : Part 4 shall be used.

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

Table 2. Filler wires

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

6.2 Shielding gas

The shielding gas shall be as specified in either (a) or (b).

(a) Argon or an argon/helium mixture. Only argon complying with the requirements of BS 4365 shall be used. The rate of flow of shielding gas shall be sufficient to ensure stable arc conditions and clean welds, i.e. generally in the range 15 L/min to 35 L/min for argon.

NOTE. Mechanized welding may require higher flow rates.

(b) When agreed between the contracting parties, other inert gas mixtures provided the weld quality is not adversely affected (see **3.2**(c)).

6.3 Welding current

The welding current shall be appropriate to the diameter of the filler wire used.

NOTE. Guidance on the selection of welding current is given in appendix C and should be followed unless otherwise agreed between the contracting parties (see **3.2**(d)).

6.4 Storage and handling

Filler wires shall be stored and handled with care and in accordance with the supplier's recommendations. They shall be stored in their original packaging, in a dry store room. Filler wires that show signs of deterioration, e.g. dirtiness or corrosion, shall not be used.

7 Equipment

7.1 Plant

Welding plant, instruments, cables and accessories shall comply with the appropriate British Standard. The contractor shall be responsible for ensuring that their capacity 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. The welding return lead shall be of the same or greater current rating than the welding lead.

7.3 Instrumentation

Adequate means for measuring the gas flow, voltage, current or wire feed speed shall be available either as part of the welding equipment or by the use of portable instruments. When means for measuring true arc voltage, i.e. between workpiece and gun, are not available, allowance shall be made for voltage drop between the workpiece and power source resulting from, for example, length of welding leads or contacts.

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

8 Welding details

8.1 Butt welds

8.1.1 Joint details and approximate spray transfer conditions for manual welding differing from those given in **E.2** shall be permitted subject to welding procedure approval.

NOTE 1. For mechanized welding, similar edge preparations may be used but higher currents, gas flows and welding speeds may be utilized.

NOTE 2. 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 throat 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**(e)).

8.1.3 The weld face shall be as specified in either (a) or (b).

(a) In the as-welded condition. The weld face shall be proud of the surface of parent metal and the weld profile shall be as specified in the application standard where this exists. If no application standard exists the weld profile shall be agreed between the contracting parties (see **3.2**(f)).

(d) Dressed where a flush surface is required.

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 this can be shown by procedure testing to be unnecessary.

NOTE. Guidance on back gouging is given in appendix F.

8.1.5 When temporary backing is specified this may be of freshly cleaned carbon steel, but for high quantity production stainless steel is preferred. If the temporary backing is ungrooved, the back of the first run shall be gouged out to sound metal before welding is commenced on the second side. Dimensions for temporary backing material shall be as given in figure 1.

8.1.6 Where access to the reverse side is not possible and full penetration welds are required, either:

(a) permanent backing shall be used, or

(b) by agreement between the contracting parties (see **3.2**(g)) either;

(i) an approved special method of welding that gives full penetration without the use of backing shall be adopted, or

(ii) a TIG welding procedure shall be applied to the root of the weld to provide controlled penetration (see BS 3019 : Part 1).

Where 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**(h)).

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:

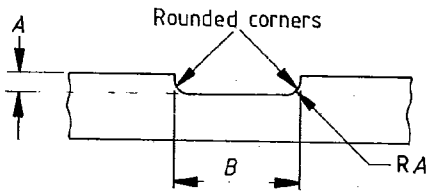
(a) less than 3 mm, or

(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 2(a) and (b)). For greater differences in thicknesses, the thicker shall be tapered on one or both sides (see figure 2(c) to (f)), to a slope of no greater than 1 in 5, so that the weld is made between members of equal thickness.

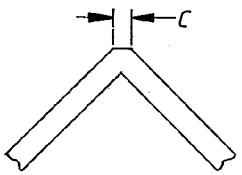
NOTE. The choice of method may be dictated by the application requirements.

Butt joints



Parent metal thickness	Dimension *A*	Dimension *B*
mm	mm	mm
2.0 to 5.0	1.5	5.0
greater than 5.0	3.0	6.5

Corner joints



Parent metal thickness	Dimension *C*
mm	mm
2.0 to 3.0	Nil
3.0 to 6.5	3.0
6.5 upwards	5.0 max.

Figure 1. Temporary backing

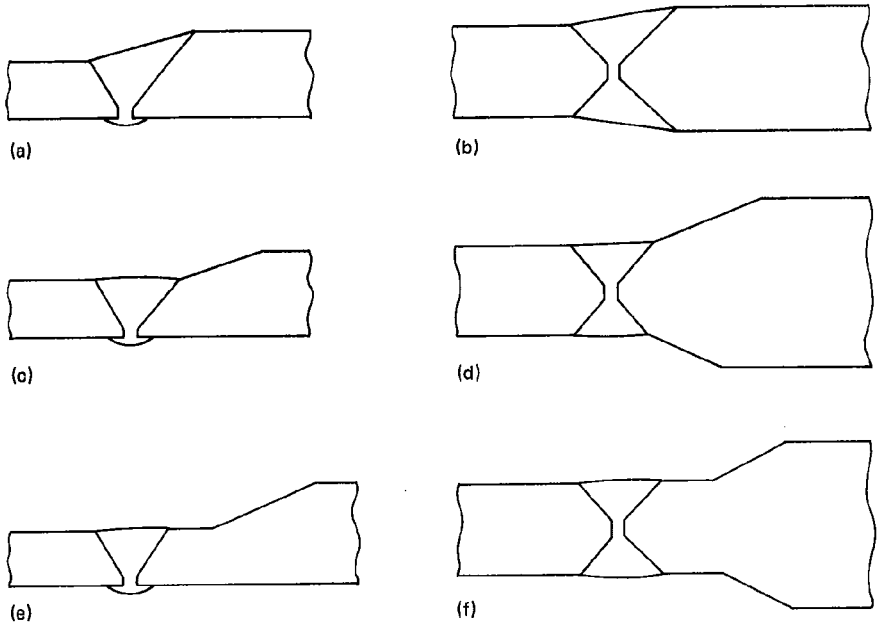


Figure 2. Butt joints of unequal cross section

8.2 Fillet welds

8.2.1 Joint details and approximate spray transfer conditions for manual welding differing from those given in **E.3** shall be permitted subject to welding procedure approval.

NOTE. For mechanized welding similar edge preparations may be used and higher currents, gas flow and welding speeds may be utilized.

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. (See tables 9 and 10.)

8.2.3 For fillet welds having their fusion faces at right angles, 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**(i)).

9 Preparation of joint faces

9.1 Preparation or cutting of the material shall be done by shearing, sawing, grinding, machining or gouging.

9.2 Material prepared by grinding shall be either:

(a) dressed with a file to smooth the surface and to remove any debris which may have become embedded in the metal surface, or

(b) by agreement between the contracting parties, left undressed (see **3.2**(j)).

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 6 to 11.

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**(k)).

(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.

The interval between cleaning and welding shall be as short as possible and preferably not exceed 6 h. 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 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 9 and 10, shall be subject to agreement between the contracting parties (see **3.2**(l)).

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 times of low ambient temperature 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 remove condensation in the inert gas passages of the welding equipment 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. The 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.

In the welding or repair of castings it shall be determined whether preheating is necessary to prevent stress cracking and if so, 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) parts of the welding head or gun (e.g. loose contact tube) and the workpiece;

(b) the welding earth return lead connection;

(c) any part at earth potential.

Items (a), (b) and (c) 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. Such areas shall be removed by mechanical means.

Item (a) shall be avoided by ensuring that the contact tube is firmly located, and (b) and (c) 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**(m)).

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. 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 this purpose, the 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**(n)).

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 ground to a smooth finish. 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**(o)).

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 by either 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, table 3 gives cross-references between the new and the old BS designations for aluminium alloys together with the nearest equivalent ISO designations.

Table 3. 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
5356	–	Al Mg 5
5056A	N6	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 metals

Recommendations as to the choice of filler metals are given in table 4. In order to simplify the table, parent metal and filler metal grouping have been used, details of these groupings being given in table 4a. Certain alloys which cannot be grouped have been specifically listed. The recommendations given in table 4b 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**).

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 4a. Groupings used in table 4b

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 4b. Selection of filler wires

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 Mg_2Si 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.

Appendix C. Recommendations on welding current

Typical welding currents which are recommended for different filler wire diameters are given in table 5.

Table 5. Typical welding current for MIG welding

Filler wire diameter	Welding current
mm	A
0.8	75 to 150
1.0	95 to 210
1.2	110 to 240
1.6	160 to 350
2.4	240 to 410

Appendix D. Guidance on the use and maintenance of welding equipment

Direct current electrode positive is normally used for the MIG welding of aluminium and its alloys and a consumable electrode of suitable quality and alloy is employed.

A wire drive system, capable of feeding the electrode wire consistently at a rate to match the wire burn off, without damaging the surface or distorting the shape, is fundamental to the system.

The welding gun, whether air or water cooled, has to be designed to cope adequately with the current range used and house a copper contact tube of suitable dimensions to correspond to electrode diameter. For manual welding, normally a 6.5 kg wire spool is mounted on a carriage unit and fed by means of drive rolls (preferably grooved, *not* knurled) which push the wire through a flexible conduit to the welding gun. Additionally, there are push-pull systems (where a supplementary drive motor and feed roll are housed in the gun) which allow distances of up to 10 m between gun and wire feed unit, thus increasing versatility. Spool-on-gun systems, employing air cooled guns which incorporate wire drive and a 0.5 kg electrode wire spool, can be used for even greater mobility but current ratings do not exceed 250 A and 0.5 kg spools are relatively expensive.

Constant potential power sources with rapid response to changes in arc voltage are generally chosen for MIG welding to maintain a constant arc length, but in some circumstances (such as the root run in a deep vee preparation) constant current sets can offer greater arc stability for aluminium.

The electrical equipment requires little maintenance, but the wire feed rolls, wire guides, conduit and contact tube and tips may need adjusting and cleaning from time to time; also 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 should 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 should be scrupulously clean and these, as well as the tubes, should be free from moisture or grease.

Shielding gas nozzles have to be in good condition and there should be no excessive internal spatter deposit.

A positive pressure of shielding gas 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 argon 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 reproducible uniform travel speed.

Appendix E. Recommended joint details, welding conditions and joint preparation

E.1 General

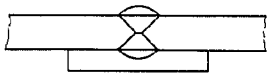
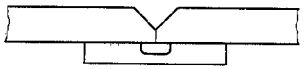
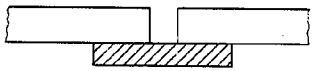
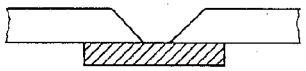
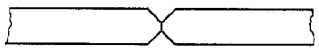
Guidance on welding design and weld dimensions is given in CP 118 and application standards such as BS 5500, BS 5222 and BS 5387.

E.2 Butt joints

Recommended joint details and welding conditions are given in tables 6 to 8.

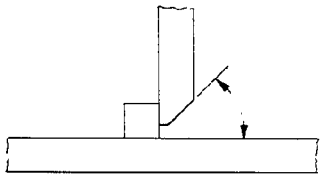
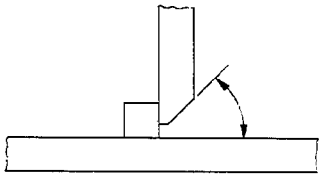
*1 bar = 10^5 N/m^2 = 10^5 Pa.

Table 6. Recommended joint details and typical welding conditions for butt joints

Thickness	Joint detail	Position	Number of runs	Current	Arc voltage	Filler diameter	Nozzle diameter	Argon flow*	Notes
mm 2.0 to 5.0	 Temporary backing	All	1 to 2	A 140 to 200	V 19 to 23	mm 0.8 1.0 1.2	mm 12.7	L/min 17	Nominal gap: 1.5 mm Maximum gap: 2.5 mm Back gouge before second pass if required
5.0 to 12.7	 Temporary backing	All	3 to 4	200 to 260	21 to 24	1.2 1.6 2.4	12.7 to 15.9	19	Nominal gap: 1.5 mm Maximum gap: 2.5 mm Root face: 1.5 mm Included angle: 60° Back gouge on reverse side
2.0 to 5.0	 Permanent backing	All	1 to 2	170 to 220	20 to 23	1.0 1.2 1.6	15.9	19	Nominal gap: 5.0 mm Maximum gap: 6.5 mm
5.0 to 12.5	 Permanent backing	All	2 to 4	195 to 275	20 to 24	1.2 1.6 2.4	15.9	19	Nominal gap: 5.0 mm Maximum gap: 6.5 mm Rootface: NIL Included angle: 40° to 60°
12.5 to 25.0	 Unbacked	All	4 to 12	215 to 275	20 to 25	1.6 2.4	15.9	19	Nominal gap: NIL Maximum gap: 1.0 mm Root face: 1.5 mm Included angle: 70° to 90° Back gouge on reverse side

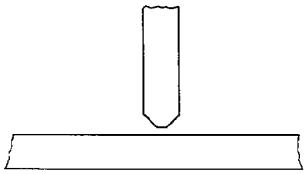
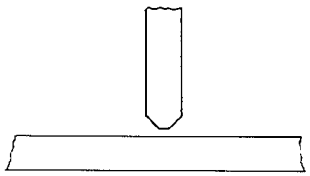
*Argon flow may be increased as required to provide adequate shielding when welding pipes and/or site welding.

Table 7. Recommended joint details and typical welding conditions for butt joints: permanent backing (joints with access one side only)

Thickness	Joint detail	Position	Number of runs	Current	Arc voltage	Filler diameter	Nozzle diameter	Argon flow*	Notes
mm 6.5 to 9.5		All	3 to 4	A 250 to 295	V 22 to 30	mm 1.2 to 1.6	mm 12.7	L/min 17	Flat or horizontal/vertical position preferred Nominal gap: 1.5 mm Maximum gap: 3.0 mm Roof face: 1.0 mm Included angle: 60°
9.5 to 12.5		All	6	250 to 295	22 to 25	1.6	12.7	17	Flat or horizontal/vertical position preferred Nominal gap: 1.5 mm Maximum gap: 3.0 mm Root face: 1.0 mm Included angle: 60°

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

Table 8. Recommended joint details and typical welding conditions for 'T' butt joints: unbacked

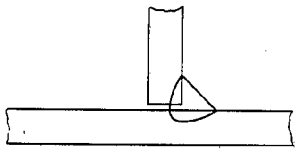
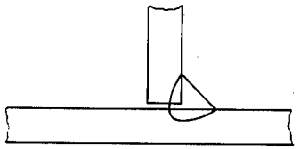
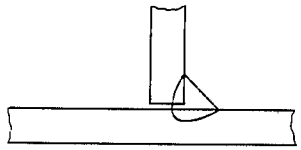
Thickness	Joint detail	Position	Number of runs	Current	Arc voltage	Filler diameter	Nozzle diameter	Argon flow*	Notes
mm 6.5 to 12.5		All	1 to 4	A 230 to 290	V 20 to 23	mm 1.2 to 1.6	mm 12.7 to 15.9	L/min 19	Nominal gap: NIL Maximum gap: 1.0 mm Root face: 1.0 mm Included angle: 60°
12.5 to 25.0		All	4 to 12	250 to 320	22 to 26	1.6 to 2.4	15.9	19	Nominal gap: NIL Maximum gap: 1.0 mm Root face: 1.0 mm Included angle: 60°

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

E.3 Fillet joints

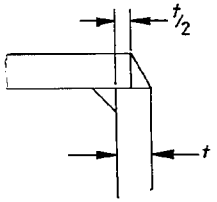
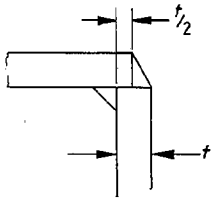
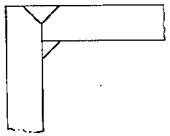
Recommended joint details and welding conditions are given in tables 9 and 10.

Table 9. Recommended joint details and typical welding conditions for fillet joints

Thickness	Joint detail	Position	Number of runs	Current	Arc voltage	Filler diameter	Nozzle diameter	Argon flow*	Notes
mm 2.0 to 5.0		All	1	A 90 to 200	V 18 to 21	mm 0.8 1.0 1.2	mm 12.7	L/min 17	Nominal gap: NIL Maximum gap: 1.0 mm
5.0 to 12.5		All	1 to 3	200 to 270	22 to 24	1.2 1.6	15.9	19	Nominal gap: NIL Maximum gap: 1.5 mm
12.5 to 25.0		All	3 to 10	245 to 330	22 to 28	1.6 2.4	15.9	19	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.

Table 10. Recommended joint details and typical welding conditions for corner joints

Thickness	Joint detail	Position	Number of runs	Current	Arc voltage	Filler diameter	Nozzle diameter	Argon flow*	Notes
mm 5.0 to 12.5		All	2 to 6	A 200 to 275	V 22 to 25	mm 1.2 to 1.6	mm 12.7	L/min 17	Nominal gap: NIL Maximum gap: 1.0 mm Overlap: $t/2$
12.5 to 25.0		All	6 to 20	210 to 275	24 to 25	1.6 to 2.4	15.9	19	Nominal gap: NIL Maximum gap: 1.0 mm Overlap: $t/2$
6.5 to 12.5		All	2 to 6	200 to 270	22 to 24	1.6	12.7 to 15.9	19	Nominal gap: NIL Maximum gap: 1.0 mm Included angle: 70° to 90°

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

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 11 and figures 3 to 6. As a general guide, the conditions given in tables 6 to 10, for welding sheet and plate of equivalent thickness and which are accessible from one side only, may be used. Where control of weld penetration is required, permanent or temporary backing should be used. Where accessibility and gun manipulation may be difficult, e.g. with pipes of less than 100 mm diameter, the use of TIG welding is normally preferred.

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 11. Butt welded hollow sections

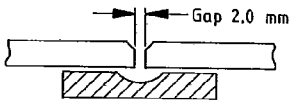
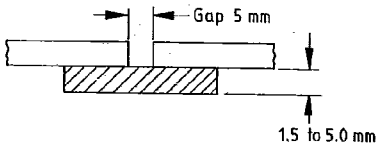
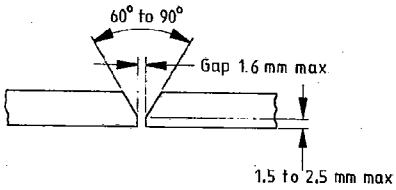
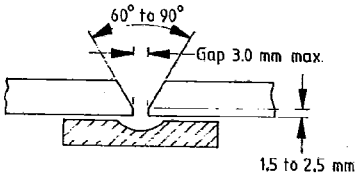
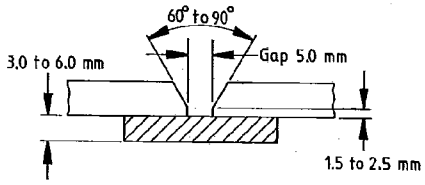
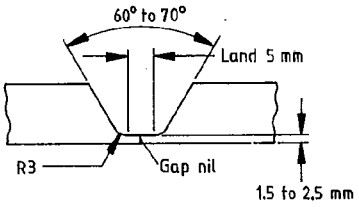
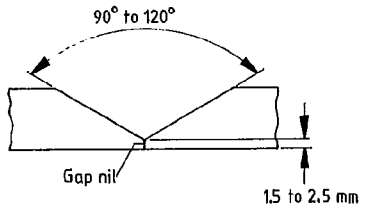
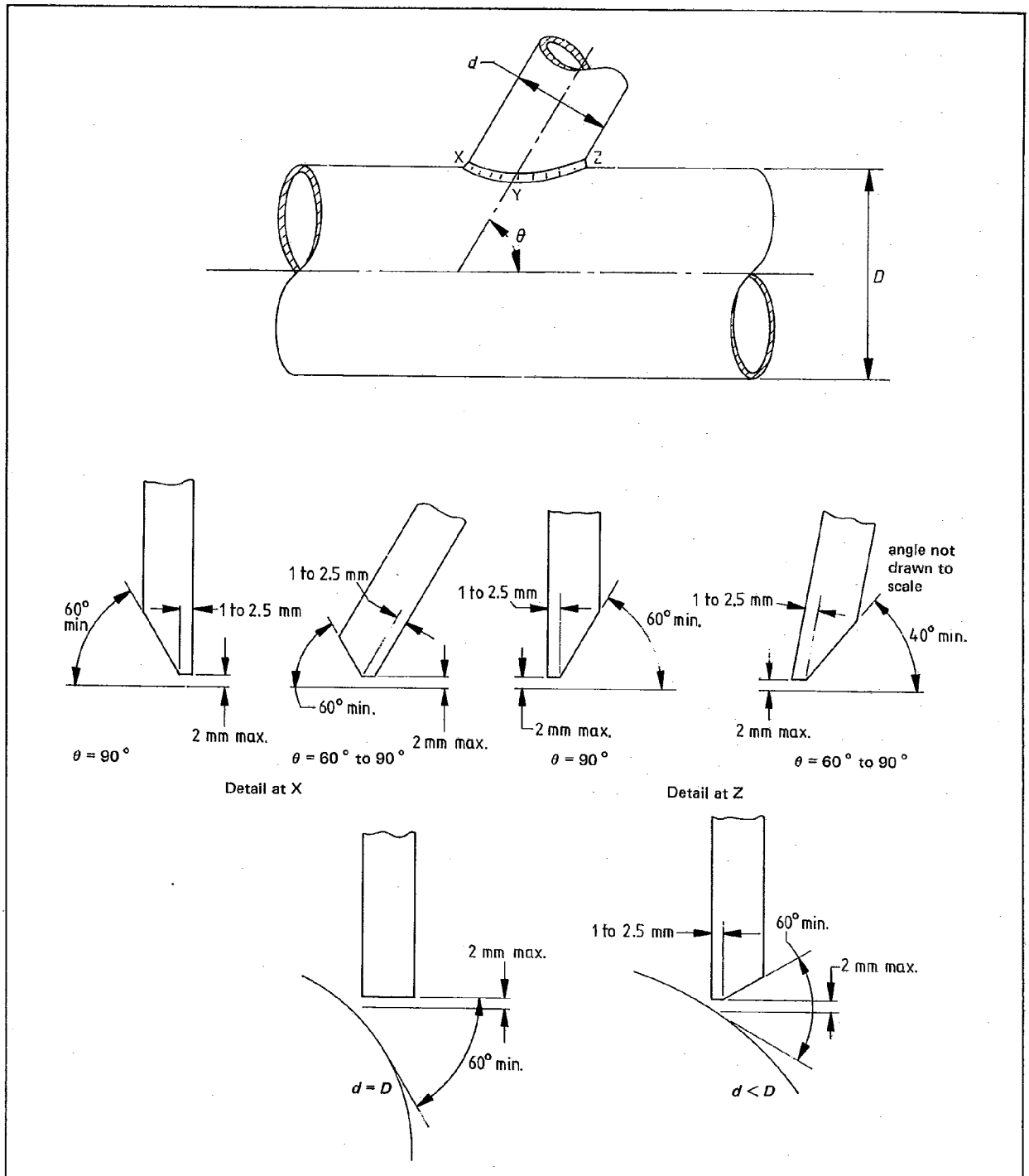
Wall thickness	Preparation	Position	Remarks
mm 2.0 to 5.0		Pipe fixed: All	Small sighting vee optional. Stainless steel temporary backing ring. One run.
		Pipe fixed: All	Permanent aluminium backing ring. 1st run to fuse backing ring. 2nd capping run as required.
5.0 to 9.5		Pipe fixed: All	Use TIG 1st run to fuse root faces. Subsequent MIG 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.

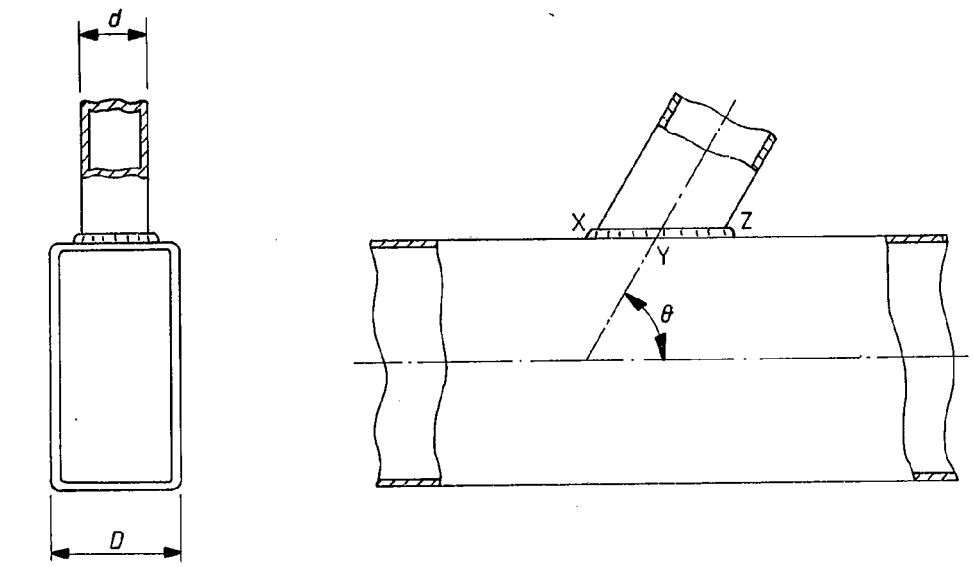
Table 11 *(concluded)*

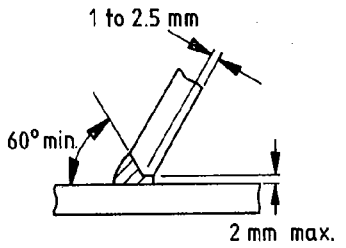
Wall thickness	Preparation	Position	Remarks
mm 6.0 to 19.0		Pipe fixed: All	Preferred preparation for pressure piping system. Use temporary backing ring or TIG 1st run to fuse root faces. 2nd and subsequent MIG runs to fill and cap as required.
		Pipe fixed: All	Alternative to J preparation above when special tools are not available. Ideal for site work. May use temporary backing or use TIG. 1st run to fuse root faces. 2nd and subsequent runs to fill and cap as required.



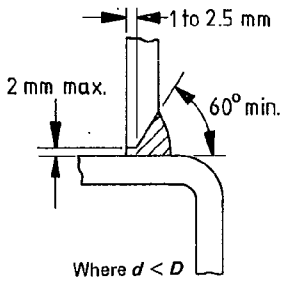
NOTE. The angle of intersection θ of the axes of the circular hollow sections should not be less than 60° unless adequate efficiency of the junction has been demonstrated. For angles θ = less than 60°, special consideration should be given to joint design to permit access for welding.

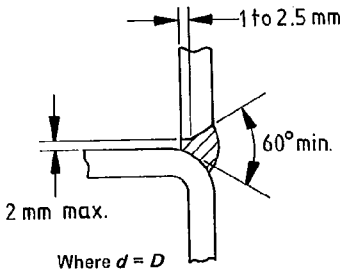
Figure 3. Typical details for branch connections for circular structural hollow sections: butt welds



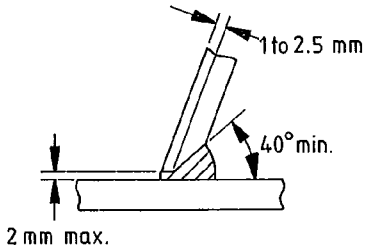


Detail at X





Detail at Y

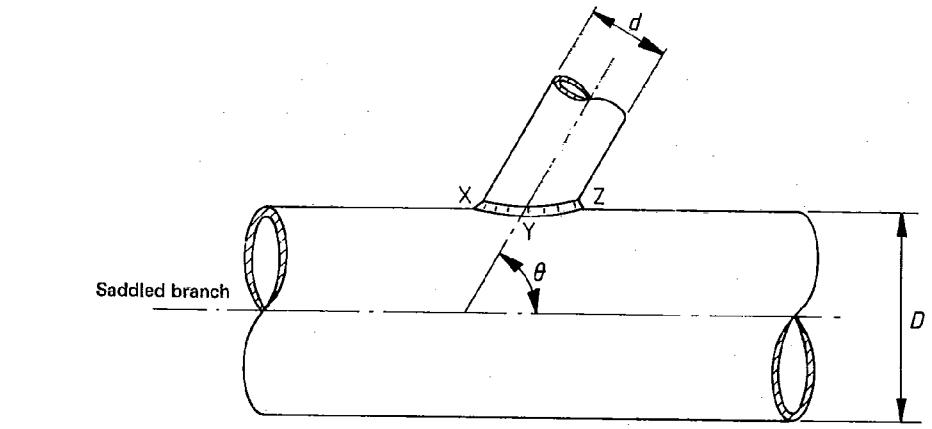


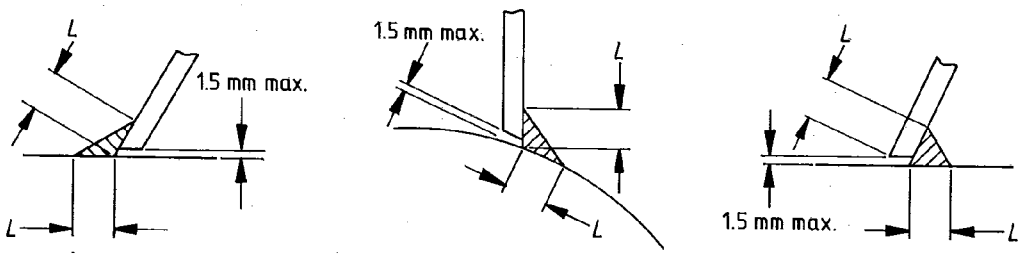
θ = 60 ° to 90 °

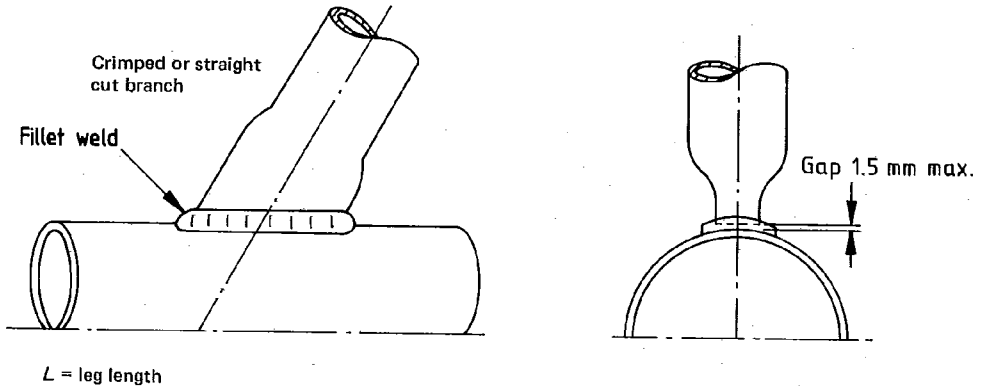
Detail at Z

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 design to permit access for welding.

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



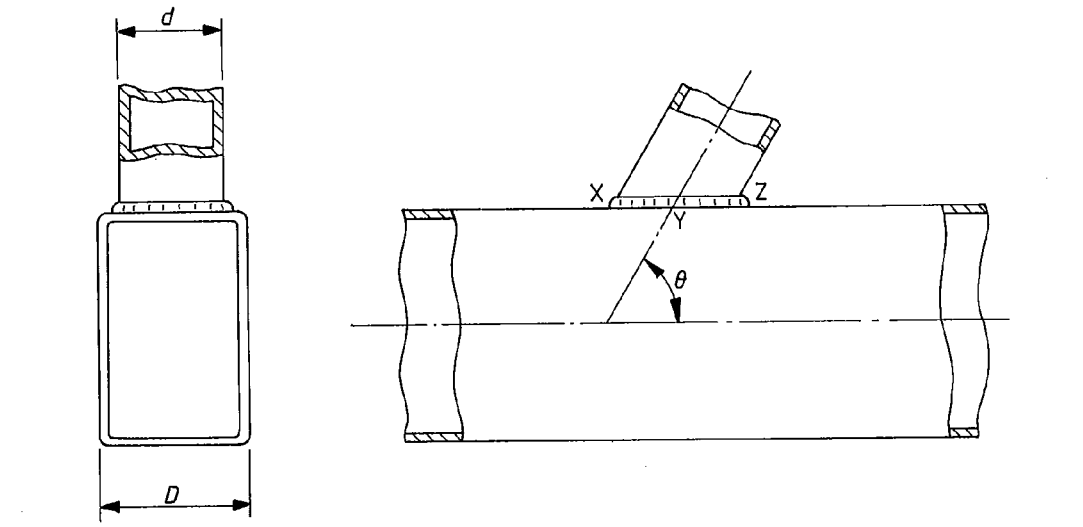


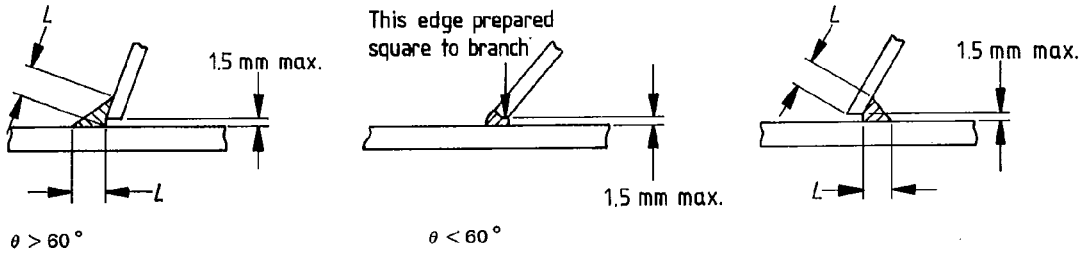


NOTE 1. Leg lengths should be such that the stresses in fillet welds are in accordance with the permissible stresses given in the relevant specification and that the welds will transmit the loads in the member.

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.

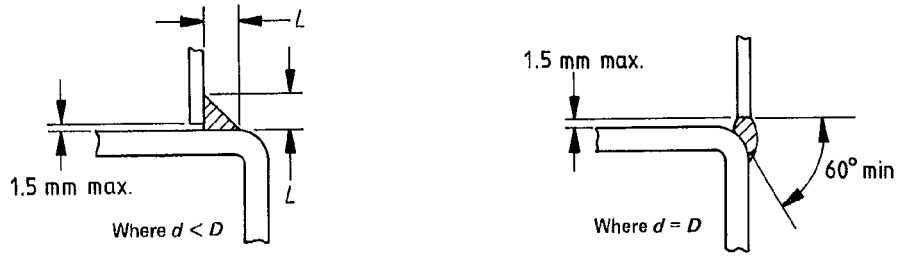
Figure 5. Typical details for branch connections for circular structural hollow sections: fillet welds





Details at X

Detail at Z



Details at Y

L = leg length

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 rectangular structural hollow sections: fillet welds

E.5 Joint preparation

Preformed edges, e.g. formed or extruded details, are acceptable. Plasma arc cutting equipment may also be used for thick material. However, the heat treatable alloys, e.g. 6XXX and 7XXX series alloys, may suffer edge cracking 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 vee 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 8 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.

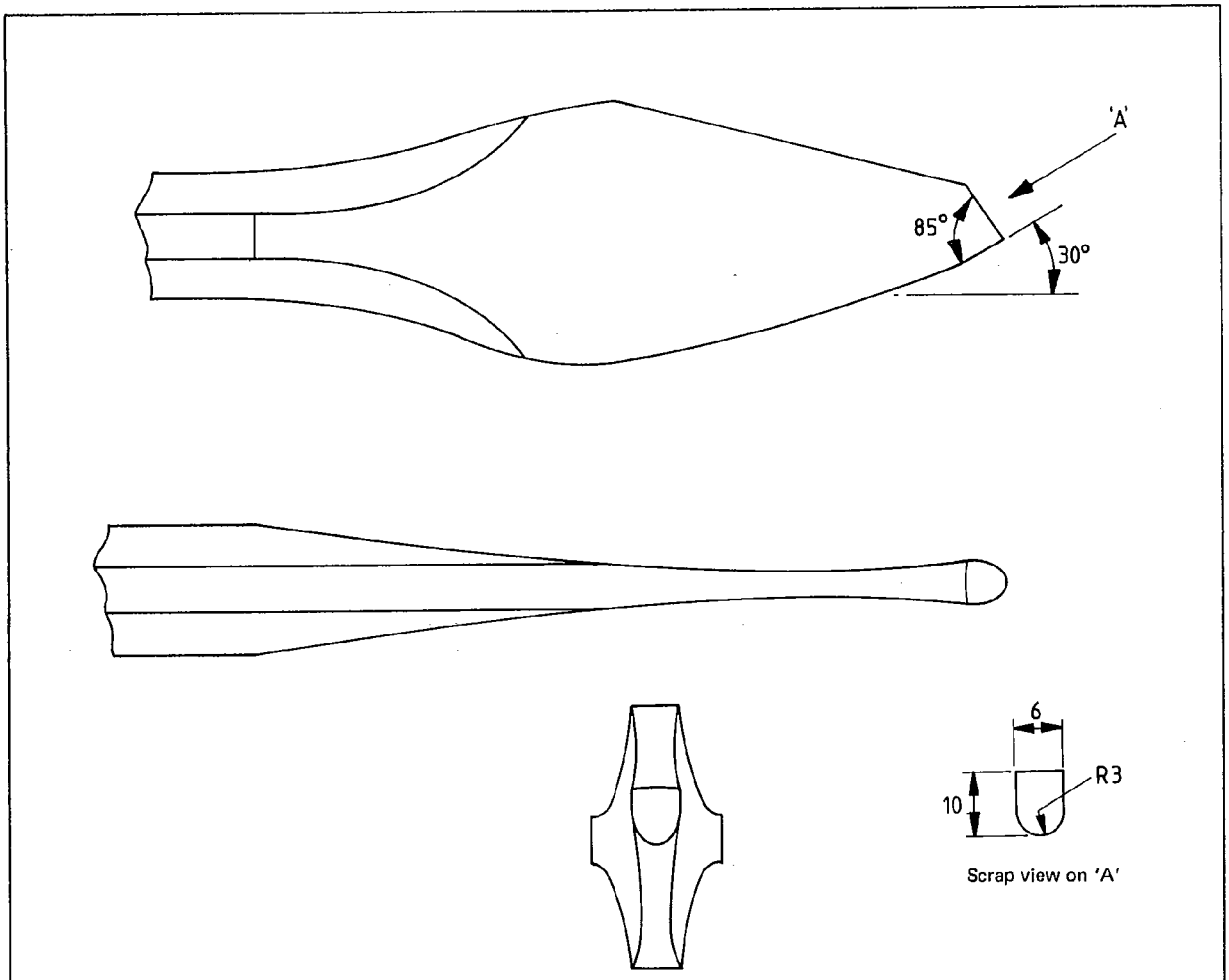
To prevent lack of penetration and fusion, back-gouged grooves should not deviate from the centre-line of the weld and should not be excessively deep or narrow or undercut. Attention to these points will assist the achievement of effective side wall fusion in subsequent welding. The profiles of grooves can best be controlled by using chisels of the type shown in figures 7 to 9.

The narrow chisel (figure 7) 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 8) 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 9) 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 vee-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.

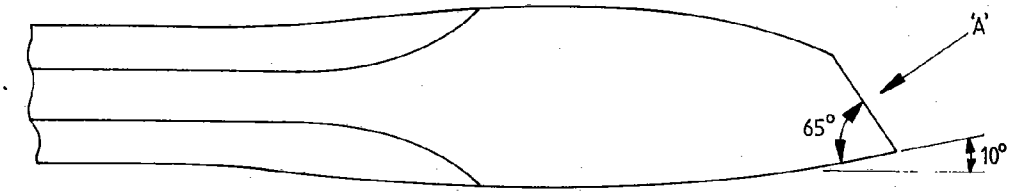
As an alternative to chisels, high speed rotary cutters may be used and are preferable on thin material.

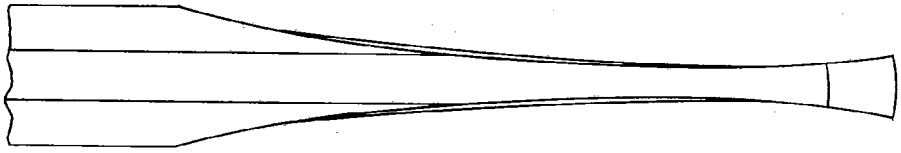


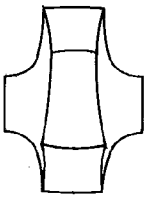
End tool forged and ground from standard chisel blanks

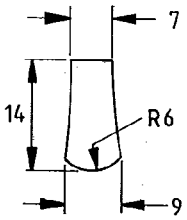
All linear dimensions are in millimetres.

Figure 7. Narrow chisel







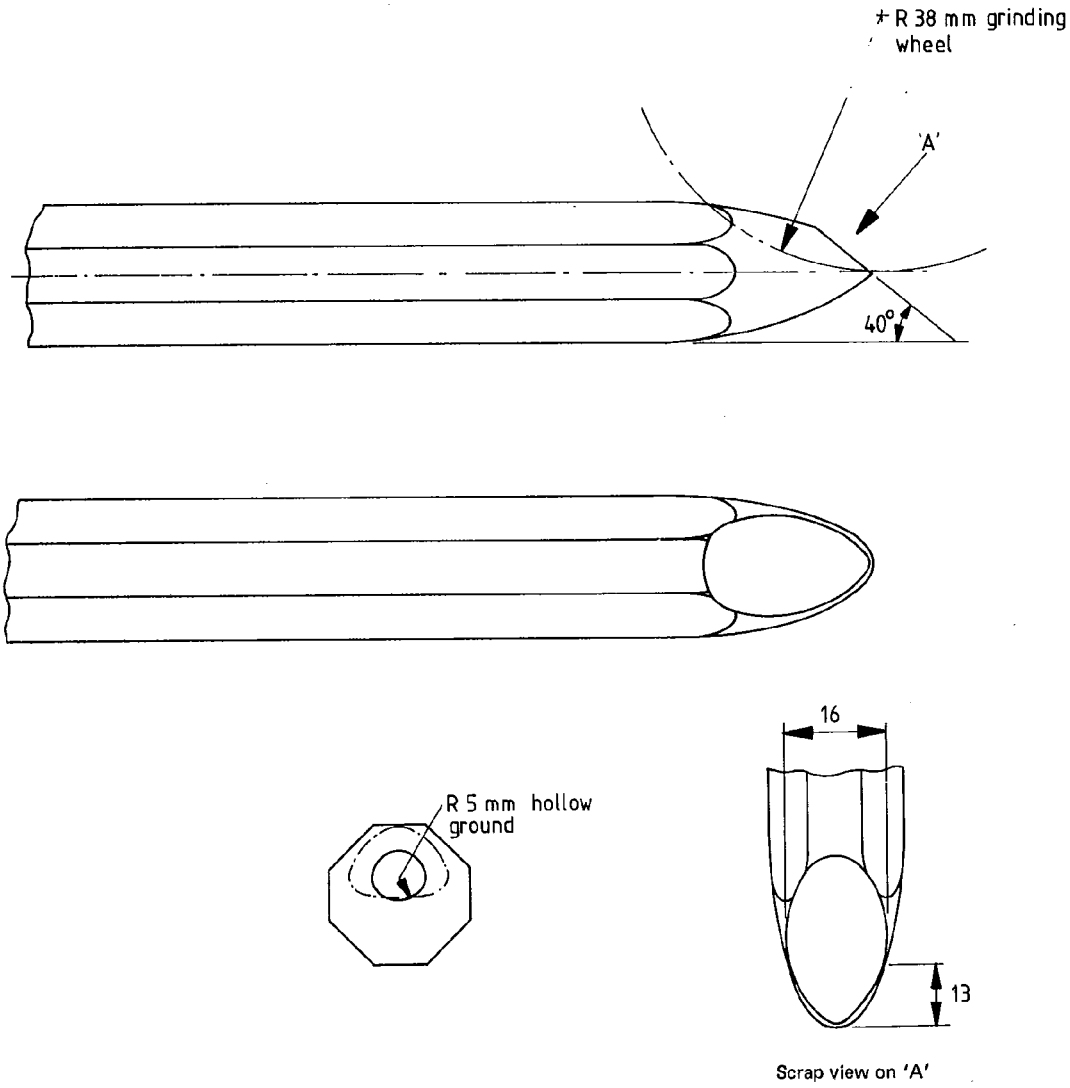


Scrap view on 'A'

End tool forged and ground from standard chisel blanks.

All linear dimensions are in millimetres.

Figure 8. Wide chisel



End tool ground from standard chisel blanks.

All linear dimensions are in millimetres.

Figure 9. 'C' chisel

Publications referred to

BS 499	Welding terms and symbols Part 1 Glossary for welding, brazing and thermal cutting 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 3019	TIG welding Part 1 Specification for TIG welding of aluminium, magnesium and their alloys
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 Part 6 3105 Sheet and strip Part 7 5005 Sheet and strip Part 8 5454 Plate sheet and strip Part 10 5454 Drawn tube Part 11 5454 Forging stock and forgings Part 12 5454 Bar, extruded round tube and sections Part 13 5454 Welding wire Part 14 7020 Plate sheet and strip Part 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 5500	Unfired fusion welded pressure vessels
CP 118	The structural use of aluminium

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