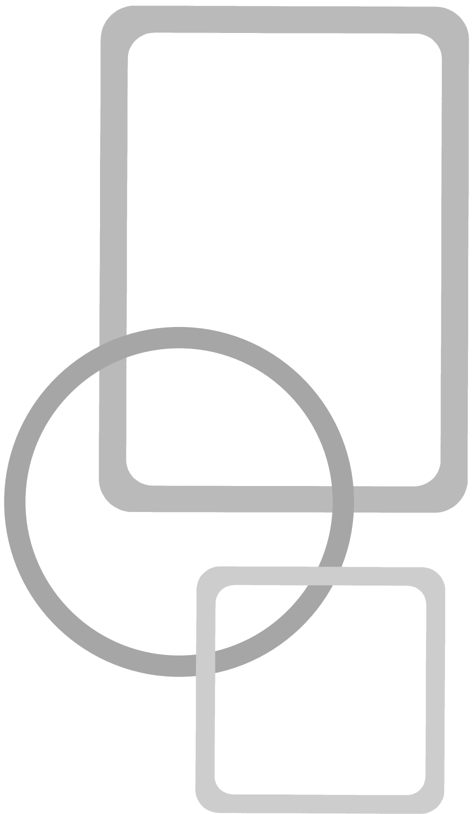
Corus Tubes

SHS welding

Structural & Conveyance Business

Contents

Introduction



Welding represents the major method by which structural hollow sections are joined. When considering welding, the most essential requirement is that the deposited weld should have mechanical properties not less than the minima specified for the sections being joined.

In addition, because hollow sections are welded from one side only, correctness of fit-up of components, weld preparations and procedures are also key factors.
In light of this, it is recommended that welding parameters, consumables, etc. are checked, prior to commencement of full production, by conducting welding procedure tests. Guidance on the most appropriate tests can be found in EN 288 Part 1: Specification and approval of welding procedures for metallic materials - General rules for fusion welding.
Successful welding, however, is concerned not only with materials and procedures but also with the ability of the welding operator. It is always advisable to use welders qualified in accordance with the requirements of EN 287 Part 1 or alternatively BS 4872. The designer of welded structures also has an important part to play, since poor design/detailing can produce welded joints that are impossible or at least difficult to fabricate.

Welding is a subject which encompasses the materials, types of joint, welding conditions/positions and the required quality or mechanical properties of the finished joint. The recommendations made in this publication are thus of guidance towards good practice and should be used in conjunction with other standards, especially EN 1011*: Welding - Recommendations for welding of metallic materials, ENV 1090 and EN 29692.

* Superceeds BS 5135 which was withdrawn March 2001.

Product specification

Corus Tubes produces four types of hollow section: Celsius® 275, Celsius® 355, Hybox® 355 and Strongbox® 235.
Celsius® hot finished structural hollow sections are produced by the Corus Tubes Structural & Conveyance Business. They are availble in two grades Celsius® 275 and Celsius® 355, which fully comply with EN 10210 S275J2H and EN 10210 S355J2H respectively. All Celsius® hot finished structural hollow sections have an improved corner profile of 2T maximum. For full details see Corus Tubes publication CTO6.
Hybox® 355 and Strongbox® 235 cold formed hollow sections are produced by Corus Tubes Cold Form Business. Hybox® 355 fully complies with EN 10219 S355J2H. Strongbox® 235 is in accordance with the Corus Tubes publication CTO5. The chemical composition and mechanical properties of these products, are given below.

Chemical composition

	Cold formed hollow sections		Hot finished hollow sections	
	Strongbox® 235	**Hybox® 355**	**Celsius® 275**	**Celsius® 355**
Specification	**TS 30** (1)	**EN 10219 355J2H**	**EN 10210 275J2H**	**EN 10210 355J2H**
C % max	0.17	0.22	0.20	0.22
Si % max	-	0.55	-	0.55
Mn % max	1.40	1.60	1.50	1.60
P % max	0.045	0.035	0.035	0.035
S % max	0.045	0.035	0.035	0.035
Ni % max	0.009	-	-	-
CEV % t ≤16mm	0.35	0.45	0.41	0.45

(1) Corus Tubes specification TS 30, generally in accordance with EN 10219 235JRH.

Mechanical properties

	Cold formed hollow sections		Hot finished hollow sections	
	Strongbox® 235	**Hybox® 355**	**Celsius® 275**	**Celsius® 355**
Specification	**TS 30** (1)	**EN 10219 355J2H**	**EN 10210 275J2H**	**EN 10210 355J2H**
Tensile strength R_m N/mm²				
t < 3mm	340 min	510-680	430-580	510-680
3 < t ≤ 40mm		490-630	410-560	490-630
Yeild strength R_{eh}min N/mm²				
t ≤ 16mm	235	355	275	355
t > 16mm	-	-	-	345
Min Elongation %				
L_o=5.65 $\sqrt{S_0}$ t ≤ 40mm	24 (2)(3)	20 (2)(3)	22	22
Impact properties				
Min Ave energy (J)	-	27 @ -20ºC	27 @ -20ºC	27 @ -20ºC
10 x 10 specimen				

(1) Corus Tubes specification TS 30, generally in accordance with EN 10219 235JRH excluding upper tensile limit and mass tolerance.

(2) 17% min for sizes 60 x 60, 80 x 40 and 76.1mm and below.

(3) Valve to be agreed for t< 3mm

Note: For Strongbox® 235, reduced section properties and thickness applies.
All thicknesses used in the design formulae and calculations are nominal, except for Strongbox® 235 which should use $0.9t_{nom}$ or (t_{nom}-0.5mm) whichever is the larger.

Welding practice

All Corus Tubes structural hollow sections are made from steels of weldable quality. The weldability of a steel is determined by the Carbon Equivalent Value (CEV), which is calculated from the ladle analysis using the formula

$$C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

To maintain weldability the maximum CEV for steel sections should not exceed 0.54%.
All Corus Tubes products are below this limit (see table opposite)

All Corus Tubes test certificates state values for the full 16 element range of the chemical analysis and the determined CEV.

The welding practice for carbon and carbon manganese steels is given in EN 1011-2. Requirements are given for all ferritic steels, except ferritic stainless steel, dependent on the material grade and it's CEV. The most common processes used with hollow sections are manual metal arc (MMA) and the semi-automatic gas shielded processes (MIG/MAG/FCAW).

Note - Where it is necessary to weld two different grades of steel, the welding procedure for the higher grade should normally be adopted.

Manual metal arc welding (MMA)

Manual metal arc welding (MMA) was once the most commonly used welding process for structural hollow section construction, however the development of the semi-automatic welding processes (MIG/MAG/FCAW) has led to a decline in its use except where restricted access and/or site conditions prevail when MMA is still extensively used.

Electrode selection should have regard to the particular application, i.e. joint design, weld position and the properties required to meet the service conditions. Advice on particular electrodes should be sought from their manufacturer and, if required or considered necessary, their performance evaluated by weld procedure tests in accordance with EN 288 Part 3.

All electrodes must be handled and stored with care to avoid damage and electrodes with damaged coatings should never be used. Electrode coatings readily absorb moisture and the manufacturer's instructions regarding protection and storage must be carefully followed to avoid this. Where hydrogen controlled electrodes are being used, these may require oven drying immediately prior to use, using drying procedures recommended by the manufacturer.

Where impact properties of the weld are important, or where structures are subject to dynamic loading - such as, for example, crane jibs and bridges - hydrogen controlled electrodes should be used irrespective of the thickness or steel grade being joined.

Where there are several steel grades in a workshop it is advisable to use only hydrogen controlled electrodes to avoid errors. Welding operators must, of course, be familiar with the techniques required for using these electrodes.

Whilst EN 499 provides a classification system for electrodes, electrode manufacturers generally supply their range of products by trade names. The following is a guide to electrode designations to EN 499 for use on various grades of hollow section.

For Strongbox® 235:
Electrodes matching this grade may not be available. User is recommended to use guidance for S275J0 material or consult the electrode manufacturer.

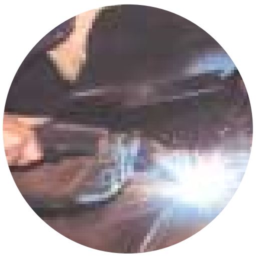
For Celsius® 275, Celsius® 355 and Hybox® 355:
Depending on the application thickness and service conditions, rutile or hydrogen controlled electrodes to EN 499 designation: 'E 35 (or 42) 2 Rx Hx' (rutile) and 'E 35 (or 42) 2 B H5' (low hydrogen) can be used. Rutile electrodes have good operability, a stable arc and are versatile but, produce a high hydrogen input. In cases of high restraint or high fabrication stresses low hydrogen electrodes are to be preferred. Prior to making a final selection the user is recommended to discuss requirements with the electrode manufacturer.

Note - If the project requirements only require the properties of S275J0H or S355J0H material the electrodes designated as E 35 (or 42) 0 Rx Hx and E35 (or 42) 0 B H5 can be used.

For Sub-grades NLH and NH:
Only hydrogen controlled electrodes (E 50 2 B H5) are recommended and care should be taken to ensure that the deposited weld has mechanical properties not less than the minima specified for the parent material.

For weather resistant steel to BS 7668 grade S345GWH:
The choice of electrodes is restricted to hydrogen controlled types which give the deposited weld mechanical properties not less than the minima specified for the parent material, i.e. E 42 2 B H5. Because of the weathering properties of S345GWH it is also necessary to consider the weathering properties and the colour match of the weld metal if the steelwork is to be an architectural feature. In cases where the dilution of the weld metal is high sufficient weathering and colour matching properties will be imparted to the weld metal even when using a plain carbon steel electrode. This will normally be the case when welding S345GWH thicknesses up to and including 12mm. With thicknesses in excess of 12mm the use of electrodes containing 2-3% nickel (E 42 2 2Ni (or 3Ni) B H5) should be considered, either for the complete weld or for the capping runs only.

Semi-automatic welding

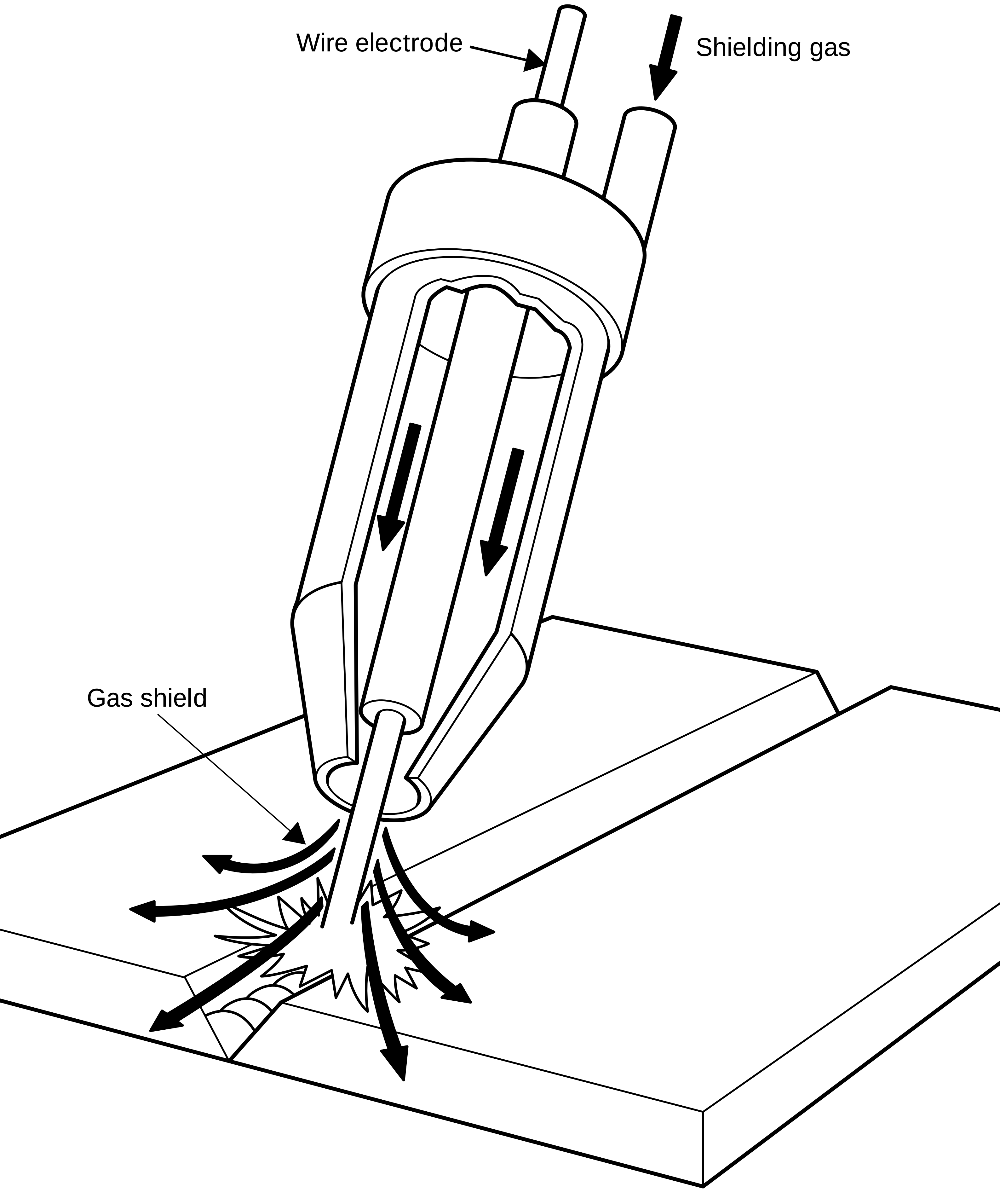


Semi-automatic welding employing a gas shield with a bare solid metal wire or flux and metal cored wire may be used where suitable applications exist. The process is capable of depositing weld metal with a low hydrogen content and is suitable for welding all material grades. The popular wire sizes are 1.0 and 1.2mm diameter, although 0.8mm diameter bare wire can be used to advantage on light sections and for root runs without backing. Bare wires should conform to the requirements of EN 440. Flux and metal cored wires should conform to EN 758.

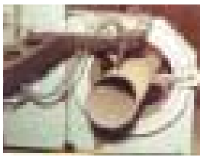
Shielding gases used include CO_2 , argon/CO_2 and argon/oxygen mixtures. The gas used will depend on the material compatibility and physical properties, the mode of operation, joint type and thickness. The characteristics of the process depend on the mode of metal transfer from the electrode to the weld pool, the common modes of transfer being "dip" and "spray". Low current "dip" transfer is used for welding lighter structural hollow sections and for positional welding whilst the high current "spray" mode of metal transfer can be used for downhand welding of thick sections.

Semi-automatic gas shielded welding with bare wire has the advantage of continuous weld deposition which, by virtue of the gas shield, does not require deslagging between subsequent runs. This results in faster welding times and hence can produce cost reductions in the fabrication process.

The electrode wire and gas are deposited at the weld location through a nozzle. Hence, sufficient access to the weld area to present the nozzle at the required angle is needed. Where access is severely restricted it may be appropriate to change the details or to use the manual metal arc process.


Wire electrode
Shielding gas
Gas shield

End preparation of members



Cutting/sawing
The first stage in any end preparation of members is cutting.

Circular Hollow Sections (CHS) and Rectangular Hollow Sections (RHS) may be cut by any of the usual steel cutting methods. The end preparation may involve either square cutting, mitre cutting, profiling or crimping.

Power hacksaws
Power hacksaws, which are available in most workshops, are very useful for "one off" and small quantity production and have the advantage that they can often be used for the larger sizes, which could require more expensive equipment.
The utility of these saws is greatly improved if they can be adapted for mitre as well as straight 90° cutting. Their main drawback is their relatively low speed of operation.

Friction-toothed and abrasive disc cutting machines
High-speed rotary friction-toothed cut-off machines and abrasive disc cutting machines are the most widely used for cutting SHS.
The choice is largely one of initial cost, plus blade life and the resharpening of the friction-toothed blade, compared to the life of the abrasive wheel.

Friction-toothed machines
These machines are fast in operation and give a good finish relatively free from burrs. The alloy or mild steel cutting discs have peripheral serrations or teeth, depending upon type, which serve a two-fold purpose - first to induce localised heat to the workpiece by friction and then to remove the hot particles under the forward motion of the cutter.

The capacity of friction machines is usually limited to the smaller sections, although machines are available for cutting quite heavy sections at the expense of a rather high capital outlay. Where large cross sections are to be cut, the available power needs to be high to prevent slowing down of the disc.

Few of these machines incorporate a swivel head mounting to allow mitre cuts and hence for these cuts the workpiece must be angled.

Abrasive disc cutting machines
As with the friction toothed machines, the abrasive disc type are fast in operation and their use is usually limited to the smaller sections. Their capacity is not as wide as for friction machines, probably due to the more specialised type of blade required and the difficulties associated with their manufacture in the larger diameters.

Some of the abrasive machines available, however, do provide a swivel cutting head for carrying our angle cuts without the need for moving the workpiece, although the maximum angle does not usually exceed 45°. In the larger machines the blades are metal centred to minimise wheel breakage.

Bandsaws
These are of more general use and, cost for cost, capable of tackling a larger range of sizes than the disc cutters. They are therefore more useful for the jobbing shop where the variety of section shapes and sizes is extensive but where speed of cutting is not so essential. Blades are relatively cheap, fairly long lasting and if broken can very often be repaired by the use of a small welding/annealing machine. Bandsaws are safe to use if the blade is adequately guarded and cutting oil is used to control the swarf.

Flame cutting
Hand flame-cutting may be used for cutting any structural hollow section, but this method is mostly used for site-cutting, for cutting the larger sized sections and for profile-cutting of ends. A ring fixed to CHS or a straight-edge for RHS may be used as a guide for the cutting torch, thus producing a clean cut and reducing subsequent grinding.

Crawler rigs are available which can be fixed to the section to give semi-automatic straight cutting.

Where a number of ends require identical profile-shaping by hand flame-cutting, templates can be used to reduce individual marking off time.

Machines are available which will flame-cut CHS and profile-shape the ends to any combination of diameters and angles within their range, and will also simultaneously chamfer the ends for butt-welding if necessary. The cost of these machines varies considerably, being controlled mainly by the range of sizes they cover and the complexity of the operations they can perform.

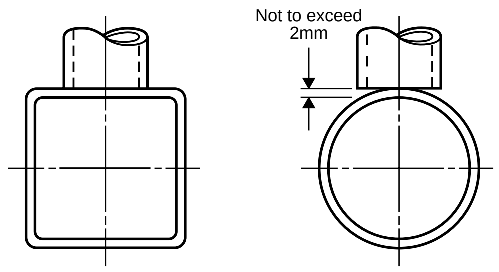
See section on fabrication for any pre-heat requirements.

Grinding or chamfering
When required this is usually done with a portable grinder, but pedestal grinders can be adapted for dealing with short lengths by fitting an adjustable guide table.

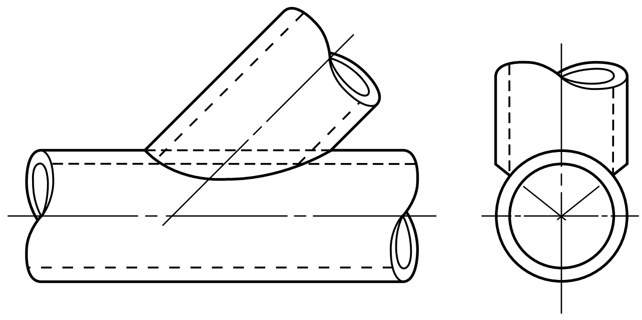
Machining
Turning or parting-off in a lathe is generally too slow for ordinary structural work. It is more commonly used for end preparation for high quality full-penetration butt-welds for pressure services. Horizontal milling also tends to be too slow, although where a great deal of repetition is involved, gang-millers with high-speed cutters have been used successfully for shaping the ends of hollow sections.

An end mill of the same diameter as the CHS main member can be used for cutting and shaping the ends of smaller branches. Where these branches are to be set at 90° this method offers the advantage of being able to cut two ends at the same time.

End preparation of members



Straight cutting



Profile shaping

Shearing, punching and cropping
Shaping the end of a hollow section by cropping through one wall at a time by means of a suitably shaped tool in a punch or fly-press or a nibbling machine is acceptable, providing the section is not distorted in the process.

By reason of possible eccentricity and distortion, hollow sections cut by means of a punch or shears are not recommended for load bearing members. Hollow sections with the ends cut and shaped simultaneously by means of a punch or "crop-crimped" (cut and crimped by means of a press, in one operation) are, however, often used for light fabrications.

Straight cutting
In accordance with EN 1090-4, “Straight-cut” structural hollow sections may be fillet welded to any suitable flat surface such as RHS, or to any suitable curved surface providing the welding gap caused by such curvature does not exceed 2mm. Details of the size combinations where a bracing can have a straight cut and still fit up to a CHS main member without exceeding the 2mm weld gap limit are given in Appendix 1 Table 1.

Where the gap exceeds 2mm, some method must be employed to bring the gap within this limit.

The two methods most generally used are: profile shaping (or saddling) and crimping (or part flattening).

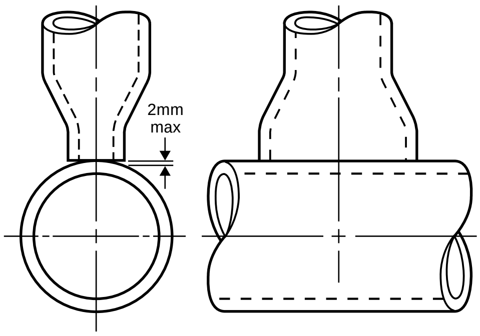
Note: Whichever method is used bracings should not ordinarily intersect the main members at angles of less than 30° to allow sufficient accessibility for welding at the crotch.

Profile-shaping or saddling
This is the process of shaping the ends of an SHS member to fit the contour of a curved surface such as a CHS main member.

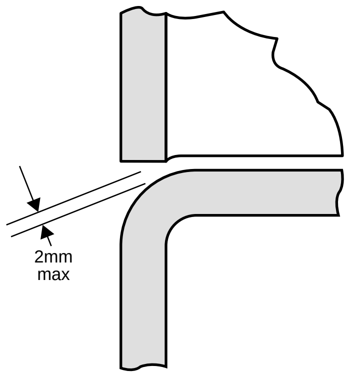
Machines are available which will flame-cut and profile-shape the ends of CHS to the required combination of diameter and angle. The profiled ends may also be chamfered at the same time if a butt welded connection is required.

For small quantity production hand flame-cutting is generally employed and Appendix 2 shows a method of setting out templates which is suitable for most work.

Templates for marking-off may be of oiled paper, cardboard or thin sheet metal, depending on the degree of permanence which is required.



Crimping or part-flattening



Partial profiling

Crimping or part-flattening
Some saws and shears can be fitting with crimpers for carrying our this simple operation: alternatively, a small press or an internal spacer may be used to limit the amount of flattening. In either case the welding gap caused by the chord curvature should not exceed 2mm for fillet welding.

Crimping or part-flattening is normally restricted to CHS and to a reduction of approximately one-third of the original diameter of the CHS branch member.
The maximum size of bracing that can be fitted to a CHS main chord to maintain a maximum gap of 2mm is given in Appendix 1 Table 1.

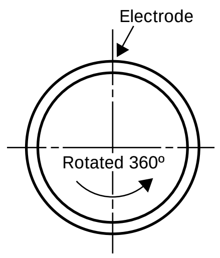
Partial profiling
When full width bracing members are welded to an RHS main member with large corner radii partial profiling may be necessary to ensure that the minimum fit-up tolerances for either a fillet weld or a butt weld are achieved.

NB: This condition can arise when using cold formed hollow sections.
See also Fabrication cold form RHS corner regions page 22.

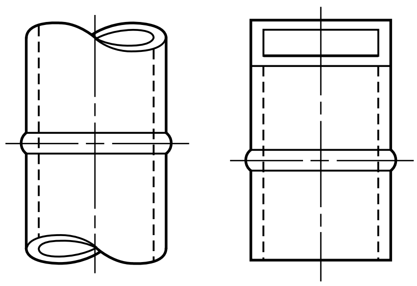
Welding procedures and sequences

The four principal welding positions, which are used for SHS, are suitable for either butt or fillet welding.

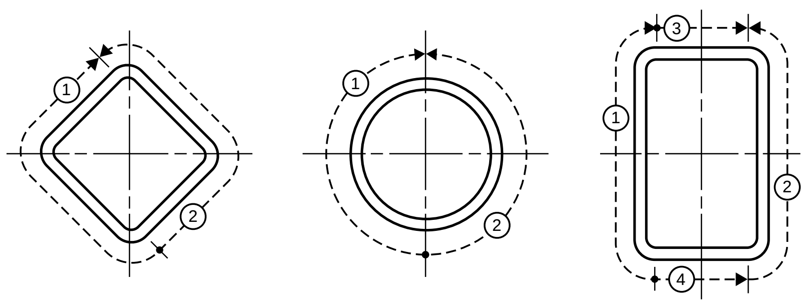
360° Flat rotated
(Butts PA* and fillets PB*)
The member is rotated through 360º in an anticlockwise direction. A downhand (flat) weld is made with the electrode always adjacent to the crown of the member.



Horizontal-vertical
(Butts PC* and fillets PB* or PD*)
This method is used when the member cannot be moved and is in an upright position.

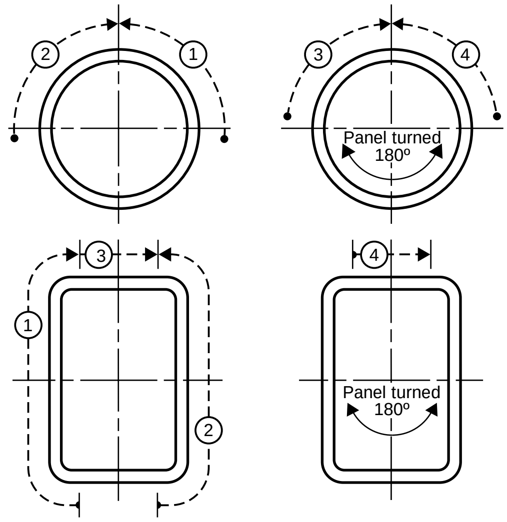


Fully positional
Vertical-upwards (PF*)
This method is used on the comparatively rare occasions when the member or assembly cannot be moved.



180º Vertical upwards (PF*)

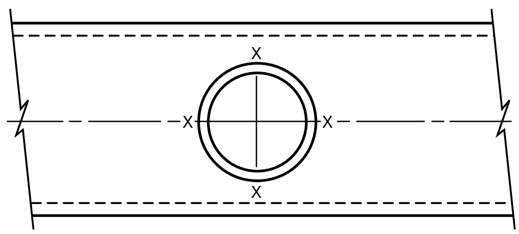
This is a commonly used method and is particularly suitable for planar lattice construction. All the welds are made on the top side and then the whole panel is turned over through 180º and the remaining welds completed.



Note:

1. When using the above sequences for welding RHS, the start/stop weld positions should be of the order of five times the section thickness (5 t) from the corners.

2. When using the above sequences for welding CHS bracings to a main or chord member, the start/stop weld positions should not be at the positions marked with an 'X' on the adjacent sketch.



* In the weld sequence descriptions shown on pages 12 and 13 the details in brackets refer to the designations given in prEN 13920-2 for welding positions.

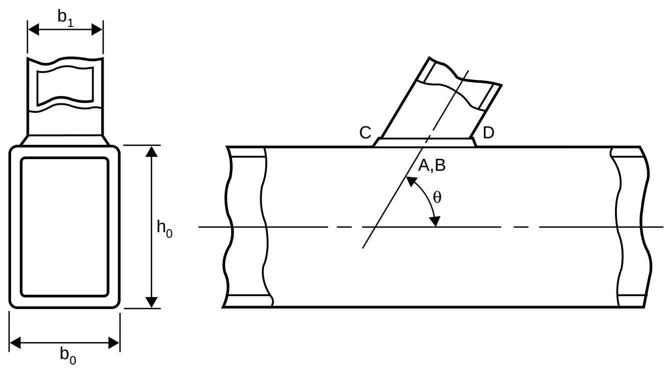
Fillet welds

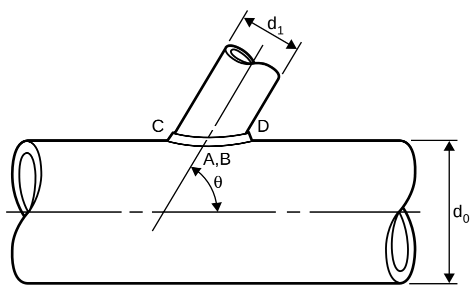
Apart from the special case of end to end connections where butt joints, developing the full strength of the sections, are usually desirable, fillet welding provides the economic answer to most of the joints in static structures.

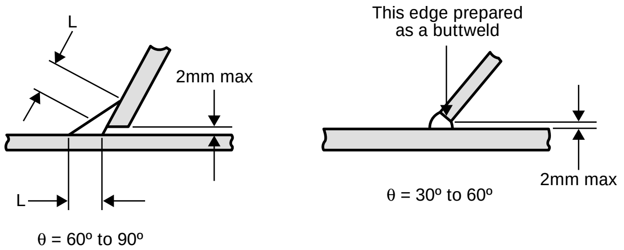
A fillet weld can be specified by its throat thickness and/or leg length and the deposited weld shall be not less than the specified dimensions.

Branch connection details - fillet welds
The following figures show the basic conditions which are encountered when making fillet welds on SHS branch members : L = Leg length.

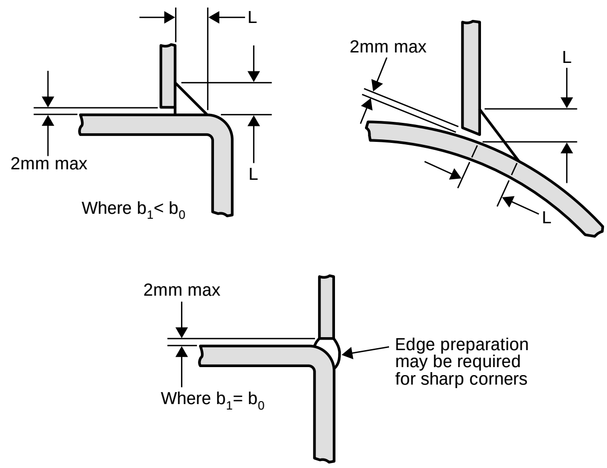
Special note: The gaps shown in the above details are those allowed by ENV 1090-4 for normal fillet welds. In the case of small size fillet welds below 5mm and, especially for crimped or straight cut branch members to circular chords, consideration should be given to increasing the minimum leg length required by 2mm to ensure adequate strength is achieved.



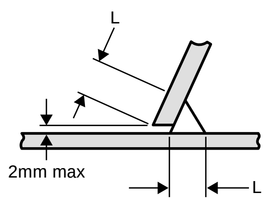




Detail at C



Detail at A,B



For smaller angles full penetration is not intended provided there is adequate throat thickness

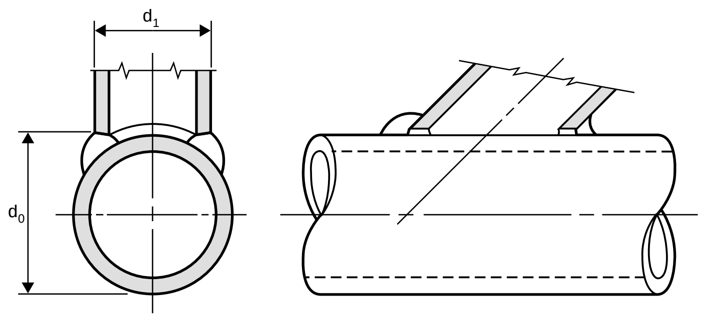
Detail at D

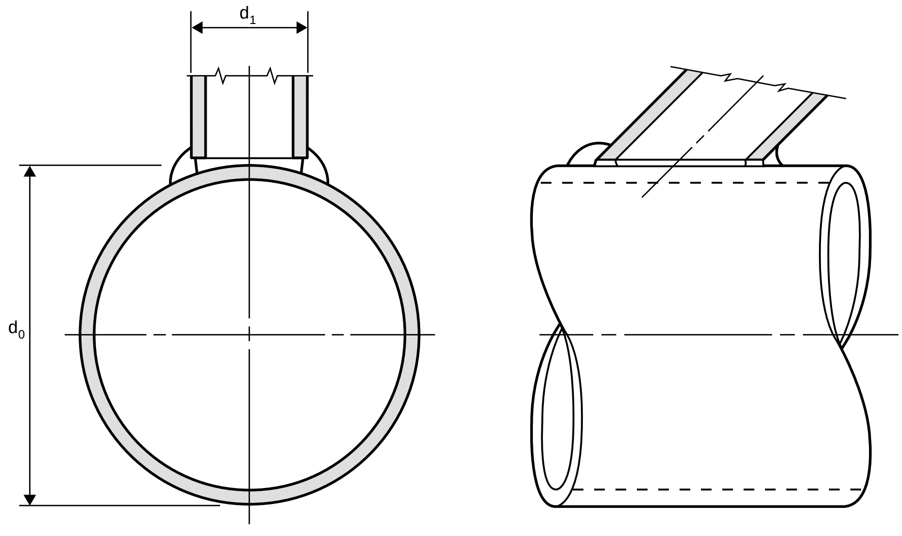
Fillet and fillet-butt welds

Fillet welds joining SHS to flat surfaces such as plates, sections, or RHS main members are self explanatory, but some confusion has arisen in the past over the terms “fillet” and “fillet-butt” where structural hollow sections are welded to CHS main members. The terms describe the welding conditions which apply when various size ratios of bracing to main member are involved.

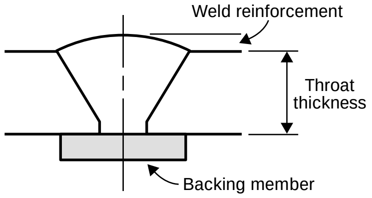
The following shows two bracings, of the same size, meeting main members of different sizes. In both cases welding conditions at the crown are similar, so for the same loads identical fillets would be used. At the flanks, however, conditions differ. The curvature of the larger main member continues to give good fillet weld conditions while the curvature of the smaller main member necessitates a butt weld. The change from fillet to butt weld must be continuous and smooth.

For calculating weld sizes, both types are considered as fillet welds. The fillet-butt preparation is used where the diameter of the bracing is one third or more of the diameter of the main member.





Butt welds



General
The end preparation for butt welding depends on many factors including the thickness of the section, the angle of intersection, the welding position and the size and type of electrode employed.

Where full penetration has been achieved and the correct electrodes for the type of steel have been employed, butt welds in SHS may be regarded as developing the full strength of the parent metal.

Butt welds may be used regardless of the thickness of the section or, in the case of CHS, of the ratio between the diameter of the bracing and that of the main member. Where multi-run butt welds are required the root run or runs should be made with 3.25mm diameter or smaller electrodes, using one of the sequences shown on pages 12 or 13 according to the technique employed.

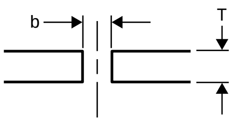
The finished weld must be proud of the surface of the parent metal by an amount not exceeding ten per cent of the throat thickness of the weld. This reinforcement may be dressed off if a flush finish is required.

End-to-end butt welds
It is permissible to butt weld hollow sections end-to-end up to and including 8.0mm thick without end preparation, i.e. square butt weld (with backing), but in general an upper limit of 5mm is recommended to avoid large weld deposites and associated shrinkage and distortion.

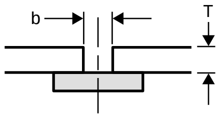
Although specifications permit end-to-end butt welds to be made without backing, the use of backing members is recommended, as they help in lining up the sections as well as assisting in ensuring a sound root run. In general, backing members are necessary for full penetration butt welds.

The following details have, unless noted, been taken from EN 29692. The end preparation shown are those normally used for joining two structural hollow sections of the same size and thickness. For joining sections of different thicknesses see page 18.
For material over 20mm thick, welding trials should be carried out to establish the most suitable procedure.

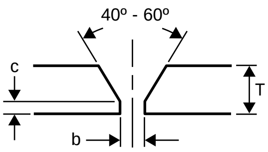
Square butt weld - without backing

Weld detail	Thickness T	Gap b
	mm ≤ 4	mm ≈T

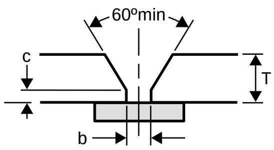
Square butt weld - with backing

Weld detail	Thickness T	Gap b	
		min.	max.
	mm 3-8	mm 6	mm 8

Single V - with or without backing

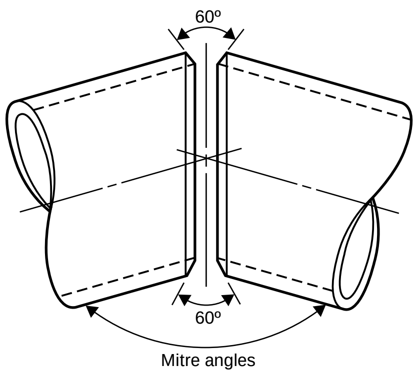
Weld detail	Thickness T	Gap b		Thickness of root face c	
		min.	max.	min.	max.
	mm Up to 10	mm -	mm 4	mm -	mm 2

Single V - with backing: not included in EN 29692

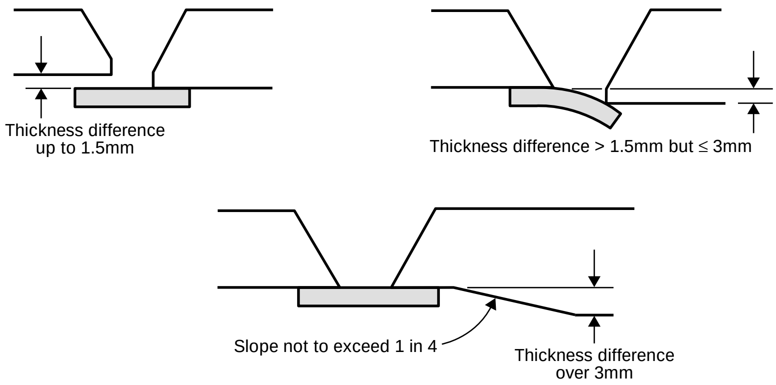
Weld detail	Thickness T	Gap b		Thickness of root face c	
		min.	max.	min.	max.
	mm Up to 20	mm 5	mm 8	mm 1	mm 2.5

Mitred butt welds: ENV 1090-4

For constructions such as bowstring girders, mitred butt welds are often used, instead of being cut square the end is cut at an angle equal to half the mitre angle. Backing members for mitred butts have to be specially made to suit the mitre.



Butt welds



Sections of different thicknesses: ENV 1090-4

When SHS of different thicknesses are butt welded end-to-end the transition between the two thicknesses should be as smooth as possible, especially for dynamic structures. The strength of such a weld is based on that of the thinner section.

For any given external size of hollow section the change in wall thickness occurs on the inside of the section. Differences in thickness may be dealt with as follows:

No special treatment is required if the difference does not exceed 1.5mm. Differences not exceeding 3mm may be accommodated by making the backing member to fit the thinner section, tacking it in position, locally heating it and dressing it down sufficiently to enter the thicker section.

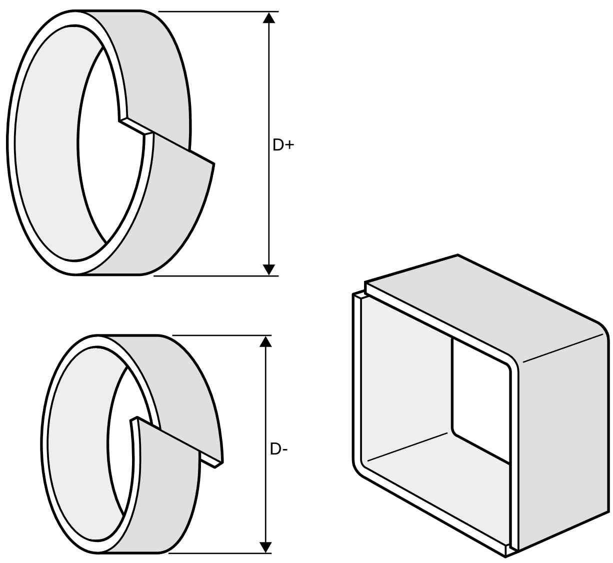
Alternatively, lay down the first root run round the thinner section and dress down the backing member while it is still hot. It may be necessary to mitre the corners by hacksaw in some cases.

Differences in thickness exceeding 3mm necessitate the machining of the bore to enable the backing member to fit snugly. The machined taper should not exceed 1 in 4.

Backing members: ENV 1090-4

Backing members must be of mild steel with a carbon content not exceeding 0.25% and a sulphur content not exceeding 0.060% or of the same material as the parent metal. For CHS they are usually formed from strip 20 to 25mm wide and 3 to 6mm thick, with the ends cut on the scarf to permit adjustment. They are sprung into position inside the section and are tack welded to the fusion face to hold them in place.

Backing members for RHS are usually formed from strip 20 to 25mm wide and 3 to 6mm thick, in two pieces, bent at right angles and tacked in position.



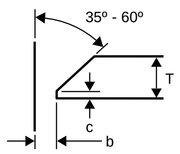
Flat plate and branch connections

Although seldom necessary to meet design requirements butt welds can be used for such joints.
The two basic conditions are: Flat plate vertical - SHS horizontal and horizontal-vertical butt welds.

Flat Plate Vertical - SHS Horizontal

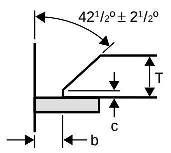
A typical example of this condition could be a flange plate welded to SHS. For most general work the end preparation shown for a single bevel without a backing member is suitable, but where it is required to ensure complete penetration a backing member should be used.

Single bevel - without backing

Weld detail	Thickness T	Gap b		Thickness of root face c	
		min.	max.	min.	max.
	mm Up to 20*	mm 2	mm 4	mm 1	mm 2

* EN 29692 max 10

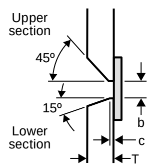
Single bevel - with backing - not included in EN 29692

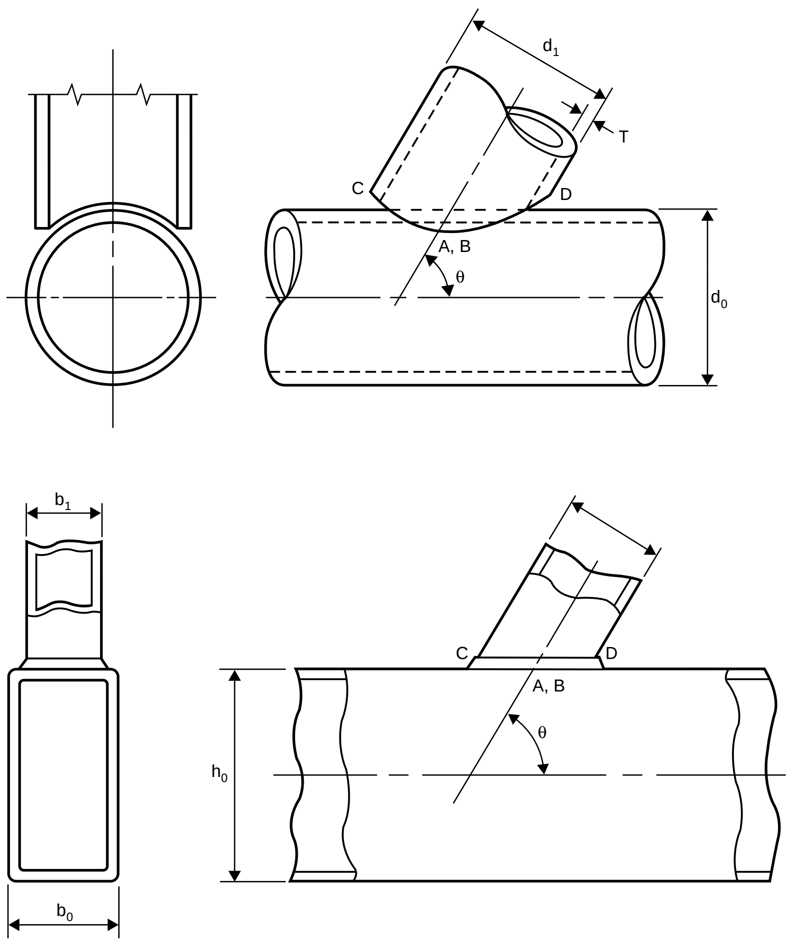
Weld detail	Thickness T	Gap b		Thickness of root face c	
		min.	max.	min.	max.
	mm Up to 20	mm 5	mm 8	mm 1	mm 3

Horizontal-vertical butt Welds

Where SHS are in a vertical position and cannot be moved for welding, a double bevel form of preparation is used. The weld face of the upper member is bevelled at 45° and that of the lower at 15°. The weld gap may be adjusted to suit welding conditions. Backing members are strongly recommended for joints of this type.

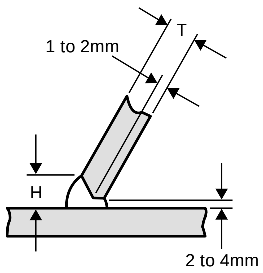
Double bevel - with backing - not included in EN 29692

Weld detail	Thickness T	Gap b		Thickness of root face c	
		min.	max.	min.	max.
	mm Up to 20	mm 5	mm 8	mm 1	mm 2.5

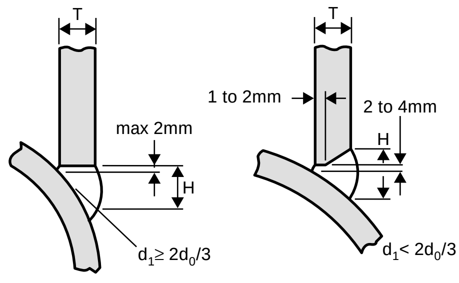


Branch connections to structural hollow section main members: ENV 1090-4

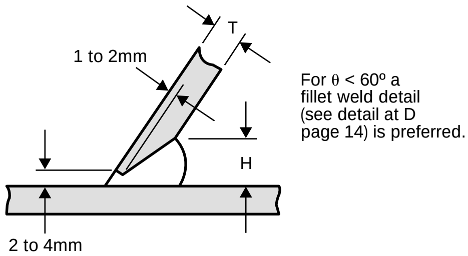
If the main member is a circular hollow section, then the angle of intersection between the bracing and the surface of the main member changes from point to point around the perimeter of the bracing. The basic preparations used give, as far as possible, a constant 45º single bevel between the weld face of the bracing and the surface of the main member.



Detail at C

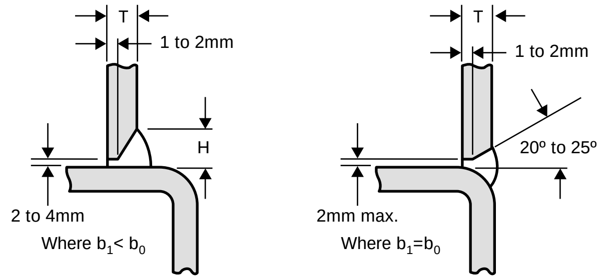


Detail at A,B for CHS



Detail at D

θ = 60º to 90º



Detail at A,B for RHS

In all cases H ≥ T

Note: The angle of intersection θ of the axes of the hollow sections should not be less than 30° unless adequate efficiency of the junction has been demonstrated.

Fabrication

General

While Structural Hollow Sections are light, strong and graceful, there is sometimes a tendency for fabricators, not familiar with their use, to over weld. This is a bad practice; it spoils the appearance of the structure and tends to distort it as well as adding unnecessarily to the welding costs. Welds should be the minimum size commensurate with the load to be carried and the conditions of working.

Even when the weld sizes have been correctly specified there are two common causes of over welding during fabrication and care should be taken to avoid them. These are:

a) Fillet welds with too large a throat thickness and/or leg length.
b) Butt welds with excessive reinforcement, this should be limited to 10% of the section thickness.

Poor "fit-up" of structural members can also increase welding and rectification costs. Whilst it is not necessary to have "machine fits" time spent at the preparation and assembly stages is usually amply repaid at the welding stage.

Cold formed RHS corner regions

EN1993-1-1: Annex K: Table A4 restricts welding within 5t of the corner region of cold formed square or rectangular hollow section chord members unless the steel is a fully killed (A1≥ 0.025%) type.
Both Corus Tubes Strongbox® 235 and Hybox® 355 meet the fully killed requirements and can be welded in the corner region unless the thickness is greater than 12mm when the 5t restriction applies.

Preheating for flame cutting

Preheating for flame cutting or gouging is usually not required for Strongbox® 235 or Celsius® 275 materials. However, a minimum preheating temperature of 120ºC should be used when either the ambient temperature is below 5ºC or when Celsius® 355, Hybox® 355 and S460N grades over 13mm thick are being flame cut.

Preheating for tacking and welding

The temperature of any grade of material prior to welding should not be less than 5ºC.

To establish the need for preheat and the required preheat temperature EN 1011-2 should be consulted. The requirement for preheating is dependent upon the variables listed below:

Grade/composition of the section e.g. it's CEV.

Combined thickness of the joint to be welded.

Welding process parameters. (Amperage, Voltage & travel speed)

Hydrogen scale of the process and consumables.

If required, preheating should be applied to a distance of 75mm either side of the joint to be welded and checked using a suitable temperature indicating device, e.g. indicating crayon or contact pyrometer.

For Celsius® 275 and Strongbox® 235:-
Further preheat is not generally required.

For Celsius® 355 and Hybox® 355:-
Further preheat is generally not required with sections up to 13mm thick for fillet welds and up to 20mm thick for butt welds.
A minimum pre-heat temperature of 125°C is required when fillet welding sections over 13mm thick and butt welding sections over 20mm thick.

For Sub-grades NH and NLH:-
No further preheat is required with sections up to 8mm thick for fillet welds and up to 12mm thick for butt welds. A minimum pre-heat temperature of 175°C is required when fillet welding sections over 8mm thick and butt welding sections over 12mm thick.

For Grade S345GWH:-
The recommendations for Celsius® 355 apply.

Tack welds

Particular attention should be paid to the quality of tack welds and they should be deposited by qualified welders. The throat thickness of tack welds should be similar to that of the initial root run. The minimum length of a tack weld should be 50mm, but for material less than 12mm thickness should be four times the thickness of the thicker part being joined. The ends of the tack welds should be dressed to permit proper fusion into the root run.

Special notes:
Tack welds must not be applied at corners. Backing members must always be tack welded to the root face, never internally.

Jigs and manipulators
The shapes and close dimensional tolerances of SHS make them very suitable for jig assembly and the use of simple jigs and fixtures is recommended wherever possible.The strength and stiffness of SHS usually permit them to be assembled and tacked in a jig and then moved elsewhere for welding, thus freeing the jig for further assembly work. Manipulators, other than supporting rollers for 360° rolling welds are seldom required for general work.
The vast majority of work can be planned using the 180° vertical-up technique.

Welding sequence
The usual practice in the fabrication of panels and frames from SHS is to work to open ends. That is to start welding in the middle of a panel and work outwards on alternate sides to the ends. This tends to reduce distortion and avoid cumulative errors.

Flange joints are usually associated with close length tolerance and it is good practice to first complete all the other welding before fixing and welding on the flanges as a final operation.

Weld distortion and shrinkage
Provided the joints have been well prepared and assembled and the welding sequence has been correct, distortion will be kept to a minimum and rectification will not be a major problem. It is a common mistake to make bracing members a tight fit. A small allowance should be made for shrinkage. Flanges are sometimes clamped to heavy "strongbacks" approximately twice the thickness of the flange, to prevent distortion during cooling. Weld shrinkage depends on many factors, but a useful approximation is to allow 1.5mm for each joint in the length of a main member.

Welding conditions
Wherever possible, welding should be carried out in workshops under controlled conditions using suitably qualified welding procedures. The surfaces to be joined should be free from rust, oil, grease, paint or anything which is likely to be detrimental to weld quality. Special attention should be given to cold formed hollow sections as these are normally supplied with a corrosion inhibitor/oil preparation applied to the steel surfaces. When using the so called "weld-through" primers, care should be taken to avoid welding defects by ensuring these are applied strictly in accordance with manufacturer's recommendations.

Where site welding is required, additional precautions should be taken to protect the workpiece from adverse weather conditions, i.e. damp and low temperatures.

Inspection of welding
In addition to visual examination for dimensional inconsistencies and surface breaking weld defects, the Magnetic Particle and Dye Penetrant Inspection (MPI & DPI) techniques are most commonly used for SHS welds. For critical applications these may also be supported by the use of ultrasonic or radiographic inspection for sub-surface defects.
Prior to undertaking any inspection it is essential to establish the criteria on which welds are accepted or rejected. Welding repairs can significantly increase fabrication costs and may lead to excessive distortion, restraint and in the most severe cases scrapping of the component or structure.

Hazards from fumes
When subjected to elevated temperatures during welding or cutting, fumes will be produced which may be injurious to health. Good general ventilation and/or local extraction is essential. When welding galvanised, metal coated or painted material care should be taken to ensure that threshold limits are not exceeded and, where possible, it is recommended that coatings are removed local to the area to be welded.

Welding of galvanised and metal coated SHS
There should be no difficulty in welding galvanised or zinc-coated hollow sections, but because of the fumes given off when the zinc volatises, the operation must be carried out in a well ventilated area.
The correct welding procedure is to use a back-stepping technique; volatising the galvanised coating with a lengthened arc for 50mm then coming back and laying the weld. Where SHS are aluminium sprayed before fabrication, a distance of 75mm around the welding position should be left clear.

Repair of metal coatings at weld area
The completion of the protection at welds on structures fabricated from either hot dipped galvanised or aluminium/zinc sprayed tubes can be satisfactorily achieved by metal spraying. The sprayed metal coating should be at least 130µm thick. To ensure good adhesion of the sprayed metal on the weld it is necessary to grit blast or alternatively remove all welding slag with a pneumatic needle pistol or by hand chipping and preheat the weld area to a temperature of 150°C to 350°C.

Due to the roughness of the parent coating on aluminium/zinc sprayed tubes, this method of weld protection gives a firm bond at the overlap with the parent coating. With hot dip galvanised SHS there is less adhesion of the sprayed zinc at the overlap with the parent coating. It is therefore advisable to seal the whole of the sprayed coating, including at least 25mm of the parent hot dip galvanised coating, with zinc rich paint. Coatings applied in this manner ensure that the protection at the weld is as good as the parent coating.

For galvanised coatings a less satisfactory but more convenient method, which may be acceptable for mildly corrosive environments, is to clean the weld area thoroughly and apply two or three coats of a good quality zinc rich paint to give a coating thickness of about 130µm.

Design of welds

General

A weld connecting two hollow section members together should normally be continuous, of structural quality and comply with the requirements of the welding standard EN 1011 and ENV 1090-4 and the appropriate application standard. The following design guidance on the strength of welds is based on the requirements of BS 5950-1:2000 and ENV 1993:Part 1.1.

Fillet welds

Pre-qualified fillet weld size

According to ENV 1993-1-1:1992/A1:1994 : Annex K: Section K.5. for bracing members in a lattice construction, the design resistance of a fillet weld should not normally be less than the design resistance of the member. This requirement will be satisfied if the effective weld throat size (a) is taken equal to (α t) as shown in table 3, provided that electrodes of an equivalent grade (in terms of both yield and tensile strength) to the steel are used.

Steel grade	Minimum throat size a (mm)	Minimum throat size, a (mm) UK NAD: $\gamma_{Mw}=1.35$ $\gamma_{Mj}=1.1$
Celsius® 275	0.87 α t	0.94t
Celsius® 355	1.01 α t	1.09t
Strongbox® 235	0.84 α t	0.91t
Hybox® 355	1.01 α t	1.09t

where t = bracing member thickness and $\alpha = \frac{1.1}{\gamma_{Mj}} \cdot \frac{\gamma_{Mw}}{1.25}$

Table 3 : Pre-qualified weld throat size

The criterion above may be waived where a smaller weld size can be justified with regard to both resistance and deformational/ rotational capacity, taking account of the possibility that only part of the weld's length may be effective.

General design of fillet welds

The design capacity of a fillet weld, where the fusion faces form an angle of not more than 120º and not less than 30º is found from the multiplication of the weld design strength (p_W), the effective weld throat size (a) and the effective weld length (s).

Weld design capacity = p_W x a x s

If the angle between fusion faces is greater than 120º, for example at the toe of an inclined bracing, then a full penetration butt weld should be used.
If the angle is less than 30º then adequacy of the weld must be shown.

Weld Design Strength (p_W)

The values of the weld design strength p_W (N/mm²) using covered electrodes to EN 499 are given in BS 5950 and are shown in table 4.

Steel grade	Weld design strength, p_W, for EN 499 Electrode designation	
	E 35 2 xxxx	E 42 2 xxxx
Celsius® 275	220	220
Celsius® S355	220	250
Strongbox® 235	187	187
Hybox® S355	220	250

Table 4 : Weld design strengths

Effective weld throat size (a)

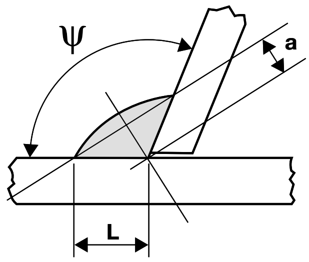
The effective throat size (a) is taken as the perpendicular distance from the root of the weld to the straight line joining the fusion faces, which lies within the cross section of the weld, but not greater than 0.7 times the effective weld leg length (L).

Where the fusion faces are between 30º and 120º the effective weld throat size is calculated from the effective leg length by using the reduction factor (fr), given in table 5, such that :

Effective weld throat size, a = fr x L

Angle ψ in degrees between fusion faces	Reduction factor (fr)
30 to 90	0.70
91 to 100	0.65
101 to 106	0.60
107 to 113	0.55
114 to 120	0.50

Table 5 : Throat size reduction factors



Weld design capacities per millimetre run of weld are given in table 6, they have been calculated from (a x p_W).

Weld effective throat size, a mm	Steel grade S235 with E35 2 xxxx electrodes kN/mm run	Steel grade S275J2H with E 35 2 xxxx electrodes, kN/mm run	Steel grade S355J2H with E 42 2 xxxx electrodes, kN/mm run
3	0.56	0.66	0.75
4	0.75	0.88	1.00
5	0.94	1.10	1.25
6	1.12	1.32	1.50
7	1.31	1.54	1.75
8	1.50	1.76	2.00
9	1.68	1.98	2.25
10	1.87	2.20	2.50

Table 6 : Weld design capacity per unit length

Effective weld length(s)

The effective weld length for design will depend on the following

1. The actual length of the intersection. This will depend upon the angle of intersection and the type of surface being welded to, e.g. flat or curved. Lengths of curves of intersections are given in Appendix 1, tables 2A, 2B and 2C.
2. The effectiveness of the actual length of intersection. Generally connections to relatively thin flat surfaces, such as lattice bracings to the face of an RHS will be less than fully effective, whilst those to a thick plate or a curved surface are more likely to be fully effective.

Joints with CHS chords

For joints with CHS chord members the weld effective throat size can be determined using a calculated effective bracing thickness, t_{eff} as shown below.
Assuming that the bracing member capacity, N_{mem} is required to be equal to the joint capacity, N_{joint}, calculated from ENV1993-1-1:1992/A1:1994. Then $N_{joint} = N_{mem} = \pi\, t\, (d-t)\, f_y / 10^3$
d/t is generally about 20, hence (d-t) = 0.95d and has a top limit in ENV1993 of $d/t \leq 50$

Hence the effective bracing thickness,

$$t_{eff} = \frac{N_{joint} \times 10^3}{0.95\, \pi\, d\, f_y} = \frac{335\, N_{joint}}{d\, f_y} \quad \text{but with } t_{eff} \geq d/50$$

Using the prequalified weld throat thickness factors (α) given in table 3, the minimum throat sizes becomes $\alpha\, t_{eff}$, see table 7.

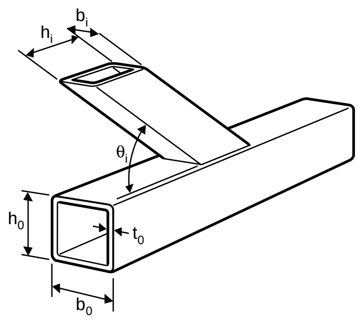
For CHS joints with moments and axial loads

replace N_{joint} in the above with $\left(\frac{N_{app}}{A} + \frac{M_{xapp}}{Z_x} + \frac{M_{yapp}}{Z_y} \right) A$
where A, Z_x and Z_y are the nominal section properties.

Yield strength, fy N/mm²	α factor	Effective bracing thickness, t_{eff} = higher value of	Minimum weld throat thickness, a mm = higher value of
Celsius® 275	0.94	$(1.22\, N_{joint} / d)$ and $(d / 50)$	$(1.15\, N_{joint} / d)$ and $0.94(d / 50)$
Celsius® 355	1.09	$(0.94\, N_{joint} / d)$ and $(d / 50)$	$(1.02\, N_{joint} / d)$ and $1.09(d / 50)$
Strongbox® 235	0.91	$(1.43\, N_{joint} / d)$ and $(d / 50)$	$(1.30\, N_{joint} / d)$ and $0.91(d / 50)$
Hybox® 355	1.09	$(0.94\, N_{joint} / d)$ and $(d / 50)$	$(1.02\, N_{joint} / d)$ and $1.09(d / 50)$

Table 7 : Minimum Weld Throat Size for CHS Chord Joints

Joints with RHS chords and either two bracings with a gap or one bracing



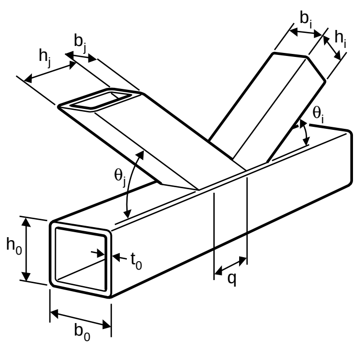
The weld effective lengths are based to a great extent on the bracing effective periphery determined during the calculation of the static capacity of welded lattice type joints. The effective peripheries for bracing connections to RHS chord members are given in ENV1993-1-1: 1992/A1:1994 and are shown below.

The weld effective length, s, for K- or N-joints with a gap between the bracings and predominantly axial loads can be taken as :

$s = [(2\, h_i / \sin\theta_i) + b_i]$ for $\theta_i \geq 60°$ and
$s = [(2\, h_i / \sin\theta_i) + 2b_i]$ for $\theta_i \leq 50°$
for angles between 50º and 60º linear interpolation should be used.

For T-, Y- and X-joints with predominantly axial loads a conservative estimate of the weld effective length, s, is given by
$s = [2\, h_i / \sin\theta_i]$ for all values of θ_i

Joints with RHS chords and overlapping bracings



The weld effective length, s, for the overlapping bracing of K- or N-joints with overlapping bracings and predominantly axial loads can be taken as

$s = 2h_i + b_i + b_{e(ov)}$	for overlaps ≥ 80%
$s = 2h_i + b_e + b_{e(ov)}$	for overlaps ≥ 50% < 80%
$s = (Ov/50)2h_i + b_e + b_{e(ov)}$	for overlaps ≥ 25% < 50%

with $b_{e(ov)} = \frac{10}{b_j/t_j} \frac{f_{yj}\, t_j}{f_{yi}\, t_i} \; b_i$ but $\leq b_i$

$b_e = \frac{10}{b_0/t_0} \frac{f_{y0}\, t_0}{f_{yi}\, t_i} \; b_i$ but $\leq b_i$

and Ov = percentage overlap = $q \sin\theta_i / h_i \times 100$

The weld effective length, s, for the overlapped bracing can be taken as being the same percentage of the actual weld length as that for the overlapping bracing, i.e.

$s_{overlapped} = s_{overlapping} (h_j + b_j)/(h_i + b_i)$ but $\leq 2 (h_j/\sin\theta_j + b_j) - b_i$

because the hidden part of the weld need not be welded if the vertical components of the bracing loads do not differ by more than 20%

For RHS joints with moments and axial loads

the required weld throat thickness can be found from table 6 using the stress in kN/mm found from

$$\frac{N_{app}}{A} + \frac{M_{xapp}}{Z_x} + \frac{M_{yapp}}{Z_y}$$

where A, Z_x and Z_y are the bracing area and section modulii reduced where appropriate for the ineffective widths.

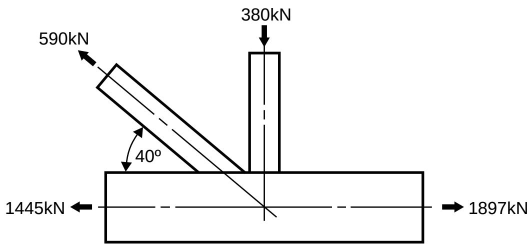
Fillet weld design examples

All of the joint capacities quoted in these examples have been calculated using the joint design formulae in ENV 1993-1-1: 1992/A1: 1994

RHS gap joint

All material grade S355J2H
Chord : 200 x 200 x 8
Compression bracing : 150 x 100 x 5 at 90º
Tension bracing : 120 x 80 x 5 at 40º

Joint capacity : Comp brace 402kN
Tens brace 598kN



Compression bracing weld

Using prequalified weld sizes, throat thickness, a = 1.09 t = <u>5.5mm</u>
Using member load
effective length, $s = 2h/\sin\theta + b = 2 \times 100/\sin 90^\circ + 150 = 350$mm
and throat thickness, $a = N_{app}/(p_w.s) = 380000 / (250 \,.\, 350) =$ <u>4.3mm</u>
The required throat thickness is the lesser of these two values, ie <u>4.3mm</u>

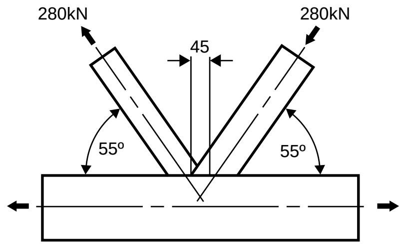
Tension bracing weld

Using prequalified weld sizes, throat thickness, a = 1.09 t = <u>5.5mm</u>
Using member load
effective length, $s = 2h/\sin\theta + 2b = 2 \times 80/\sin 40^\circ + 2 \times 120 = 489$mm
and throat thickness, $a = N_{app}/(p_w.s) = 590000 / (250 \,.\, 489) =$ <u>4.8mm</u>
The required throat thickness is the lesser of these two values, ie <u>4.8mm</u>

RHS overlap joint

All material grade S275J2H
Chord : 180 x 180 x 8
Compression bracing : 120 x 120 x 5 at 55º
Tension bracing : 90 x 90 x 5 at 55º
Overlap %, Ov = q sinθ / h = 45 sin55º / 90 = 41%

Joint capacity : Comp brace 447kN
Tens brace 330kN



Overlapping bracing weld

Using prequalified weld sizes, throat thickness, a = 0.94 t = 4.7mm
Using member load
effective length, $s = (Ov/50)2h_i + b_e + b_{e(ov)}$

with $b_{e(ov)} = \dfrac{10}{b_j/t_j}\,\dfrac{f_{yj}\,t_j}{f_{yi}\,t_i}\,b_i = \dfrac{10 \times 8}{180}\,\dfrac{275 \times 8}{275 \times 5}\,90 = 64mm < b_i = 90mm$

and $b_e = \dfrac{10}{b_0/t_0}\,\dfrac{f_{y0}\,t_0}{f_{yi}\,t_i}\,b_i = \dfrac{10 \times 5}{120}\,\dfrac{275 \times 5}{275 \times 5}\,90 = 38mm < b_i = 90mm$

Hence effective length, s = 41 / 50 (2 x 90) + 64 + 38 = 249mm
and throat thickness, $a = N_{app}/(p_w.s)$ = 280000 / (220 . 249) = 5.1mm
The required throat thickness is the lesser of these two values, ie 4.7mm

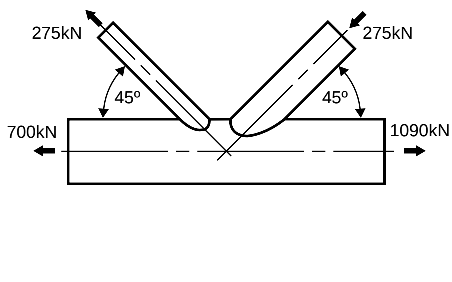
Overlapped bracing weld

Using prequalified weld sizes, throat thickness, a = 0.94 t = 4.7mm
Using member load effective length,
$s = s_{overlapping}\,(h_j+b_j)/(h_i+b_i)$ = 249 (120+120)/(90+90) = 314mm < $2(h_j/\sin\theta_j+b_j)-b_i$ = 443mm
and throat thickness, $a = N_{app}/(p_w.s)$ = 280000 / (220 . 314) = 4.1mm
The required throat thickness is the lesser of these two values, ie 4.1mm

CHS gap joint

All material grade S355J2H
Chord : 193.7 x 6.3
Compression bracing : 114.3 x 3.6 at 45º
Tension bracing : 88.9 x 3.2 at 45º

Joint capacity : Comp brace 281kN
Tens brace 281kN



Compression bracing weld

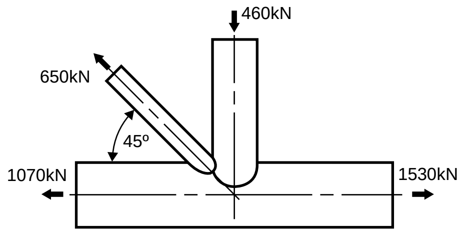
Using prequalified weld sizes, throat thickness, a = 1.09 t = 3.9mm
Using joint capacity method
$t_{eff} = 0.94\,N_{joint} / d$ = 0.94 x 281 / 114.3 = 2.32mm > d / 50 = 2.29mm
throat thickness = $\alpha\,t_{eff}$ = 1.09 x 2.32 = 2.6mm
The required throat thickness is the lesser of these two values, ie 2.6mm

Tension bracing weld

Using prequalified weld sizes, throat thickness, a = 1.09 t = 3.5mm
Using joint capacity method
$t_{eff} = 0.94\,N_{joint} / d$ = 0.94 x 281 / 88.9 = 2.98mm > d / 50 = 1.78mm
throat thickness = $\alpha\,t_{eff}$ = 1.09 x 2.98 = 3.3mm
The required throat thickness is the lesser of these two values, ie 3.3mm

CHS overlap joint

All material grade S275J2H
Chord : 273 x 8.0
Compression bracing : 193.7 x 5.0 at 90º
Tension bracing : 168.3 x 5.0 at 45º



Joint capacity : Comp brace 483kN
Tens brace 683kN

Overlapped bracing weld

Using prequalified weld sizes, throat thickness, a = 0.94 t = 4.7mm
Using joint capacity method
t_{eff} = 1.22 N_{joint} / d = 1.22 x 483 / 193.7 = 3.04mm < d / 50 = 3.87mm
throat thickness = α t_{eff} = 0.94 x 3.87 = 3.6mm
The required throat thickness is the lesser of these two values, ie 3.6mm

Overlapping bracing weld

Using prequalified weld sizes, throat thickness, a = 0.94 t = 4.7mm
Using joint capacity method
t_{eff} =1.22 N_{joint} / d = 1.22 x 683 / 168.3 = 4.94mm > d / 50 = 3.37mm
throat thickness = α t_{eff} = 0.94 x 4.94 = 4.6mm
The required throat thickness is the lesser of these two values, ie 4.6mm.

Butt welds

The design strength of full penetration butt welds should be taken as equal to that of the parent metal, provided the weld is made with electrodes that produce all weld tensile specimens (both yield and tensile) not less than those specified for the parent metal.

Design note: When designing welds for full width Vierendeel joints, to cater for the non-uniform stress distribution at the connection and to ensure that stress re-distribution can take place, the welds should be designed to have the same capacity as the bracing member capacity.

Appendix 1

Table 1
Sizes of RHS and CHS bracings which can be fitted to CHS main members without shaping

Diameter of main member	Size of bracing (d_1) up to and including:-		
	Straight cut		Partial flattening
(d_o)	RHS width	CHS dia.	Original dia. of CHS
33.7	-	-	-
42.4	-	-	26.9
48.3	20	-	26.9
60.3	20	-	33.7
76.1	20	-	33.7
88.9	20	26.9	33.7
114.3	30	33.7	42.4
139.7	30	33.7	48.3
168.3	30	33.7	48.3
193.7	40	42.4	48.3
219.1	40	42.4	60.3
244.5	40	42.4	60.3
273.0	40	42.4	60.3
323.9	50	48.3	76.1
355.6	50	48.3	76.1
406.4	50	48.3	88.9
457.0	60	60.3	88.9
508.0	60	60.3	88.9

(All dimensions are in mm)

Note: Partial flattening has been taken as two thirds of the original diameter.

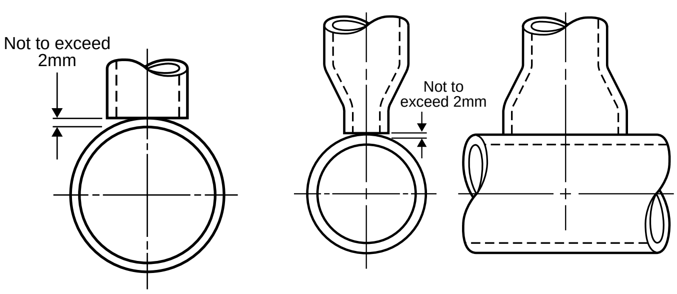


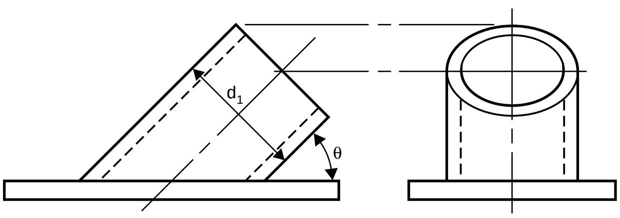
Table 2A

Length of curve of intersection of CHS bracing on a flat plate or RHS main member

Size of bracing	**Angle of intersection θ**										
d_1	**30º**	**35º**	**40º**	**45º**	**50º**	**55º**	**60º**	**65º**	**70º**	**80º**	**90º**
26.9	131	118	109	102	97	93	91	88	87	85	84
33.7	164	148	137	128	122	117	114	111	109	106	106
42.4	206	186	172	161	153	147	143	139	137	133	133
48.3	234	212	196	184	175	168	163	159	156	152	152
60.3	293	264	244	229	218	210	203	198	194	190	189
76.1	369	334	308	290	275	265	256	250	245	239	239
88.9	432	390	360	338	322	309	299	292	286	280	279
114.3	555	501	463	435	414	398	385	376	368	360	359
139.7	678	613	566	532	506	486	471	459	450	439	439
168.3	817	738	682	640	609	585	567	553	542	529	529
193 7	940	850	785	737	701	674	652	636	624	609	609
219.1	1064	961	888	834	793	762	738	720	706	689	688
244.5	1187	1072	991	930	885	850	824	803	788	769	768
273.0	1325	1198	1106	1039	988	949	920	897	880	859	858
323.9	1572	1421	1312	1232	1172	1126	1091	1064	1044	1019	1018
355.6	1726	1560	1441	1353	1287	1237	1198	1168	1146	1119	1117
406.4	1973	1783	1647	1546	1471	1413	1369	1335	1310	1278	1277
457.0	2218	2005	1852	1739	1654	1589	1539	1501	1473	1437	1436
508.0	2466	2228	2058	1933	1839	1767	1711	1669	1637	1598	1596

(All dimensions are in mm)

Length of curve for 90º bracing = πd and for other angles may be taken as $\frac{d_1}{2}\left[1 + \text{Cosec}\,\theta + 3\sqrt{1 + \text{Cosec}^2\,\theta}\right]$

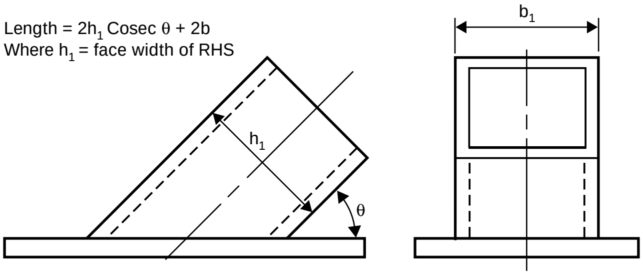


Square sections

Table 2B
Length of intersection of RHS bracing on a flat plate or RHS main member

Size of bracing	Angle of intersection θ										
h_1 x b_1	30º	35º	40º	45º	50º	55º	60º	65º	70º	80º	90º
25 x 25	150	137	128	121	115	111	108	105	103	101	100
30 x 30	180	165	153	145	138	133	129	126	124	121	120
40 x 40	240	219	204	193	184	178	172	168	165	161	160
50 x 50	300	274	256	241	231	222	215	210	206	202	200
60 x 60	360	329	307	290	277	266	259	252	248	242	240
70 x 70	420	384	358	338	323	311	302	294	289	282	280
80 x 80	480	433	409	386	369	355	345	337	330	322	320
90 x 90	540	494	460	435	415	400	388	379	372	363	360
100 x 100	600	549	511	483	461	444	431	421	413	403	400
120 x 120	720	658	613	579	553	533	517	505	495	484	480
140 x 140	840	768	716	676	646	622	603	589	578	564	560
150 x 150	900	823	767	724	692	666	646	631	619	605	600
160 x 160	960	878	818	773	738	711	690	673	661	645	640
180 x 180	1080	988	920	869	830	799	776	757	743	726	720
200 x 200	1200	1097	1022	966	922	888	862	841	826	806	800
250 x 250	1500	1372	1278	1207	1153	1110	1077	1052	1032	1008	1000
300 x 300	1800	1646	1533	1449	1383	1332	1293	1262	1239	1209	1200
350 x 350	2100	1920	1789	1690	1614	1555	1508	1472	1445	1411	1400
400 x 400	2400	2195	2045	1931	1844	1777	1724	1683	1651	1612	1600

(All dimensions are in mm)



Rectangular sections

Size of bracing	Angle of intersection θ									
h_1 x b_1	**30º**	**35º**	**40º**	**45º**	**50º**	**55º**	**60º**	**65º**	**70º**	**80º**	**90º**
50 x 25	250	224	206	191	181	172	165	160	156	152	150
25 x 50	200	187	178	171	165	161	157	155	153	151	150
50 x 30	260	234	216	201	191	182	175	170	166	162	160
30 x 50	220	205	193	185	178	173	169	166	164	161	160
60 x 40	320	289	267	250	237	226	219	212	208	202	200
40 x 60	280	259	244	233	224	218	212	208	205	201	200
80 x 40	400	359	329	306	289	275	265	257	250	242	240
40 x 80	320	299	284	273	264	258	252	248	245	241	240
90 x 50	460	414	380	355	335	320	308	299	292	283	280
50 x 90	380	354	336	321	311	302	295	290	286	282	280
100 x 50	500	449	411	383	361	344	331	321	313	303	300
50 x 100	400	374	356	341	331	322	315	310	306	302	300
100 x 60	520	469	431	403	381	364	351	341	333	323	320
60 x 100	440	409	387	370	357	346	339	332	328	322	320
120 x 60	600	538	493	459	433	413	397	385	375	364	360
60 x120	480	449	427	410	397	386	379	372	368	362	360
120 x 80	640	578	533	499	473	453	437	425	415	404	400
80 x 120	560	519	489	466	449	435	425	417	410	402	400
150 x 100	800	723	667	624	592	566	546	531	519	505	500
100 x 150	700	649	611	583	561	544	531	521	513	503	500
160 x 80	800	718	658	613	578	551	530	513	501	485	480
80 x 160	640	599	569	546	529	515	505	497	490	482	480
200 x 100	1000	897	822	766	722	688	662	641	626	606	600
100 x 200	800	749	711	683	661	644	631	621	613	603	600
250 x 150	1300	1172	1078	1007	953	910	877	852	832	808	800
150 x 250	1100	1023	967	924	892	866	846	831	819	805	800
300 x 200	1600	1446	1333	1249	1183	1132	1093	1062	1039	1009	1000
200 x 300	1400	1297	1222	1166	1122	1088	1062	1041	1026	1006	1000
400 x 200	2000	1795	1645	1531	1444	1377	1324	1283	1251	1212	1200
200 x 400	1600	1497	1422	1366	1322	1288	1262	1241	1226	1206	1200
450 x 250	2300	2069	1900	1773	1675	1599	1539	1493	1458	1414	1400
250 x 450	1900	1772	1678	1607	1553	1510	1477	1452	1432	1408	1400
500 x 300	2600	2343	2156	2014	1905	1821	1755	1703	1664	1615	1600
300 x 500	2200	2046	1933	1849	1783	1732	1693	1 662	1639	1609	1600

(All dimensions are in mm)

Table 2C

Length of curve of intersection of CHS bracing on a CHS main member

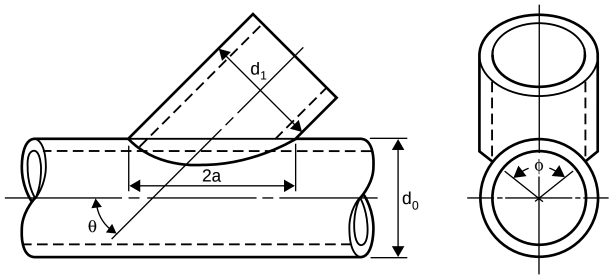
Size of bracing d_1	Size of main d_o	Angle of intersection θ										
		30º	**35º**	**40º**	**45º**	**50º**	**55º**	**60º**	**65º**	**70º**	**80º**	**90º**
26.9	26.9	151	139	131	125	121	118	115	113	112	110	110
	33.7	136	123	115	108	104	100	97	95	93	91	91
	42.4	133	121	112	105	101	97	94	92	90	88	88
33.7	33.7	189	174	164	157	152	148	144	142	140	138	137
	42.4	170	155	144	136	130	125	122	119	117	114	114
	48.3	168	152	141	133	127	123	119	116	114	112	111
42.4	42.4	237	220	207	198	191	186	182	179	176	174	173
	48.3	217	198	185	175	167	162	157	154	151	148	147
	60.3	211	192	178	168	160	154	150	146	144	141	140
48.3	48.3	270	250	236	225	217	212	207	204	201	198	197
	60.3	244	222	206	195	186	179	174	171	168	164	163
	76.1	239	217	201	189	181	174	169	165	162	158	157
60.3	60.3	338	312	294	281	271	264	259	254	251	247	246
	76.1	304	276	257	243	232	224	217	212	209	204	203
	88.9	300	272	252	238	227	218	212	207	204	199	198
	114.3	297	269	249	234	223	214	208	203	199	195	193
76.1	76.1	426	394	371	355	343	333	326	321	317	312	310
	88.9	388	354	329	311	298	288	280	274	270	264	262
	114.3	378	343	318	300	286	275	267	261	256	251	249
	139.7	375	339	314	296	282	271	263	257	252	246	244
88.9	88.9	498	460	434	415	400	389	381	375	370	364	363
	114.3	447	407	378	356	341	328	319	312	307	300	298
	139 7	440	399	370	349	332	320	311	303	298	291	289
114.3	114.3	640	592	558	533	515	501	490	482	476	468	466
	139.7	579	527	490	463	442	427	415	406	399	391	388
	168.3	568	516	478	451	430	414	402	393	386	377	375
	193.7	564	511	474	446	425	409	397	388	381	372	369
	219.1	562	509	471	443	422	406	394	385	377	364	366

(All dimensions are in mm)

Length of curve may be taken as $a+b+3\sqrt{a^2+b^2}$

Where:- $a = \frac{d_1}{2}$ Cosec θ $\qquad \phi = 2\ \text{Sin}^{-1}\ (d_1/d_o)$

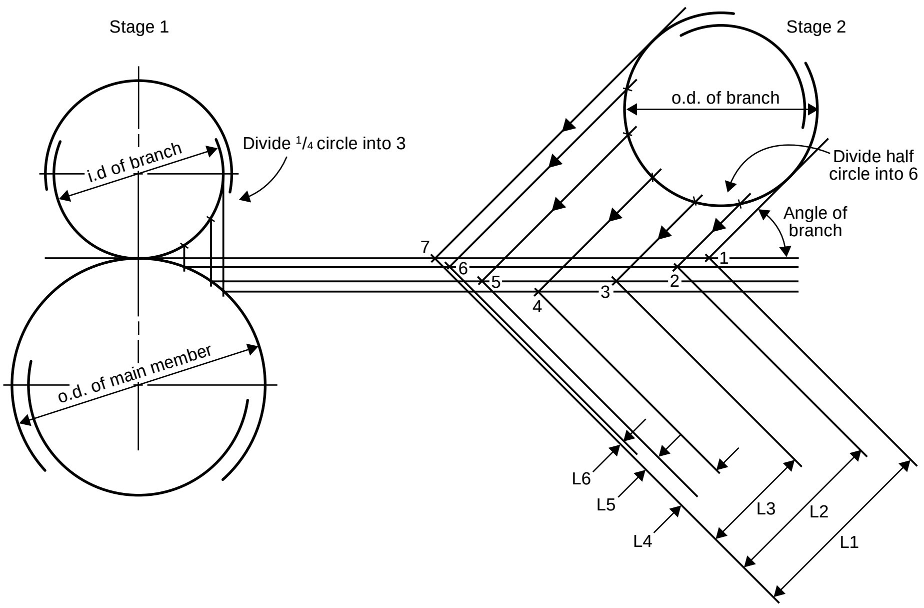
$b = \frac{d_o \phi}{4}$ - Where ϕ is measured in radians (1 radian = 57.296º)



Size of bracing d_1	Size of main d_o	Angle of intersection θ										
		30º	**35º**	**40º**	**45º**	**50º**	**55º**	**60º**	**65º**	**70º**	**80º**	**90º**
139.7	139.7	782	723	682	651	629	612	599	589	582	573	570
	168.3	709	645	600	567	542	523	509	498	490	479	476
	193.7	698	634	588	554	529	510	495	484	476	465	462
	219.1	692	628	582	548	523	503	488	477	468	458	455
	244 5	689	624	578	544	518	499	484	473	464	454	450
168.3	168.3	942	871	821	785	758	737	722	710	701	690	686
	193.7	861	785	731	691	661	639	622	609	599	587	583
	219.1	845	769	714	674	643	620	603	589	579	567	563
	244.5	838	760	705	665	634	611	593	580	569	557	553
	273.0	832	755	699	659	628	604	587	573	563	550	546
193 7	193.7	1085	1003	945	903	872	848	830	817	806	794	790
	219.1	994	907	845	800	766	740	720	705	694	680	676
	244.5	976	888	825	779	745	718	698	683	671	657	652
	273.0	966	877	814	767	732	706	685	664	658	643	639
	323.9	957	867	803	756	721	694	673	658	646	631	627
219.1	219.1	1227	1134	1069	1022	986	960	939	924	912	898	894
	244.5	1128	1030	960	909	870	841	819	802	789	774	769
	273.0	1106	1006	936	883	844	814	792	774	761	745	740
	323.9	1089	988	917	864	824	794	771	753	739	723	718
	355.6	1084	983	910	857	817	787	764	746	732	716	711
244.5	244.5	1369	1266	1193	1140	1101	1071	1048	1031	1018	1002	997
	273.0	1259	1149	1071	1014	971	939	914	895	881	863	858
	323.9	1226	1114	1035	976	932	899	873	853	839	821	815
	355.6	1217	1104	1024	965	921	887	861	842	827	809	803
	406.4	1208	1095	1014	955	910	876	850	830	815	797	791
273.0	273.0	1529	1414	1332	1273	1229	1196	1170	1151	1137	1119	1113
	323.9	1388	1265	1177	1112	1064	1027	999	977	961	941	935
	355.6	1371	1247	1158	1093	1044	1006	978	956	940	919	813
	406.4	1357	1231	1141	1075	1026	988	959	937	921	900	894
323.9	323.9	1814	1677	1580	1510	1458	1419	1389	1366	1349	1328	1321
	355.6	1675	1530	1427	1352	1296	1253	1220	1195	1176	1153	1146
	406.4	1634	1486	1381	1304	1246	1202	1169	1143	1124	1100	1092
	457.0	1616	1467	1361	1283	1224	1180	1146	11 20	1100	1076	1068
	508.0	1605	1455	1349	1270	1212	1167	1132	1106	1086	1062	1054
355.6	355.6	1991	1841	1735	1658	1601	1557	1524	1499	1481	1458	1450
	406.4	1821	1661	1547	1463	1401	1353	1317	1289	1268	1243	1235
	457.0	1789	1627	1511	1426	1362	1314	1277	1248	1227	1201	1193
	508.0	1772	1609	1492	1407	1342	1293	1256	1227	1206	1179	1171
406.4	406.4	2276	2104	1983	1895	1830	1780	1742	1714	1692	1666	1658
	457.0	2089	1906	1776	1681	1610	1556	1514	1483	1459	1430	1421
	508.0	2051	1866	1734	1638	1565	1510	1468	1435	1411	1381	1372
457.0	457.0	2559	2366	2230	2131	2057	2002	1959	1927	1903	1873	1864
	508.0	2356	2151	2005	1898	1818	1758	1711	1626	1649	1617	1607
508.0	508.0	2845	2630	2479	2369	2287	2225	2178	2142	2115	2082	2072

(All dimensions are in mm)

Appendix 2

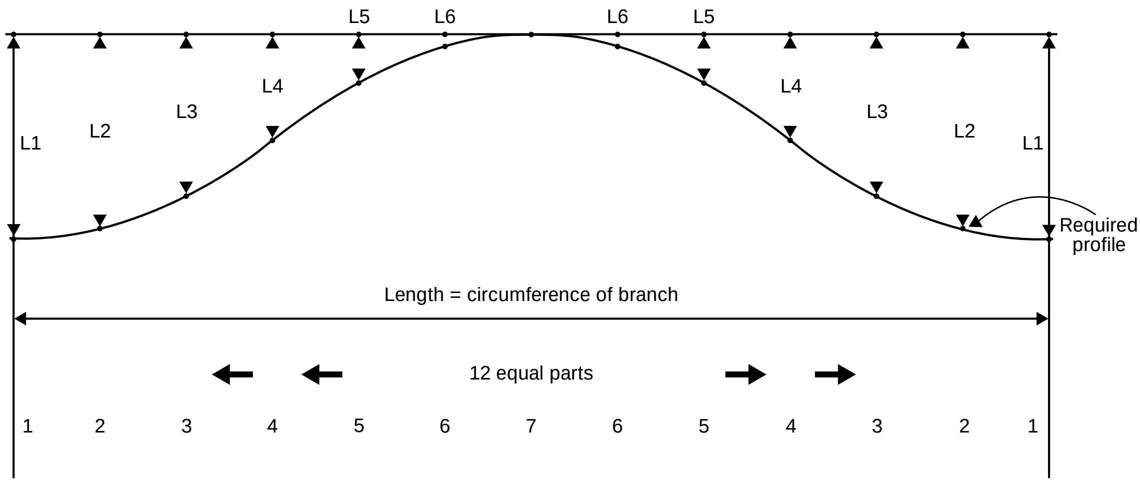


Templates for profile shaping ends of CHS bracing to fit CHS main member

The usual procedure for making templates for marking-off for profile-shaping the ends of CHS is as follows:

1. Draw a vertical line with a horizontal line cutting it. Above the horizontal line draw a circle equal in diameter to the INTERNAL DIAMETER of the branch (bracing) and divide the quarter circle into three equal parts. Below the horizontal line draw an arc equal in diameter to the OUTSIDE DIAMETER of the main member. Project the divisions from the quarter-circle on to the arc and draw horizontal lines from the points where these intersect.

2. Draw a separate circle equal in diameter to the OUTSIDE DIAMETER of the branch, and from its centre draw a line to cut the horizontal lines at the angle required between the branch and the main member. Divide half of this circle into 6 equal parts and join these to the horizontal lines from stage 1, numbering the points of intersection 1 to 7.



3. Now on a card or paper template draw a straight line equal in length to the circumference of the branch and divide it into 12 equal parts numbered as shown. Mark off the length L1 to L6 from stage 2 on the template as shown and join up their extremities with a fair curve. This gives the shape of the profile to which the end of the branch should be cut. The profile template may then be cut out and wrapped around the end of the branch tube for marking-off purposes.

Reference standards & documents

Structural steel hollow sections & materials:

EN 10210-1 -	Hot finished structural hollow sections of non-alloy and fine grain structural steels- Part 1: Technical delivery requirements.
EN 10210-2 -	Hot finished structural hollow sections of non-alloy and fine grain structural steels- Part 2: Tolerances, dimensions and sectional properties.
EN 10219-1 -	Cold formed welded structural hollow sections of non-alloy and fine grain steels- Part 1: Technical delivery requirements.
EN 10219-2 -	Cold formed welded structural hollow sections of non-alloy and fine grain steels- Part 2: Tolerances, dimensions and sectional properties.
BS 7668 -	Weldable structural steels: Hot finished structural hollow sections in weather resistant steels.
TS30 -	Corus Tubes specification for Strongbox® 235

Welding:

EN 439 -	Welding Consumables. Shielding gases for arc welding and cutting.
EN 440 -	Welding Consumables. Wire electrodes and deposits for gas shielded metal arc welding of non-alloy and fine grain steels. Classification.
EN 499 -	Welding Consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels. Classification.
EN 758 -	Welding Consumables. Tubular cored electrodes for metal arc welding with or without a gas shield of non-alloy and fine grain steels. Classification.
EN 1011-1 -	Welding - Recommendations for welding of metallic materials - Part 1: General guidance for arc welding.
EN 1011-2 -	Welding - Recommendations for welding of metallic materials - Part 2 : Ferritic steels.
EN 29692 -	Metal-arc welding with covered electrode, gas-shielded. Metal-arc welding and gas welding - Joint preparations for steel.
13920-2 -	

Testing & inspection:

EN 287-1 -	Approval testing of welders for fusion welding - Part 1 : Steels.
EN 288-1 -	Specification and approval of welding procedure for metallic materials - Part 1 : General rules for fusion welding.
EN 288-3 -	Specification and approval of welding procedure for metallic materials - Part 3 : Welding procedure tests for the arc welding of steels.
EN 288-8 -	Specification and approval of welding procedure for metallic materials - Part 8 : Approval by a pre-production welding test.
EN 970 -	Non-destructive examination of welds - Visual examination.
EN 1290 -	Non-destructive examination of welds - Magnetic particle examination of welds.
EN 1714 -	Non-destructive examination of welds - Ultrasonic examination of welded joints.
EN 12062 -	Non-destructive examination of welds - General rules, for metallic materials.
BS 4872: Part 1 -	Approval testing of welders when welding procedure approval is not required Part 1 - Fusion welding of steel.

Application standard:

BS 5400 -	Steel, concrete and composite bridges.
BS 5950-1: 2000 -	Structural use of steelwork in building Part 1 - Code of practice for design -Rolled and welded sections.
ENV 1993 :	Eurocode 3: Design of steel structures.
ENV 1994 :	Eurocode 4: Design of composite steel and concrete structures.
ENV 1090-1 -	Execution of Steel Structures - Part 1 : General Rules and Rules for Buildings.
ENV 1090-4 -	Execution of Steel Structures - Part 4 : Supplementary Rules for Hollow Section Structures.

Note: EN's and ENV's are published in the UK by The British Standards Institute as BS EN's and BS DD ENV's respectively 'pr' designates a draft standard

General

'Health and Safety in Welding and Allied Processes' and 'Safe Working with Arc Welding'
obtainable from:
The Welding Institute,Abington Hall, Abington, Cambridge, CB1 6AL.
Tel: O1223 891162
Fax: 01223 892588
E-mail: twi@twi.co.uk

'National Structural Steelwork Specification for Building Construction'
obtainable from:
British Constructional Steelwork Association Ltd ,4, Whitehall Court, Westminster, London, SW1A 2ES.
Tel: 020 7839 8566
Fax: 020 7976 1634
E-mail: postroom@steelconstruction.org

***CIDECT design guides**

No.1 - 'Design Guide for Circular Hollow Section (CHS) Joints under Predominantly Static Loading', Verlag TUV Rheinland, Cologne, Germany, 1991, ISBN 3-88585-975-0.

No.3- 'Design Guide for Rectangular Hollow Section (RHS) Joints under Predominantly Static Loading', Verlag TUV Rheinland, Cologne, Germany, 1992, ISBN 3-8249-0089-0.

No.6 - 'Design Guide for Structural Hollow Sections in Mechanical Applications', Verlag TUV Rheinland, Cologne, Germany, 1995, ISBN 3-8249-0302-4.

No.7 - 'Design Guide for Structural Hollow Sections - Fabrication, Assembly and Erection', Verlag TUV Rheinland, Cologne, Germany, 1998, ISBN 3-8249-0443-8.

***CIDECT Design Guides** obtainable from:
The Steel Construction Institute, Silwood Park, Ascot, Berkshire, SL5 7QN.
Tel: 01344 623345
Fax: 01344 622944
E-mail: publications@steel-sci.com

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