Australian/New Zealand Standard™

Cold-formed structural steel hollow sections

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Australian/New Zealand Standard™

Cold-formed structural steel hollow sections

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PREFACE

This Standard was prepared by the Standards Australia/Standards New Zealand Committee BD-023 on Structural Steel, to supersede AS 1163—1991, *Structural steel hollow sections*.

This edition incorporates the following major changes to the previous edition:

(a) The adoption by Standards New Zealand to make it a joint Australian/New Zealand Standard (i.e. AS/NZS 1163).

(b) Guidance Note on chemical composition classes, which considers suitability for after-fabrication hot-dip galvanizing.

(c) The provision for non-destructive testing of the hollow section longitudinal weld seam.

(d) Qualification for impact test requirements for hollow sections with nominal thickness less than 6 mm.

(e) Increased groupings for elongation results for hollow sections based on the diameter or face slenderness.

(f) A minimum weld seam or parent metal thickness after external scarfing or removal of surface defects, or both.

(g) The requirement for individual length marking in order to comply with this Standard. This requirement does not apply to New Zealand.

(h) Further information in the 'informative' appendix on 'Purchasing Guidelines'.

(i) The mandatory requirement for test reports and test certificates to be performed by third-party accredited laboratories.

(j) The introduction of mandatory minimum information required on test certificates.

(k) The inclusion of Appendix B on 'Product Conformity' as a mandatory provision for conformance with this Standard.

(l) The introduction of new 'informative' Appendix C on 'Basis of Assessment of Compliance of Mechanical Properties by Statistical Sampling'.

(m) Where applicable, the alignment of technical requirements, dimension symbols and section tolerances with ISO 10799, *Structural steels—Cold-formed, welded, structural hollow sections—Technical delivery requirements,* ISO 4019, *Structural steels—Cold-formed, welded, structural hollow sections, dimensional and section properties,* and EN 10219, *Cold formed welded structural hollow sections of non-alloy and fine grain steels.*

(n) Where possible, the alignment of contents with AS 3597, *Structural and pressure vessel steel—Quenched and tempered plate,* AS/NZS 3678, *Structural steel—Hot-rolled plates, floorplates and slabs*, AS/NZS 3679.1, *Structural steel—Hot-rolled bars and sections* and AS/NZS 3679.2, *Structural steel—Welded I sections*.

To permit the steel industries time to adjust to the new Standard, the 1991 version of AS 1163 will remain available superseded and will be withdrawn 12 months from the date of publication of this Standard.

A statement expressed in mandatory terms in a Note to a table is deemed to be a requirement of this Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Cold-formed structural steel hollow sections

1 SCOPE

This Standard specifies the requirements for cold-formed, electric resistance-welded, carbon steel hollow sections used for structural purposes. It considers three strength grades, with or without impact properties, that are suitable for welding.

It is applicable to structural hollow sections formed cold without subsequent heat treatment.

The Standard does not cover submerged arc-welded, helically welded or U'ed and O'ed steel hollow sections.

NOTE: For guidelines on information to be supplied at the time of enquiry or order, see Appendix A.

Means for demonstrating conformance with this Standard are given in Appendix B.

2 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard:

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

AS	
1391	Metallic materials—Tensile testing at ambient temperature
1544	Methods for impact tests on metals
1544.2	Part 2: Charpy V-notch
1733	Methods for the determination of grain size in metals
2706	Numerical values—Rounding and interpretation of limiting values
4750	Electrogalvanized (zinc) coatings on ferrous hollow and open section
AS/NZS	
1050	Methods for the analysis of iron and steel
1050.1	Part 1: Sampling iron and steel for chemical analysis
1554	Structural steel welding
1554.1	Part 1: Welding of steel structures
4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
4792	Hot-dip galvanized (zinc) coatings on ferrous hollow sections, applied by a continuous or a specialized process
4855	Welding consumables—Covered electrodes for manual metal arc welding of non-alloy and fine grain steels—Classification
ISO	
643	Steels—Micrographic determination of the apparent grain size
2566	Steel—Conversion of elongation values
2566-1	Part 1: Carbon and low alloy steels
7966	Acceptance control charts

ISO	
9304	Seamless and welded (except sub-merged arc-welded) steel tubes for pressure purposes—Eddy current testing for the detection of imperfections
9402	Seamless and welded (except sub-merged arc-welded) steel tubes for pressure purposes—Full peripheral magnetic transducer/flux leakage testing of ferromagnetic steel tubes for the detection of longitudinal imperfections
9764	Electric resistance and induction welded steel tubes for pressure purposes—Ultrasonic testing of the weld seam for the detection of longitudinal imperfections
14284	Steel and iron—Sampling and preparation of samples for the determination of chemical composition

3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

3.1 Batch

Hollow sections of the same size, nominal thickness and grade manufactured from the same cast and tube forming process (tube mill).

3.2 Cast analysis

Chemical analysis determined from a test sample taken during steel casting.

3.3 Cold-formed hollow section

Hollow section formed and shaped at ambient temperature from a single strip of steel, both edges of which are continuously welded by the contact tip or induction coil electric resistance process.

3.4 Longitudinal direction

Direction parallel to the longitudinal weld seam.

3.5 Longitudinal weld seam

Continuous weld joining both edges of the single strip of steel used to form a hollow section.

3.6 Product analysis

Chemical analysis determined from a test sample of the finished material.

3.7 Structural hollow sections

Tube intended to be used for structural purposes.

3.8 Testing

Mechanical and chemical analysis tests as required by this Standard.

3.9 Test piece

Piece prepared for testing, made from a test specimen by a mechanical operation.

3.10 Test sample

Portion of material or product or a group of items selected from a batch or group by sampling.

3.11 Test specimen

Portion or a single item taken from the test sample for the purpose of applying a particular test.

3.12 Transverse direction

Direction at right angles to the longitudinal weld seam.

3.13 Unit

Length of hollow section.

4 NOTATION

The symbols used in this Standard are listed in Table 1.

5 DESIGNATION

All grades shall be designated in the format shown in the following example:

AS/NZS 1163–C350L0

where

AS/NZS 1163	=	number of this Standard
C	=	cold-formed sections
350	=	minimum yield strength in MPa (see Table 6)
L	=	guaranteed impact properties of the material (when applicable)
0	=	low temperature impact test at 0°C (when applicable)

6 MANUFACTURING PROCESS—STEEL FEED

The steel shall be made by the basic oxygen process or an electric process at the steel manufacturer's option. The steelmaking process shall be shown on test certificates.

Additional refining by vacuum arc remelt, electroslag refining or secondary steelmaking practices such as vacuum degassing or calcium injection, or both, is permitted.

The steel shall be fine-grained and be made from fully killed, continuously cast steels. The coil shall be produced on a hot strip mill.

TABLE 1

NOTATION

Symbol	Unit	Description
A	mm^2	cross-sectional area
A_g	mm^2	gross area of the cross-section
b	mm	nominal length of side of a square hollow section; nominal length of the shorter side of a rectangular hollow section
C	mm^3	torsion modulus
c_1, c_2	mm	length of external corner profile of a square or rectangular hollow section
d	mm	nominal length of the longer side of a rectangular hollow section
d_o	mm	nominal outside diameter of a circular hollow section
$d_{o\max}$, $d_{o\min}$	mm	maximum and minimum outside external diameter of a circular hollow section, measured in the same plane
e	mm	deviation from straightness
I	mm^4	second moment of area
J	mm^4	torsion constant (polar moment of inertia for circular hollow sections only)
L	mm	length
L_o	mm	gauge length
m	kg/m	mass per unit length
o	%	out-of-roundness
r	mm	radius of gyration
r_o	mm	external corner radius of a square or rectangular hollow section
S	mm^3	plastic section modulus
S_o	mm^2	original cross-sectional area
t	mm	nominal thickness
v	mm	total twist
v_1	mm	twist measured at one end of a section
x_1	mm	concavity of a side of a square or rectangular hollow section
x_2	mm	convexity of a side of a square or rectangular hollow section
Z	mm^3	elastic section modulus
θ	degrees	angle between adjacent sides of a square or rectangular hollow section

7 CHEMICAL COMPOSITION

7.1 General

The method of sampling for chemical analysis shall be in accordance with ISO 14284. Chemical composition shall be determined in accordance with AS/NZS 1050.1.

7.2 Cast analysis

A chemical analysis of the steel from each cast shall be made to determine the proportions of the specified elements.

The reported cast analysis of the steel from which a hollow section is manufactured shall conform to the limits given in Table 2 for the appropriate grade.

7.3 Product analysis

The chemical analysis of the finished product is not a requirement of this Standard. When the steel is subject to a product analysis, the analysis shall conform to the limits given in Table 2 for the appropriate grade.

TABLE 2

CHEMICAL COMPOSITION

Grades (see Note 1)	Chemical composition (cast or product analysis) (see Note 2) % max.										
	C	Si	Mn	P	S	Cr	Mo	Al (see Note 3)	Ti	Micro-alloying elements	CE (see Note 4)
C250, C250L0	0.12	0.05	0.50	0.03	0.03	0.15	0.10	0.10	0.04	0.03 (see Note 5)	0.25
C350, C350L0	0.20	0.45	1.60	0.03	0.03	0.30	0.10	0.10	0.04	0.15 (see Note 6)	0.43
C450, C450L0	0.20	0.45	1.70	0.03	0.03	0.50	0.35	0.10	0.04	0.15 (see Note 6)	0.43

NOTES:

1 The use of sulphide modification manufacturing techniques for these grades is permitted.

2 The following elements may be present to the limits stated:

(a) Copper 0.25%.

(b) Nickel 0.25%.

3 Limits specified are for soluble or total aluminium.

4 Carbon equivalent (CE) is calculated from the following equation:

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

5 Applies to niobium and vanadium only. However, niobium greater than 0.010% is not permitted.

6 Applies to niobium, vanadium and titanium only. However, vanadium greater than 0.10% is not permitted.

7.4 Suitability for zinc coating

Zinc coating requirements shall be agreed between the manufacturer and the purchaser.

Hot-dip galvanized coating requirements shall be as specified in AS/NZS 4680, AS 4750 or AS/NZS 4792, as appropriate.

NOTE: The suitability for hot-dipped zinc coating should be agreed between the manufacturer and the purchaser (see Paragraph A2 of Appendix A). As a guide only, the following steel chemistry percentage limits are noted by the industry associated with hot-dip galvanizing (i.e. Galvanizers Association of Australia (GAA), Galvanizers Association of New Zealand (GANZ)):

(a) Suitable: $Si \leq 0.060$; $Si + 2.5P \leq 0.090$.

(b) Suitable: $0.14 < Si \leq 0.24$.

(c) Caution: $0.040 < Si \leq 0.14$.

(d) For $Si > 0.24$, it is recommended that the purchaser and supplier agree on the adequacy of the product for hot-dip galvanizing.

Further information may be obtained from hot-dip galvanizers, hollow section and steel manufacturers.

Unless further advice is provided, it is recommended that a sample be hot-dip galvanized to determine the actual performance for any given process, bath and tube characteristics.

8 MANUFACTURING TOLERANCES

8.1 General

Tolerances and limits on the dimensions and mass of cold-formed hollow sections shall conform with the values given in—

(a) Table 3, for shape and mass;

(b) Table 4, for external corner profiles; and

(c) Table 5, for length.

Where relevant, Tables 3, 4 and 5 shall be read in conjunction with Clause 8.2.

The internal corners of square and rectangular hollow sections shall be rounded.

NOTE: The internal corner profile is not specified.

TABLE 3

TOLERANCES FOR SHAPE AND MASS

Characteristic	Circular hollow sections	Square and rectangular hollow sections
External dimensions (d_o, d and b)	±1%, with a minimum of ±0.5 mm and a maximum of ±10 mm	±1%, with minimum of ±0.5 mm
Thickness (t)	For $d_o \leq 406.4$ mm: ±10% For $d_o > 406.4$ mm: ±10% with a max of ±2 mm	±10%
Out-of-roundness (o)	2% for hollow sections having a diameter to thickness ratio not exceeding 100 (see Note 1)	—
Concavity/convexity (see Note 2)	—	Max. 0.8% or 0.5 mm, whichever is greater
Squareness of sides	—	90°±1°
External corner profile	—	See Table 4
Twist (v)	—	2 +0.5 mm/m length
Straightness (see Note 3)	0.20% of total length	0.15% of total length
Mass (m) per unit length	Not less than 0.96 times the specified mass (Note 4) on individual lengths	

NOTES:

1 Where the diameter to thickness ratio exceeds 100, the tolerance on out-of-roundness becomes the subject of agreement between the manufacturer and purchaser.

2 The tolerance on convexity and concavity is independent of the tolerance on external dimensions.

3 The straightness tolerance applies to straightness in any one plane.

4 In lieu of any other requirement, the specified mass is considered to be the nominal mass as noted in Clause 16.

TABLE 4

EXTERNAL CORNER PROFILE

Perimeter mm	External corner profile (c_1, c_2 or r_o) (see Note) mm
Equivalent to 50 × 50 or less	1.5t to 3.0t
Equivalent to greater than 50 × 50	1.8t to 3.0t

NOTE: The sides need not be tangential to the corner arcs.

TABLE 5

TOLERANCES ON LENGTH (see Note)

Type of length	Range mm	Tolerance
Random length	4000 to 16 000 with a range of 2000 per order item	10% of sections supplied may be below the minimum for the ordered range but not less than 75% of the minimum
Mill (or 'unspecified') length	All	+100 mm 0
Precision length	<6000	+5 mm 0
	≥6000 ≤10 000	+15 mm 0
	>10 000	+5 mm + 1 mm/m 0

NOTE: The purchaser shall indicate in the enquiry and order the type of length required and the length or length range, as appropriate. Alternatively, length tolerances shall be specified at the time of order.

8.2 Measurement of size and shape

8.2.1 *General*

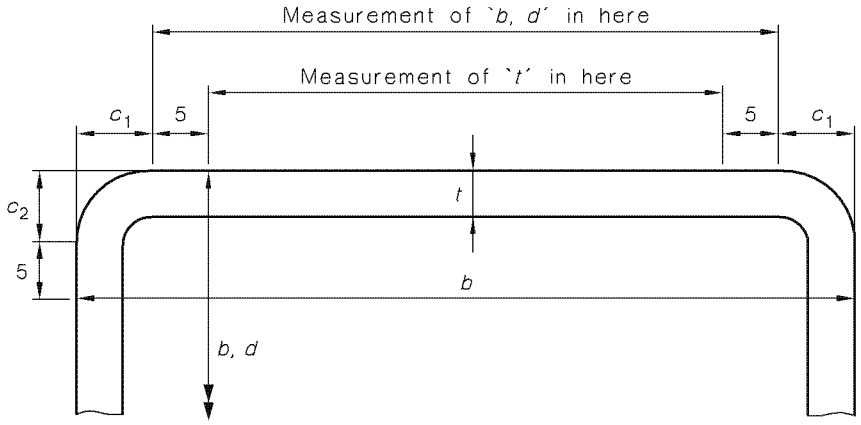
All external dimensions shall be measured at a distance from the end of the hollow section of not less than d_o for circular sections, b for square sections and d for rectangular sections, with a minimum of 100 mm.

8.2.2 *External dimensions*

For circular hollow sections, the diameter (d_o) shall be measured.

The limiting cross-sectional positions for measuring b and d of square and rectangular hollow sections are shown in Figure 1.

NOTE:A caliper gauge, circumference tape or other suitable device may be used at the discretion of the manufacturer.



NOTE: The 5 mm dimension is a maximum when measuring b or d, and a minimum when measuring t.

DIMENSIONS IN MILLIMETRES

FIGURE 1 LIMITING CROSS-SECTIONAL POSITIONS FOR MEASURING DIMENSIONS b, d AND t FOR SQUARE OR RECTANGULAR HOLLOW SECTIONS

8.2.3 *Thickness*

The thickness (t) shall be measured at a position of not less than $2t$ or 25 mm, whichever is lesser, from the weld seam.

The limiting cross-sectional positions for measuring the thickness of square and rectangular hollow sections are shown in Figure 1.

NOTE: Thickness is normally measured within a distance of half the outside diameter or half the longer side length from the end of the section.

8.2.4 *Out-of-roundness*

The out-of-roundness (o) of a circular hollow section shall be calculated as a percentage, from the following equation:

$$o = \frac{d_{o_{max.}} - d_{o_{min.}}}{d_o} \times 100 \qquad \ldots 8.2.4$$

8.2.5 *Concavity and convexity*

The concavity (x_1) or the convexity (x_2) of the sides of a square or rectangular hollow section shall be measured as shown in Figure 2.

The percentage concavity or convexity shall be calculated as follows:

$$\frac{x_1}{b} \times 100\%$$

$$\frac{x_2}{b} \times 100\%$$

$$\frac{x_1}{d} \times 100\%$$

$$\frac{x_2}{d} \times 100\%$$

where b and d are the lengths of the sides containing the concavity (x_1) or the convexity (x_2).

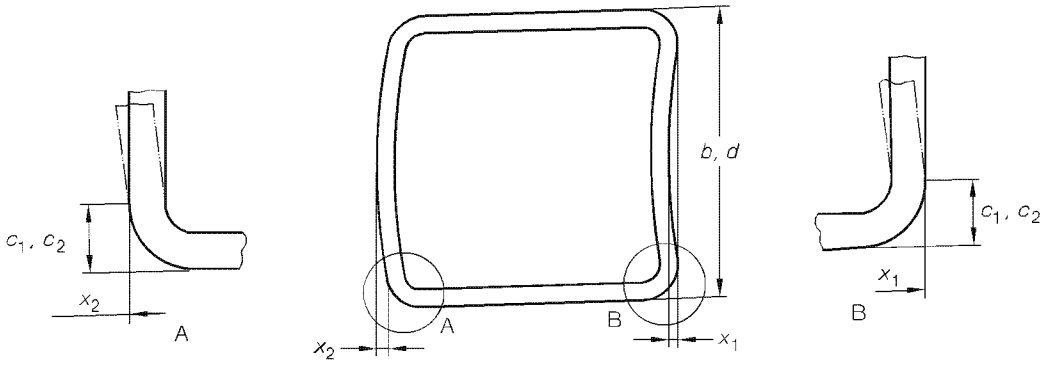


FIGURE 2 MEASUREMENT OF CONCAVITY/CONVEXITY OF SQUARE OR RECTANGULAR HOLLOW SECTIONS

8.2.6 *Squareness of sides*

The deviation from squareness of the sides of a square or rectangular hollow section is defined as the difference between 90° and θ as shown in Figure 3.

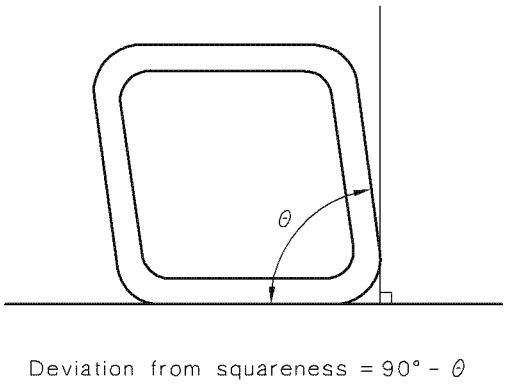


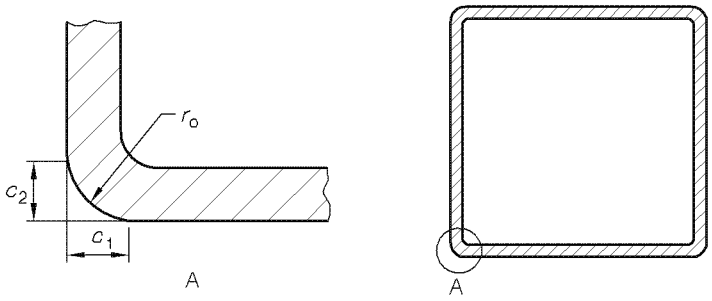
FIGURE 3 SQUARENESS OF SIDES OF SQUARE OR RECTANGULAR HOLLOW SECTIONS

8.2.7 *External corner profile*

The external corner profile of a square or rectangular hollow section shall be measured at the discretion of the manufacturer, as follows:

(a) Measure the external corner radius (r_o). Use a radius gauge or other suitable device.

(b) Measure the length of the external corner profile (c_1 and c_2) (see Figure 4).



NOTE: c_1 and c_2 can be measured as the distance between the intersection of the flat side and the corner arc and the intersection of the line projections of the flat sides to the corner.

FIGURE 4 EXTERNAL CORNER PROFILE OF SQUARE OR RECTANGULAR HOLLOW SECTIONS

8.2.8 *Twist*

The total twist (v) in a square or rectangular hollow section shall be determined, at the discretion of the manufacturer, as follows:

(a) Place the hollow section on a horizontal surface with one side at one end pressed flat against the surface. At the opposite end of the hollow section, determine the difference of v in the height of the two lower corners from a horizontal surface (see Figure 5).

(b) Measure v with a spirit level and micrometer (screw) gauge or other suitable device. The reference length of the spirit level shall be the distance between the intersection of the flat sides and the external corner profile (see Figure 6). v is the difference between the values v_1 (see Figure 6) measured at each end of the section.

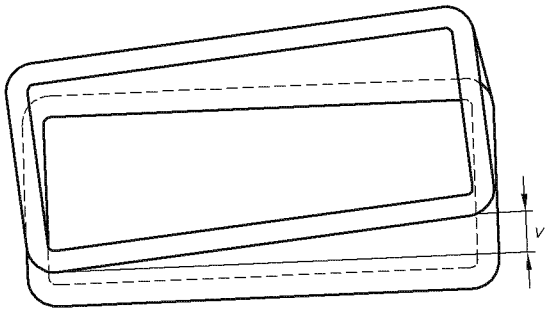
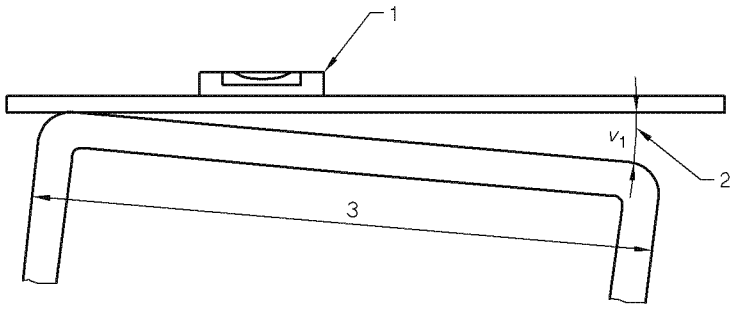


FIGURE 5 TOTAL TWIST OF SQUARE OR RECTANGULAR HOLLOW SECTIONS



Legend:
1 Spirit level
2 Micrometer gauge
3 *d* for rectangular sections, *b* for square sections

FIGURE 6 MEASUREMENT OF TWIST

8.2.9 *Straightness*

The deviation from straightness (e) of the total length of a hollow section shall be measured at the point of maximum departure of the section from a straight line connecting its two ends, as shown in Figure 7. The percentage deviation from straightness shall be calculated as follows:

$$\frac{e}{L} \times 100\%$$

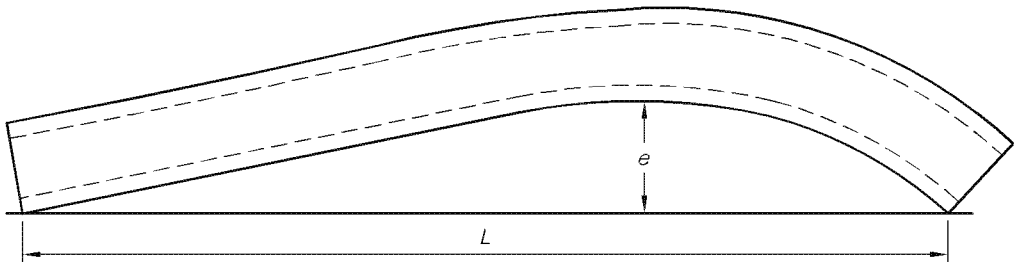


FIGURE 7 MEASUREMENT OF DEVIATION FROM STRAIGHTNESS

9 FREEDOM FROM DEFECTS

9.1 General

The section shall be free from lamination, surface flaws and other defects detrimental to its use for structural purposes.

9.2 Weld seam

9.2.1 *Position*

For rectangular and square hollow sections, the weld seam shall not be placed within a distance of three times the wall thickness from the apex of the corner radius.

NOTES:

1 The apex of the corner radius is defined as the intersection point of the lines emanating from two external adjoining faces of the hollow section.

2 Some end-use applications may require the weld seam to be placed close to the corner radius. This should be noted at the time of enquiry or order (see Appendix A) with the finished hollow sections not exhibiting any cracking or brittle behaviour. For the adequate performance of the corner radius and weld seam, such hollow sections are not considered to be in the scope of this Standard.

9.2.2 *Defects*

At the manufacturer's discretion, the weld seam of welded structural hollow sections may be subjected to non-destructive examination (NDE). The NDE may be carried out either on the circular shape prior to final forming or on the hollow sections after final forming.

Where NDE is employed, the weld seam shall be tested in accordance with one of the following:

(a) ISO 9304 to acceptance Level L4, except that the rotating tube/pancake coil technique shall not be permitted.

(b) ISO 9402 or ISO 9764, with the exception that the acceptance level shall be based on, at minimum, the use of N 15 internal/external notches and for the application of ISO 9402, a notch of no greater than twice the depth of the reference notch, with a maximum of 1.0 mm, shall apply.

10 TESTING

10.1 Selection of test samples

Test pieces for tensile tests, impact tests and cold-flattening tests shall be taken from a single test sample.

Test pieces shall be in the same condition as the sections that they represent.

10.2 Position and orientation of test pieces

10.2.1 *Tensile test and impact test*

The test piece shall be cut such that the major axis is in the longitudinal direction and shall be selected from any position along the length of the test specimen such that the requirements of Clause 10.5.2 or 10.5.3 are complied with.

10.2.2 *Cold flattening test*

The test piece shall be cut in the transverse direction and shall be cut from one end of a test specimen that contains a longitudinal weld seam.

10.3 Number of mechanical tests

One of the methods specified in Appendix B shall be used.

10.4 Retests

The test piece shall be cut from a test sample from the same batch.

Retests procedure shall be as described in Appendix B.

10.5 Preparation of test pieces for mechanical testing

10.5.1 *General*

It shall be permissible to discard a test piece that shows defective machining or develops flaws during preparation and to submit another test piece.

10.5.2 *Tensile test pieces*

10.5.2.1 *Form of test piece*

The tensile piece shall be in the form given in either Item (a) or (b) as follows:

(a) A test piece with dimensions conforming to those specified in AS 1391, cut from the test specimen. The cross-section location of the test piece shall be as specified in Clause 10.5.2.2 or Clause 10.5.2.3, as appropriate.

(b) A length of the full section test specimen.

The test piece shall be aged in accordance with Clause 10.5.4.

10.5.2.2 *Circular hollow sections (CHS)*

For a length of circular hollow section, the test piece shall be taken at approximately 90° from the weld seam (see Figure 8(a)).

The tensile test piece cut from a test specimen shall not be flattened between gauge marks.

10.5.2.3 *Rectangular hollow section (RHS)*

The tensile test piece cut from a test specimen shall be taken from any side midway between and excluding the corners (see Figure 8(b)). The test piece shall not include a longitudinal weld seam.

10.5.3 *Impact test piece*

Three test pieces shall be prepared from each test specimen and cut parallel to the longitudinal axis of the hollow section, with the axis of the notch perpendicular to the rolled surface of the section (see Figure 8).

For circular and rectangular hollow sections, the cross-section location of the test piece shall be as specified in Figure 8 where, for rectangular hollow sections, it shall also be remote from the weld seam. The test piece shall be prepared in accordance with AS 1544.2 using, where necessary, the largest practicable subsidiary test piece with a width not less than 5 mm. For standard sized test specimen (i.e. 10 × 10 mm), the finally machined test pieces shall be extracted from the mid-thickness of the hollow section wall.

The test piece shall be aged in accordance with Clause 10.5.4.

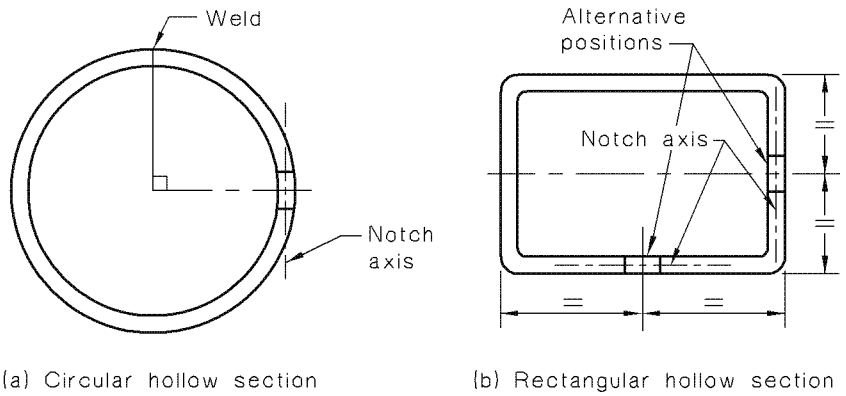


FIGURE 8 CROSS-SECTION POSITION OF TEST SPECIMEN FOR TENSILE AND IMPACT TESTS

10.5.4 *Ageing treatment*

Prior to tensile or impact testing, the test pieces shall be aged by heating to a temperature between 150°C and 200°C for not less than 15 min.

10.5.5 *Cold flattening test*

The test piece shall be taken in the form of a cross-section from one end of a finished length of a circular hollow section which contains a longitudinal weld seam. The length of the test piece shall be not less than 40 mm.

10.6 Mechanical testing

10.6.1 *Tensile test*

The tensile test shall be carried out in accordance with AS 1391.

Elongation results shall be reported on a gauge length $L_o = 5.65\sqrt{S_o}$, where S_o is the original cross-sectional area. Conversion of results from a non-proportional gauge length shall be in accordance with ISO 2566-1.

10.6.2 *Impact test*

Impact test requirements shall comply with Clauses 10.6.2.1 or 10.6.2.2.

10.6.2.1 *Hollow sections with nominal thickness of 6 mm or greater*

Impact tests shall be performed at 0°C in accordance with AS 1544.2.

10.6.2.2 *Hollow sections with nominal thickness less than 6 mm*

Impact tests are not required at 0°C in accordance with AS 1544.2 subject to satisfying one or both of the following:

(a) Using the same steel supplier, steel grade, steel processing for hollow sections complying with Clause 10.6.2.1.

(b) Ensuring that the finished product ferrite grain size is greater than or equal to 6 as verified by the method specified in AS 1733 (ISO 643), when the steel feed is aluminium killed. Alternatively, when aluminium is used as the grain-refining element, the grain size requirement shall be deemed to have been fulfilled if the cast analysis shows the aluminium content to be not less than 0.020% total aluminium, or alternatively, 0.015% soluble aluminium. In these cases, verification of the grain size shall not be required.

This method of verification is only acceptable when the following evidence is provided by the manufacturer or supplier:

(i) Confirmation of compliance with Clause 6 of this Standard.

10.6.3 *Cold flattening test*

The flattening test piece shall be flattened at room temperature between two parallel plane surfaces with the weld seam located as follows in relation to the direction of flattening:

(a) For $d_o \leq 60$ mm: 45 degrees

(b) For $d_o > 60$ mm: 90 degrees

The test piece shall be flattened until the distance between the surfaces is $0.75d_o$ or less.

11 MECHANICAL PROPERTIES

11.1 Tensile test

When tested in accordance with Clause 10.6.1, the yield strength, tensile strength and elongation of the test piece shall conform to the limits given in Table 6 for the appropriate grade.

11.2 Impact test

When tested in accordance with Clause 10.6.2.1, the absorbed energy value resulting from—

(a) each individual test; and

(b) the average of three tests,

shall conform to the specified values given in Table 7 for the appropriate grade.

11.3 Cold flattening test

When tested in accordance with Clause 10.6.3, a test piece taken from a circular section with a longitudinal weld seam shall show no signs of cracks or flaws. Superficial ruptures arising from surface imperfections shall not be cause for rejection.

TABLE 6

TENSILE TEST REQUIREMENTS

Grade	Minimum yield strength	Minimum tensile strength	Minimum elongation as a proportion of the gauge length of $5.65\sqrt{S_o}$ % (See Note)					
			Circular hollow sections d_o/t			Rectangular hollow sections b/t, d/t		
	MPa	MPa	≤15	>15 ≤30	>30	≤15	>15 ≤30	>30
C250, C250L0	250	320	18	20	22	14	16	18
C350, C350L0	350	430	16	18	20	12	14	16
C450, C450L0	450	500	12	14	16	10	12	14

NOTE: These limits apply to the face from which the tensile test is taken.

TABLE 7

CHARPY V-NOTCH IMPACT TEST REQUIREMENTS

Grade	Test temperature	Minimum absorbed energy, Joules					
		Size of test piece					
		10 mm × 10 mm		10 mm × 7.5 mm		10 mm × 5 mm	
	°C	Average of 3 tests	Individual test	Average of 3 tests	Individual test	Average of 3 tests	Individual test
C250L0 C350L0 C450L0	0	27	20	22	16	18	13

12 REMOVAL OF SURFACE DEFECTS

12.1 Grinding

When removal of surface defects by grinding is adopted, the ground area shall be well-transitioned and the remaining wall thickness in the ground areas shall be not less than 90% of the nominal thickness.

12.2 Depositing weld metal

Welding used in the repair of surface defects shall be performed in accordance with AS/NZS 1554.1, using low-hydrogen electrodes complying with AS/NZS 4855.

Welds shall be sound, the weld being thoroughly fused without undercutting or overlap. The weld metal shall project at least 1.5 mm above the rolled surface and the projecting metal shall be removed by grinding flush with the rolled surface.

12.3 Removal of upset

Hollow sections produced by electric resistance welding shall have the external upset removed.

After removal of the external upset, the remaining weld seam (excluding the upset beyond the inner surface) and wall thickness in the adjacent area shall not be less than 90% of the nominal wall thickness.

13 IDENTIFICATION, CERTIFICATION AND INDEPENDENT TESTS

13.1 Identification

13.1.1 *Individual length markings*

All hollow section lengths supplied in Australia shall be clearly and legibly identified by suitable and durable methods, such as painting (e.g. ink jet) or stamping with the following:

(a) The manufacturer's name or mark, or both.

(b) The manufacturer's site or mill identification, or both.

(c) Traceable text identification which can be in either one or both of the following forms:

  (i) The time and date of manufacture of the product.

  (ii) A serialized identification number for quality control/assurance and traceability purposes.

(d) The markings specified in Items (a), (b) and (c) shall be placed a minimum of once on each length of ex-mill tube.

Where identification is by means of die-stamping, low-stress stamps shall be used for impact tested grades.

This Clause does not apply to hollow sections supply in New Zealand.

NOTES:

1 Products not marked with the provisions specified in this Clause would be considered to be non-compliant with this Standard.

2 If the identified portion of the product is subsequently removed, then these identifications are to be transferred to each remaining portion of the product.

3 Manufacturers making a statement of compliance with this Standard on a product, packaging or promotional material related to that product are advised to ensure that such compliance is capable of being verified.

13.1.2 *Bundle/pack markings*

The material shall be marked or tagged for bundles with the following:

(a) The manufacturer's name or mark, or both.

(b) Reference to this Standard, i.e. AS/NZS 1163.

(c) The grade of steel (see Clause 5).

(d) The product dimensions to be identified with this Standard.

  NOTE: See Appendix D.

(e) A traceable identification number.

13.2 Test reports and test certificates

13.2.1 *Qualifications on test reports and test certificates*

A test report or test certificate shall provide results in relation to the following:

(a) Tests performed by a laboratory accredited by signatories to the International Laboratory Accreditation Corporation (ILAC) through their Mutual Recognition Agreement (MRA), in the field and class of testing, on behalf of the manufacturer for the purpose of establishing compliance with this Standard. The appropriate logo or further details of the ILAC (MRA) signatory shall be also noted on the document.

(b) Additional tests not considered in this Standard as agreed between the purchaser and manufacturer.

NOTE: In Australia, ILAC (MRA) accredited bodies include National Association of Testing Authorities (NATA) and in New Zealand they include International Accreditation New Zealand (IANZ).

13.2.2 *Minimum requirements for reports and test certificates*

In addition to Clause 13.2.1, any report or test certificate shall be written in English alphanumeric characters, issued by the manufacturers and shall have the following:

(a) Manufacturer's, supplier's and testing authority's name.

(b) Test certificate number and test number.

(c) Date.

(d) Product, testing specification and grade, e.g. AS/NZS 1163-C350L0 (see Clause 5).

(e) Product dimensions and size, e.g. 200 × 100 × 5.0 RHS

NOTE: See Appendix D.

(f) Product steelmaking process, e.g. basic oxygen continuously cast, fine-grained, fully killed steels, and the like (see Clause 6).

(g) Length, bundle, pack or unique identifier to which the test certificate applies (see this Clause).

(h) Heat number (from steel feed casting).

(i) Chemical analysis type, e.g. ladle and cast analysis 'L' or product 'P' (see Clauses 7.1, 7.2 and 7.3).

(j) Chemical composition of carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulphur (S), chromium (Cr), molybdenum (Mo), aluminium (Al), titanium (Ti), niobium (Nb), vanadium (V), copper (Cu), nickel (Ni), carbon equivalence (CE) (see Clauses 7.1, 7.2 and 7.3) and any other element intentionally added.

(k) Where relevant, mechanical or alternative information as noted below:

(i) Tensile tests to Clause 10.6.1: Orientation, i.e. longitudinal 'L' (see Clause 10.2.1), treatment, i.e. aged 'A' (see Clause 10.5.4) and results, i.e. yield strength in MPa, tensile strength in MPa and % elongation (see Clause 11.1).

(ii) Impact tests to Clause 10.6.2.1: Orientation, i.e. longitudinal 'L' (see Clause 10.2.1), treatment, i.e. aged 'A' (see Clause 10.5.4) and results (see Clause 11.2).

(iii) Impact test reporting to Clause 10.6.2.2(a): Statement of steel feed supplier name, grade/type, mill location, and other sizes with nominal thickness greater than or equal to 6 mm using the same steel feed type for compliance with Clause 10.6.2.1.

(iv) Impact test reporting to Clause 10.6.2.2(b): Statement of compliance with Clauses 6 and 10.6.2.2(b) with further statements of finished product ferrite grain size, use of aluminium killed steel feed and/or aluminium content in total or soluble form.

(l) Additional tests agreed between the purchaser and the manufacturer.

(m) Statement acknowledging material being supplied in accordance with Items (a) to (l) above.

(n) Signatory from manufacturer, supplier or testing authority attesting to Items (a) to (m) above.

NOTE: Test certificates may be requested by the end purchaser or at the time of manufacture.

13.3 Independent tests

In the event of a dispute as to the compliance of the steel with this Standard, the purchaser and the manufacturer, or the supplier, shall agree to have referee testing carried out by independent laboratories accredited by signatories to ILAC (MRA).

14 ROUNDING OF NUMBERS

14.1 General

For the purpose of deciding whether a particular requirement of this Standard is complied with, the determined value, observed or calculated, shall be rounded off in accordance with AS 2706. The number of significant places retained in the rounded-off values shall be the same as that of the specified value in the appropriate material Standard.

14.2 Tensile properties

The determined value of tensile strength shall be rounded off to the nearest 10 MPa and the determined value of yield strength shall be rounded off to the nearest 5 MPa.

15 MANIPULATION

Galvanized circular hollow sections of outside diameter less than or equal to 60.3 mm and other shaped hollow sections of equivalent dimensions, shall be capable of withstanding a 90° bend around a grooved mandrel having a root radius of 6 times the outside diameter of the circular hollow sections or the section dimension in the plane of the bend for non-circular hollow sections. On completion of the bending operation, the galvanized coating shall show no signs of cracks or flaws.

16 NOMINAL DIMENSIONS, SECTION PROPERTIES AND MASS

NOTE: Appendix D provides information on nominal section dimensions and, coupled with first principles, also provides the listings and basis for the evaluation of nominal section properties and mass.

17 SAMPLING AND TESTING TO DEMONSTRATE PRODUCT CONFORMITY

As a minimum, the sampling and testing procedures shall conform to Appendix B. Additional testing may be agreed between the manufacturer and the purchaser.

APPENDIX A

PURCHASING GUIDELINES

(Informative)

A1 GENERAL

Australian/New Zealand Standards are intended to include the technical provisions necessary for the supply of materials referred to in the particular Standard, but do not purport to comprise all the necessary provisions of a contract. In a number of cases, the purchaser is asked to state the requirements or is given a choice of optional requirements. These are contractual matters to be agreed upon between the purchaser and the manufacturer, or the supplier.

This Appendix contains detailed explanations, advice and recommendations on the information to be supplied by the purchaser at the time of enquiry and order. Its aims are to avoid misunderstandings and to result in the purchaser receiving satisfactory products and services.

A2 INFORMATION TO BE SUPPLIED BY THE PURCHASER

The purchaser should consider and supply the following information at the time of enquiry and order, after making due reference to the explanation, advice and recommendations contained in this Appendix:

(a) Quantity and delivery instructions (dates, schedules, delivery point).

(b) Dimensions of section, e.g. nominal length of long and short side, nominal outside diameter and nominal thickness (see Appendix D).

(c) Designation of grade and Standard number (see Clause 5).

(d) Any limitations in respect of packaging, e.g. number or sections per pack, packaging materials.

(e) Whether a test certificate or test report is required (see Clause 13.2).

(f) Whether it is the intention of the purchaser to inspect the steel at the manufacturer's works (see Paragraph A3).

(g) Any information concerning processing or end use that the purchaser considers would assist the manufacturer.

(h) Whether a product analysis is required (see Clause 7.3).

(i) Particular position of the weld seam (see Clause 9.2.1), if required.

(j) Special mill finish or coating, e.g. galvanized.

(k) End finish.

(l) Special tolerances.

(m) Length of sections (including length tolerance type – see Table 5).

(n) Zinc coating requirements (see Clause 7.4)

NOTE: Any special or supplementary requirements of this Standard are to be subject to agreement between the purchaser and the manufacturer, or the supplier at the time of enquiry and order, and stated on the order.

A3 INSPECTION

If it is the purchaser's intention to undertake any of the following functions at the manufacturer's works, this should be notified at the time of enquiry and order, and should be accomplished in a manner which will not interfere with the operation of the works. The functions are as follows:

(a) Inspect the product during manufacture.

(b) Select and identify the test samples.

(c) Witness the tests being made.

The manufacturer should provide all reasonable facilities to enable the purchaser to be satisfied that the product complies with this Standard.

A4 HEAT TREATMENT

The mechanical properties of these grades can be affected by any reheating that may be applied for its end use.

If it is intended to reheat these grades above 620°C, the purchaser should discuss the application and the proposed reheating treatment with the manufacturer.

NOTE: Welding to AS/NZS 1554 does not affect the mechanical properties of hollow sections manufactured to this Standard.

APPENDIX B

PRODUCT CONFORMITY

(Normative)

B1 SCOPE

This Appendix sets out the minimum sampling and testing plan for Product Conformity to this Standard which shall be demonstrated by the hollow section manufacturer or supplier.

The Product Conformity requirements shall enable Conformity Assessment to be made by a manufacturer or supplier (first party), a user or purchaser (second party), or an independent body (third party), and shall not be dependent on a quality management systems standard (e.g. ISO 9001, etc.). To meet this requirement the manufacturer or supplier shall also maintain all records relating to product conformity in a form suitable for second or third party assessment.

NOTE: These provisions are based on—

(a) ISO/IEC Directives, Part 2, *Rules for the structure and drafting of International Standards*, 5th Edition, 2004.

(b) ISO/IEC Directives, Supplement – Procedure specific to IEC, 4th Edition, 2009.

(c) IEC, Conformity Assessment Board (CAB/822/INF, 2009-05-27), Agenda item 7.2, ISO/IEC Directives, text concerning conformity assessment: current status.

B2 SAMPLING AND TESTING

B2.1 General

Sampling and testing shall be carried out by the manufacturer in accordance with Paragraphs B2.2 or B2.3 as appropriate. For every batch, the chemical composition shall be obtained in accordance with Clauses 7.1, 7.2 or 7.3, as appropriate.

The manufacturer or supplier shall ensure that product which does not meet the requirements of the Standard are identified, deemed nonconforming and controlled to prevent unintended use or delivery. The results from the nonconforming tests shall be excluded from the long-term conformance calculations.

Should a failure on retesting occur, then the quarantined batch shall be rejected or satisfy the provisions of Paragraph B2.2.3.

B2.2 Minimum batch sampling and testing

B2.2.1 *Batch sampling*

For tensile, impact and flattening tests, the test samples shall be taken as follows:

(a) One sample for a batch not exceeding 50 tonnes for—

  (i) circular hollow sections (CHS) with outside diameter less than 168.3 mm; and

  (ii) all other (non-CHS) shapes.

(b) One additional sample from the balance of the batch as described in (a) above.

(c) For CHS with outside diameter equal to or greater than 168.3 mm, one sample per heat for a specific outside diameter and thickness.

B2.2.2 *Conformity*

Each batch conforms with this Standard if all of the samples tested give results that are within the specified limits.

If any of the properties of the tested samples provide results outside the specified limits, the requirements of Paragraph B2.2.3 apply.

B2.2.3 *Retests*

B2.2.3.1 *Tensile test and cold flattening test*

If a retest is carried out, one or more of the following procedures shall be adopted:

(a) Make two additional tests on test pieces from samples taken from the same unit at a position as near as practicable to the failed sample. The unit conforms to this Standard provided both additional test pieces conform to Clauses 10.2, 10.5, 10.6 and 11.

(b) Make two test samples at random from the remainder of the batch. If the test pieces from both additional samples conform to Clauses 10.2, 10.5, 10.6 and 11, the remainder conforms to this Standard. If one of these samples fails to conform, the steel of the applicable batch does not conform to this Standard.

(c) Make test samples from each rolled unit of steel and individually test in accordance with this Standard. If the test piece from the additional sample conform, to Clauses 10.2, 10.5, 10.6 and 11, the rolled unit of steel conforms to this Standard.

B2.2.3.2 *Impact tests*

If a retest is carried out, one or more of the following procedures shall be adopted:

(a) If the average value of the three impact test results is less than the specified minimum average, or if one value is less than the specified individual test value given in Table 7, then test three additional test pieces from the original sample in accordance with Clauses 10.2, 10.5 and 10.6, and add the results to those previously obtained and calculate a new average.

If the average value of the six tests is not less than the specified minimum average, and not more than one result of the six tests is below the minimum specified individual test value given in Table 7, then the unit conforms to this Standard.

(b) Take two further test samples at random from the remainder of the test batch. If the test pieces from both additional samples conform to Clauses 10.2, 10.5, 10.6 and 11.2, then the remainder conforms to this Standard. If one of these additional samples fails to conform, the steel of the applicable batch does not conform to this Standard.

(c) Take test samples from each rolled unit of steel and individually test in accordance with this Standard. If the test piece from the additional sample conforms to Clauses 10.2, 10.5, 10.6 and 11.2, then the rolled unit of steel conforms to this Standard.

B2.3 Statistical Sampling

B2.3.1 *General*

Process verification by statistical sampling or alternate methods can be used to demonstrate product conformity where the conditions required by Paragraph B2.3 are met (See also Note 1).

Where it can be demonstrated that the type test (see Note 2) of any group of products (see Note 3) manufactured under the same conditions of steel supplier, steel grade, steel processing and tube processing are distributed normally, then it shall be permissible to adopt statistical sampling to verify process acceptance for each product in accordance with ISO 7966.

For product conformance to this Standard via statistical sampling, the inputs of process acceptance verification, ongoing testing and statistical sampling must be demonstrated and, where applicable, also maintained. To ensure that the process being assessed is in control (see Note 1), a statistically significant number of samples must be obtained within a rationally determined time period that is reflective of typical manufacturing practice (see Note 4). Within a defined group, each type of test sample randomly selected shall not exceed a sampling period of three months.

Additionally, any sample or sampling that indicates a predicted proportion of non-conforming product in excess of an amount considered within the demonstrated statistical sampling method, shall cause the sampling for that combination of size, thickness and grade to revert to batch sampling rules until it can be demonstrated that the conditions of statistical sampling are valid for that combination.

In the event of actual non-conforming test results, the retest provisions of normal batch testing shall also apply.

NOTES:

1 Statistical sampling is a procedure that enables decisions to be made about the quality and conformity of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

(a) The sample is drawn randomly from a population of product of known history that enables verification that the product was made from known materials at essentially the same time by essentially the same processes and under essentially the same system of control.

(b) For each different situation, a suitable sampling plan is defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with recognized Standards (e.g. AS 2490, AS 1199) and methods.

Under this approach, ongoing sampling and testing of product shall be directed primarily at monitoring the process to ensure that product outcomes are acceptable, within characteristic ranges as well as stable and under control (e.g. normally distributed).

2 The type test is the measured parameter such as tensile testing, impact testing, etc. These are long term testing plans based on initial testing undertaken to determine overall conformance and other required controls to be put into place (e.g. same steel supply, same manufacturing process) to ensure ongoing compliance.

3 To reduce sampling frequencies, a group of products can consist of an aggregation of batch data from a range of products if it can be demonstrated to be normally distributed.

4 See Appendix C for an example on statistical sampling.

B2.3.2 *Tensile tests*

B2.3.2.1 *General*

Testing to AS 1391 as noted in Paragraph 10.6.1 is only considered within Paragraph B2.3.2 for product conformance assessment to tensile testing requirements.

B2.3.2.2 *Sampling conditions*

In conjunction with the provisions of Paragraph B.2.3.1, statistical sampling shall only be used for a combination of size, thickness and grade where the statistically predicted proportion of non-conforming product is less than 5% at a confidence level of 90%.

Changes in steel supplier, steel grade and significant changes in steel or tube processing (e.g. mill) shall necessitate a re-evaluation of the conditions in this Paragraph (B2.3.2.2).

NOTE: For further information on the basis for statistical sampling, refer to Appendix C.

B2.3.3 *Impact tests*

B2.3.3.1 *General*

Testing and assessments to—

(a) Clause 10.6.2.1;

(b) Clause 10.6.2.2(a); and

(c) the grain size provisions of Clause 10.6.2.2(b).

are only considered within Paragraph B2.3.3 for product conformance assessment to impact testing requirements.

B2.3.3.2 *Sampling conditions*

In conjunction with the provisions of Paragraph B.2.3.1, statistical sampling shall only be used for a combination of size, thickness and grade where the statistically predicted proportion of non-conforming product is less than 5% at a confidence level of 90%.

Changes in steel supplier or steel grade and significant changes in steel or tube processing shall necessitate a re-evaluation of the conditions in Paragraph B2.3.3.2.

NOTE: For further information on the basis for statistical sampling, refer to Appendix C.

APPENDIX C

BASIS FOR ASSESSMENT OF COMPLIANCE OF MECHANICAL PROPERTIES BY STATISTICAL SAMPLING

(Informative)

C1 SCOPE

This Appendix provides background information and the methodology used in the application of ISO 7966.

Amongst other aspects, this Standard permits the use of statistically based sampling of product for the assessment of the tensile properties and toughness conformance.

C2 BACKGROUND

It is common practice for an ERW tube manufacturer to use the same steel grade for a range of product sizes. The strength and ductility of ERW tube supplied in the as-rolled condition is largely dependent on the properties of the steel used and the amount of cold deformation that occurs during tube forming. As the amount of cold deformation will vary with the nominal size and thickness of the finished tube, the mechanical properties will vary significantly between product sizes for the same steel grade. This is illustrated in Figure C1, where the actual distribution of yield strength test results obtained from two different product sizes over a period of 5 years and using the same steel grade for both products, which shows the normal curves appropriate to the average and standard deviation for each product. As the steel grade is designed for the lowest strength product size there will be many product sizes that will easily meet the specification limit.

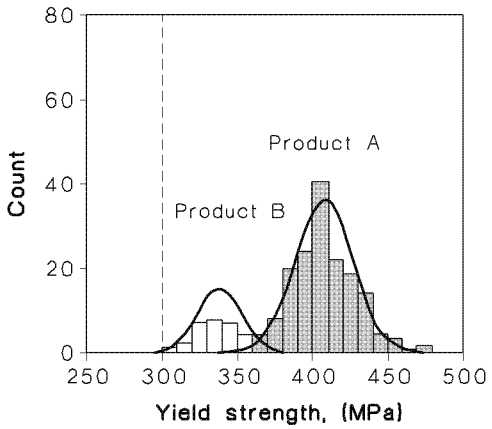


FIGURE C1 DISTRIBUTION OF YIELD STRENGTH FOR TWO PRODUCTS

Also, as the normal curve is a close approximation to the actual distribution of yield strength test results, statistical formulae based on the normal distribution may be used to predict the proportion of product that would be expected to be above or below any nominated value. For example, for a hypothetical specification of 300 MPa it can be shown that product A has a statistically negligible expected failure rate while product B has an expected failure rate of 1%. Similarly, the likelihood of results below 290 MPa is of the order of 1 in 3×10^9 for product A and 1 in 1000 for product B.

Both product A and product B can be considered to be stable and in control and consistently meeting the hypothetical yield strength requirement, although with different margins of safety. Ongoing testing of these products may be conducted with the objective of monitoring and acceptance of the process rather than the acceptance of each manufactured batch. Using this approach, the process is periodically sampled to ensure that it has not changed to an extent that it is no longer acceptable. This can be achieved through the application of statistical principles with considerably less testing than is required for batch testing, particularly where there is a good margin of safety.

C3 APPLICATION OF ISO 7966

C3.1 General

ISO 7966 provides a method by which samples from a process may be used to verify the process acceptability against a specification. For any sample size a minimum 'acceptance control limit' is determined which will ensure, with a nominated risk, that no more than a nominated proportion of the product will fail to conform with the specification limit. As the sample size decreases, the acceptance control limit increases and the manufacturer faces an increasing risk that their process will be falsely rejected due to chance, particularly if the process has a low safety margin, e.g. product B in Figure C1; this is an incentive for the manufacturer to take a large sample size for products with smaller safety margins.

C3.2 Basic criteria

To apply ISO 7966, the following example on tensile testing should be considered:

(a) The proportion of non-conforming product that is considered rejectable. In this example, this has been nominated as 5%, i.e. the process is considered rejectable if any sample indicates that 5% or more of the product may not conform.

(b) The maximum tolerable risk of not detecting a rejectable process, i.e. the likelihood that the sample will not identify a process that is producing 5% or more of non-conforming product. In this example, this has been nominated as 10% risk.

C3.3 Additional criteria

In addition to the items nominated in Paragraph C3.2, the following should be established:

(a) For this example it is considered appropriate that—

  (i) the assessment to be based on a minimum of 500 tests obtained over a minimum of one (1) year;

  (ii) the distribution of properties for any combination of steel grade and product size to approximate a normal distribution; and

  (iii) only a combination of size and steel grade where the predicted proportion of non-conforming product does not exceed 2% are considered suitable for process acceptance sampling.

(b) The maximum acceptable time between sampling, i.e. the longest period over which the process may go unchecked. This has been specified as 3 months.

(c) The actions to be taken if a sample indicates that the process is producing more than 5% of non-conforming product. In this instance it is appropriate to revert to batch sampling rules to—

  (i) increase the sample size in order to verify that the sample average is above or below the acceptance control; and

  (ii) verify that no test results are below the specification limit.

APPENDIX D

DIMENSIONS AND PROPERTIES OF CROSS-SECTION

(Informative)

This Appendix provides lists of dimensions and properties of cross-section for information only. Figures D1 to D4 are not restrictive nor exhaustive. Other sizes in various grades are also available in Australia and New Zealand. Although they appear in the following tables, certain sizes may not always be available in all grades.

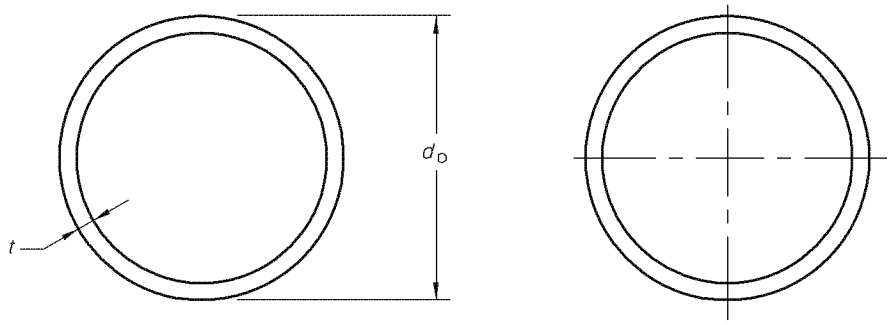
Users are advised to check availability before incorporating hollow sections in major designs.

NOTE: The following information was used to generate the data in this Appendix:

(a) First principles as typically used in calculating section properties.

(b) The corner geometry noted at the bottom of the rectangular and square hollow sections tables.

(c) Steel density of 7850 kg/m^3.



1			2	3	4	5	6	7	8	9	10	11	12
Designation			Mass per unit length	External surface area		Ratio	Gross area of cross-section	About any axis				Torsion constant	Torsion modulus
Outside diameter	×	Thickness		Per unit length	Per unit mass			Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration		
d_o	×	t	m			$\frac{d_O}{t}$	A_g	I	Z	S	r	J	C
mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	$10^6\ mm^4$	$10^3\ mm^3$	$10^3\ mm^3$	mm	$10^6\ mm^4$	$10^3\ mm^3$
610.0	×	12.7 CHS	187	1.92	10.2	48.0	23800	1060	3490	4530	211	2130	6970
610.0	×	9.5 CHS	141	1.92	13.6	64.2	17900	808	2650	3430	212	1620	5300
610.0	×	6.4 CHS	95.3	1.92	20.1	95.3	12100	553	1810	2330	213	1110	3620
508.0	×	12.7 CHS	155	1.60	10.3	40.0	19800	606	2390	3120	175	1210	4770
508.0	×	9.5 CHS	117	1.60	13.7	53.5	14900	462	1820	2360	176	925	3640
508.0	×	6.4 CHS	79.2	1.60	20.2	79.4	10100	317	1250	1610	177	634	2500
165.1	×	5.4 CHS	21.3	0.519	24.4	30.6	2710	8.65	105	138	56.5	17.3	209
165.1	×	5.0 CHS	19.7	0.519	26.3	33.0	2510	8.07	97.7	128	56.6	16.1	195

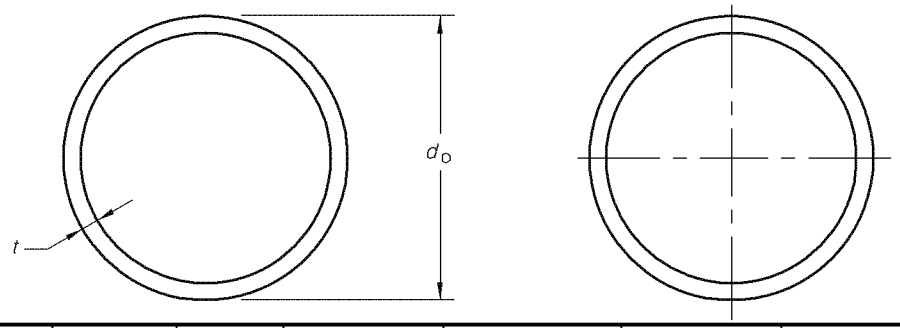
FIGURE D1 (in part) CIRCULAR HOLLOW SECTIONS (see also Figure D2 for other CHS listings)

1			2	3	4	5	6	7	8	9	10	11	12
Designation				External surface area				About any axis					
Outside diameter		Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d_o	×	t	m			$\frac{d_O}{t}$	A_g	I	Z	S	r	J	C
mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
139.7	×	5.4 CHS	17.9	0.439	24.5	25.9	2280	5.14	73.7	97.4	47.5	10.3	147
139.7	×	5.0 CHS	16.6	0.439	26.4	27.9	2120	4.81	68.8	90.8	47.7	9.61	138
114.3	×	5.4 CHS	14.5	0.359	24.8	21.2	1850	2.75	48.0	64.1	38.5	5.49	96.1
114.3	×	4.5 CHS	12.2	0.359	29.5	25.4	1550	2.34	41.0	54.3	38.9	4.69	82.0
101.6	×	5.0 CHS	11.9	0.319	26.8	20.3	1520	1.77	34.9	46.7	34.2	3.55	69.9
101.6	×	4.0 CHS	9.63	0.319	33.2	25.4	1230	1.46	28.8	38.1	34.5	2.93	57.6
88.9	×	5.9 CHS	12.1	0.279	23.1	15.1	1540	1.33	30.0	40.7	29.4	2.66	59.9
88.9	×	5.0 CHS	10.3	0.279	27.0	17.8	1320	1.16	26.2	35.2	29.7	2.33	52.4
88.9	×	4.0 CHS	8.38	0.279	33.3	22.2	1070	0.963	21.7	28.9	30.0	1.93	43.3
76.1	×	5.9 CHS	10.2	0.239	23.4	12.9	1300	0.807	21.2	29.1	24.9	1.61	42.4
76.1	×	4.5 CHS	7.95	0.239	30.1	16.9	1010	0.651	17.1	23.1	25.4	1.30	34.2
76.1	×	3.6 CHS	6.44	0.239	37.1	21.1	820	0.540	14.21	8.9	25.7	1.08	28.4
60.3	×	5.4 CHS	7.31	0.189	25.9	11.2	931	0.354	11.8	16.3	19.5	0.709	23.5
60.3	×	4.5 CHS	6.19	0.189	30.6	13.4	789	0.309	10.2	14.0	19.8	0.618	20.5
60.3	×	3.6 CHS	5.03	0.189	37.6	16.8	641	0.259	8.58	11.6	20.1	0.517	17.2
48.3	×	5.4 CHS	5.71	0.152	26.6	8.9	728	0.170	7.04	9.99	15.3	0.340	14.1
48.3	×	4.0 CHS	4.37	0.152	34.7	12.1	557	0.138	5.70	7.87	15.7	0.275	11.4
48.3	×	3.2 CHS	3.56	0.152	42.6	15.1	453	0.116	4.80	6.52	16.0	0.232	9.59
42.4	×	4.9 CHS	4.53	0.133	29.4	8.7	577	0.103	4.87	6.93	13.4	0.206	9.74
42.4	×	4.0 CHS	3.79	0.133	35.2	10.6	483	0.089 9	4.24	5.92	13.6	0.180	8.48
42.4	×	3.2 CHS	3.09	0.133	43.1	13.3	394	0.076 2	3.59	4.93	13.9	0.152	7.19

FIGURE D1 (in part) CIRCULAR HOLLOW SECTIONS (see also Figure D2 for other CHS listings)

1			2	3	4	5	6	7	8	9	10	11	12
Designation				External surface area				About any axis					
Outside diameter		Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d_o	×	t	m			$\frac{d_o}{t}$	A_g	I	Z	S	r	J	C
mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	$10^6\ mm^4$	$10^3\ mm^3$	$10^3\ mm^3$	mm	$10^6\ mm^4$	$10^3\ mm^3$
33.7	×	4.5 CHS	3.24	0.106	32.7	7.5	413	0.045 0	2.67	3.87	10.4	0.090 1	5.35
33.7	×	4.0 CHS	2.93	0.106	36.1	8.4	373	0.041 9	2.49	3.55	10.6	0.083 8	4.97
33.7	×	3.2 CHS	2.41	0.106	44.0	10.5	307	0.036 0	2.14	2.99	10.8	0.072 1	4.28
26.9	×	4.0 CHS	2.26	0.084 5	37.4	6.7	288	0.019 4	1.45	2.12	8.22	0.038 9	2.89
26.9	×	3.2 CHS	1.87	0.084 5	45.2	8.4	238	0.017 0	1.27	1.81	8.46	0.034 1	2.53
26.9	×	2.6 CHS	1.56	0.084 5	54.2	10.3	198	0.014 8	1.10	1.54	8.64	0.029 6	2.20
21.3	×	3.6 CHS	1.57	0.066 9	42.6	5.9	200	0.008 16	0.767	1.14	6.39	0.016 3	1.53
21.3	×	3.2 CHS	1.43	0.066 9	46.8	6.7	182	0.007 68	0.722	1.06	6.50	0.015 4	1.44
21.3	×	2.6 CHS	1.20	0.066 9	55.8	8.2	153	0.006 81	0.639	0.915	6.68	0.013 6	1.28
17.2	×	2.9 CHS	1.02	0.054 0	52.8	5.9	130	0.003 47	0.403	0.601	5.16	0.006 93	0.806
17.2	×	2.3 CHS	0.845	0.054 0	63.9	7.5	108	0.003 06	0.356	0.515	5.33	0.006 12	0.711
13.5	×	2.9 CHS	0.758	0.042 4	55.9	4.7	96.6	0.001 46	0.216	0.334	3.89	0.002 92	0.432
13.5	×	2.3 CHS	0.635	0.042 4	66.8	5.9	80.9	0.001 32	0.196	0.293	4.04	0.002 64	0.392

FIGURE D1 (in part) CIRCULAR HOLLOW SECTIONS (see also Figure D2 for other CHS listings)

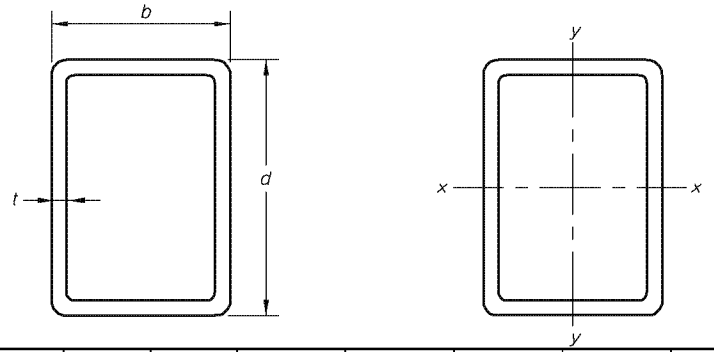


1			2	3	4	5	6	7	8	9	10	11	12
Designation				External surface area				About any axis					
Outside diameter	×	Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d_o	×	t	m			$\frac{d_o}{t}$	A_g	I	Z	S	r	J	C
mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
457.0	×	12.7 CHS	139	1.44	10.3	36.0	17 700	438	1920	2510	157	876	3830
457.0	×	9.5 CHS	105	1.44	13.7	48.1	13 400	334	1460	1900	158	669	2930
457.0	×	6.4 CHS	71.1	1.44	20.2	71.4	9 060	230	1010	1300	159	460	2010
406.4	×	12.7 CHS	123	1.28	10.4	32.0	15 700	305	1500	1970	139	609	3000
406.4	×	9.5 CHS	93.0	1.28	13.7	42.8	11 800	233	1150	1500	140	467	2300
406.4	×	6.4 CHS	63.1	1.28	20.2	63.5	8 040	161	792	1020	141	322	1580
355.6	×	12.7 CHS	107	1.12	10.4	28.0	13 700	201	1130	1490	121	403	2260
355.6	×	9.5 CHS	81.1	1.12	13.8	37.4	10 300	155	871	1140	122	310	1740
355.6	×	6.4 CHS	55.1	1.12	20.3	55.6	7 020	107	602	781	123	214	1200
323.9	×	2.7 CHS	97.5	1.02	10.4	25.5	12 400	151	930	1230	110	301	1860
323.9	×	9.5 CHS	73.7	1.02	13.8	34.1	9 380	116	717	939	111	232	1430
323.9	×	6.4 CHS	50.1	1.02	20.3	50.6	6 380	80.5	497	645	112	161	994

FIGURE D2 (in part) CIRCULAR HOLLOW SECTIONS (see also Figure D1 for other CHS listings)

1			2	3	4	5	6	7	8	9	10	11	12
Designation				External surface area				About any axis					
Outside diameter		Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d_o	×	t	m			$\frac{d_o}{t}$	A_g	I	Z	S	r	J	C
mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
273.1	×	9.3 CHS	60.5	0.858	14.2	29.4	7 710	67.1	492	647	93.3	134	983
273.1	×	6.4 CHS	42.1	0.858	20.4	42.7	5 360	47.7	349	455	94.3	95.4	699
273.1	×	4.8 CHS	31.8	0.858	27.0	56.9	4 050	36.4	267	346	94.9	72.8	533
219.1	×	8.2 CHS	42.6	0.688	16.1	26.7	5 430	30.3	276	365	74.6	60.5	552
219.1	×	6.4 CHS	33.6	0.688	20.5	34.2	4 280	24.2	221	290	75.2	48.4	442
219.1	×	4.8 CHS	25.4	0.688	27.1	45.6	3 230	18.6	169	220	75.8	37.1	339
168.3	×	7.1 CHS	28.2	0.529	18.7	23.7	3 600	11.7	139	185	57.0	23.4	278
168.3	×	6.4 CHS	25.6	0.529	20.7	26.3	3 260	10.7	127	168	57.3	21.4	254
168.3	×	4.8 CHS	19.4	0.529	27.3	35.1	2 470	8.25	98.0	128	57.8	16.5	196
165.1	×	3.5 CHS	13.9	0.519	37.2	47.2	1 780	5.80	70.3	91.4	57.1	11.6	141
165.1	×	3.0 CHS	12.0	0.519	43.2	55.0	1 530	5.02	60.8	78.8	57.3	10.0	122
139.7	×	3.5 CHS	11.8	0.439	37.3	39.9	1 500	3.47	49.7	64.9	48.2	6.95	99.5
139.7	×	3.0 CHS	10.1	0.439	43.4	46.6	1 290	3.01	43.1	56.1	48.3	6.02	86.2
114.3	×	6.0 CHS	16.0	0.359	22.4	19.1	2 040	3.00	52.5	70.4	38.3	6.00	105
114.3	×	4.8 CHS	13.0	0.359	27.7	23.8	1 650	2.48	43.4	57.6	38.8	4.96	86.8
114.3	×	3.6 CHS	9.83	0.359	36.5	31.8	1 250	1.92	33.6	44.1	39.2	3.84	67.2
114.3	×	3.2 CHS	8.77	0.359	41.0	35.7	1 120	1.72	30.2	39.5	39.3	3.45	60.4
101.6	×	3.2 CHS	7.77	0.319	41.1	31.8	989	1.20	23.6	31.0	34.8	2.40	47.2
101.6	×	2.6 CHS	6.35	0.319	50.3	39.1	809	0.991	19.5	25.5	35.0	1.98	39.0
88.9	×	5.5 CHS	11.3	0.279	24.7	16.2	1 440	1.26	28.3	38.3	29.6	2.52	56.6
88.9	×	4.8 CHS	9.96	0.279	28.1	18.5	1 270	1.12	25.3	34.0	29.8	2.25	50.6
88.9	×	3.2 CHS	6.76	0.279	41.3	27.8	862	0.792	17.8	23.5	30.3	1.58	35.6
88.9	×	2.6 CHS	5.53	0.279	50.5	34.2	705	0.657	14.8	19.4	30.5	1.31	29.6
76.1	×	3.2 CHS	5.75	0.239	41.6	23.8	733	0.488	12.8	17.0	25.8	0.976	25.6
76.1	×	2.3 CHS	4.19	0.239	57.1	33.1	533	0.363	9.55	12.5	26.1	0.727	19.1

FIGURE D2 (in part) CIRCULAR HOLLOW SECTIONS (see also Figure D1 for other CHS listings)



1					2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Designation					Mass per unit length	External surface area		Ratio		Gross area of cross-section	About *x*- axis				About *y*- axis				Torsion constant	Torsion modulus
Depth		Width		Thickness		Per unit length	Per unit mass	$\frac{b-2t}{t}$	$\frac{d-2t}{t}$		Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration		
d	× *b*	×	*t*		*m*					A_g	I_x	Z_x	S_x	r_x	I_y	Z_y	S_y	r_y	*J*	*C*
mm	× mm	×	mm		kg/m	m^2/m	m^2/t			mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^4	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
250	× 150	×	9.0 RHS		51.8	0.761	14.7	14.7	25.8	6600	53.7	430	533	90.2	24.3	324	375	60.7	56.0	554
250	× 150	×	6.0 RHS		35.6	0.774	21.8	23.0	39.7	4530	38.4	307	374	92.0	17.5	233	264	62.2	39.0	395
250	× 150	×	5.0 RHS		29.9	0.779	26.0	28.0	48.0	3810	32.7	262	317	92.6	15.0	199	224	62.6	33.0	337
200	× 100	×	9.0 RHS		37.7	0.561	14.9	9.11	20.2	4800	22.8	228	293	68.9	7.64	153	180	39.9	19.9	272
200	× 100	×	6.0 RHS		26.2	0.574	22.0	14.7	31.3	3330	16.7	167	210	70.8	5.69	114	130	41.3	14.2	200
200	× 100	×	5.0 RHS		22.1	0.579	26.2	18.0	38.0	2810	14.4	144	179	71.5	4.92	98.3	111	41.8	12.1	172
200	× 100	×	4.0 RHS		17.9	0.583	32.5	23.0	48.0	2280	11.9	119	147	72.1	4.07	81.5	91.0	42.3	9.89	142
150	× 100	×	6.0 RHS		21.4	0.474	22.1	14.7	23.0	2730	8.17	109	134	54.7	4.36	87.3	102	40.0	9.51	147
150	× 100	×	5.0 RHS		18.2	0.479	26.3	18.0	28.0	2310	7.07	94.3	115	55.3	3.79	75.7	87.3	40.4	8.12	127
150	× 100	×	4.0 RHS		14.8	0.483	32.7	23.0	35.5	1880	5.87	78.2	94.6	55.9	3.15	63.0	71.8	40.9	6.64	105
150	× 50	×	5.0 RHS		14.2	0.379	26.6	8.00	28.0	1810	4.44	59.2	78.9	49.5	0.765	30.6	35.7	20.5	2.30	56.8
150	× 50	×	4.0 RHS		11.6	0.383	32.9	10.5	35.5	1480	3.74	49.8	65.4	50.2	0.653	26.1	29.8	21.0	1.93	48.2
150	× 50	×	3.0 RHS		8.96	0.390	43.5	14.7	48.0	1140	2.99	39.8	51.4	51.2	0.526	21.1	23.5	21.5	1.50	38.3
125	× 75	×	5.0 RHS		14.2	0.379	26.6	13.0	23.0	1810	3.64	58.3	72.7	44.8	1.65	43.9	51.1	30.1	3.83	75.3
125	× 75	×	4.0 RHS		11.6	0.383	32.9	16.8	29.3	1480	3.05	48.9	60.3	45.4	1.39	37.0	42.4	30.6	3.16	63.0
125	× 75	×	3.0 RHS		8.96	0.390	43.5	23.0	39.7	1140	2.43	38.9	47.3	46.1	1.11	29.5	33.3	31.1	2.43	49.5

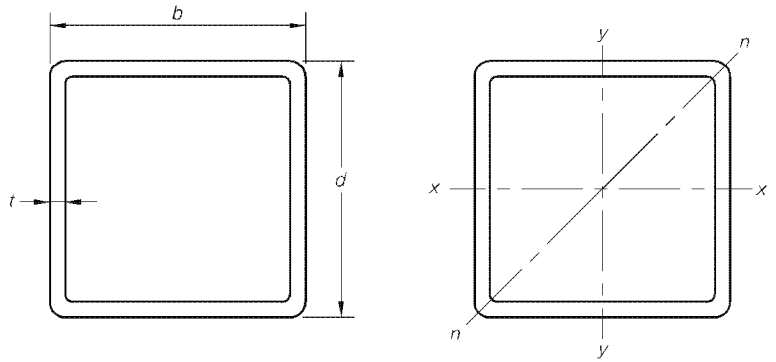
FIGURE D3 (in part) RECTANGULAR HOLLOW SECTIONS

1					2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Designation					Mass per unit length	External surface area		Ratio		Gross area of cross-section	About *x*- axis				About *y*- axis				Torsion constant	Torsion modulus
Depth		Width		Thickness		Per unit length	Per unit mass	$\frac{b-2t}{t}$	$\frac{d-2t}{t}$		Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration	Second moment of area	Elastic section modulus	Plastic section modulus	Radius of gyration		
d	×	*b*	×	*t*	*m*					A_g	I_x	Z_x	S_x	r_x	I_y	Z_y	S_y	r_y	*J*	*C*
mm	×	mm	×	mm	kg/m	m^2/m	m^2/t			mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
100	×	50	×	6.0 RHS	12.0	0.274	22.8	6.33	14.7	1530	1.71	34.2	45.3	33.4	0.567	22.7	27.7	19.2	1.53	40.9
100	×	50	×	5.0 RHS	10.3	0.279	27.0	8.00	18.0	1310	1.53	30.6	39.8	34.1	0.511	20.4	24.4	19.7	1.35	36.5
100	×	50	×	4.0 RHS	8.49	0.283	33.3	10.5	23.0	1080	1.31	26.1	33.4	34.8	0.441	17.6	20.6	20.2	1.13	31.2
100	×	50	×	3.5 RHS	7.53	0.285	37.9	12.3	26.6	959	1.18	23.6	29.9	35.1	0.400	16.0	18.5	20.4	1.01	28.2
100	×	50	×	3.0 RHS	6.60	0.290	43.9	14.7	31.3	841	1.06	21.3	26.7	35.6	0.361	14.4	16.4	20.7	0.886	25.0
100	×	50	×	2.5 RHS	5.56	0.291	52.4	18.0	38.0	709	0.912	18.2	22.7	35.9	0.311	12.4	14.0	20.9	0.754	21.5
100	×	50	×	2.0 RHS	4.50	0.293	65.1	23.0	48.0	574	0.750	15.0	18.5	36.2	0.257	10.3	11.5	21.2	0.616	17.7
75	×	50	×	4.0 RHS	6.92	0.233	33.7	10.5	16.8	881	0.630	16.8	21.1	26.7	0.335	13.4	16.0	19.5	0.754	22.7
75	×	50	×	3.0 RHS	5.42	0.240	44.2	14.7	23.0	691	0.522	13.9	17.1	27.5	0.278	11.1	12.9	20.0	0.593	18.4
75	×	50	×	2.5 RHS	4.58	0.241	52.7	18.0	28.0	584	0.450	12.0	14.6	27.7	0.240	9.60	11.0	20.3	0.505	15.9
75	×	50	×	2.0 RHS	3.72	0.243	65.4	23.0	35.5	474	0.372	9.91	12.0	28.0	0.199	7.96	9.06	20.5	0.414	13.1
75	×	25	×	2.5 RHS	3.60	0.191	53.1	8.00	28.0	459	0.285	7.60	10.1	24.9	0.0487	3.89	4.53	10.3	0.144	7.14
75	×	25	×	2.0 RHS	2.93	0.193	65.8	10.5	35.5	374	0.238	6.36	8.31	25.3	0.0414	3.31	3.77	10.5	0.120	6.04
75	×	25	×	1.6 RHS	2.38	0.195	81.7	13.6	44.9	303	0.197	5.26	6.81	25.5	0.0347	2.78	3.11	10.7	0.099 3	5.05
65	×	35	×	3.0 RHS	4.25	0.190	44.7	9.67	19.7	541	0.281	8.65	11.0	22.8	0.106	6.04	7.11	14.0	0.259	10.4
65	×	35	×	2.5 RHS	3.60	0.191	53.1	12.0	24.0	459	0.244	7.52	9.45	23.1	0.0926	5.29	6.13	14.2	0.223	9.10
65	×	35	×	2.0 RHS	2.93	0.193	65.8	15.5	30.5	374	0.204	6.28	7.80	23.4	0.0778	4.44	5.07	14.4	0.184	7.62
50	×	25	×	3.0 RHS	3.07	0.140	45.5	6.33	14.7	391	0.112	4.47	5.86	16.9	0.0367	2.93	3.56	9.69	0.0964	5.18
50	×	25	×	2.5 RHS	2.62	0.141	54.0	8.00	18.0	334	0.0989	3.95	5.11	17.2	0.0328	2.62	3.12	9.91	0.0843	4.60
50	×	25	×	2.0 RHS	2.15	0.143	66.6	10.5	23.0	274	0.0838	3.35	4.26	17.5	0.0281	2.25	2.62	10.1	0.0706	3.92
50	×	25	×	1.6 RHS	1.75	0.145	82.5	13.6	29.3	223	0.0702	2.81	3.53	17.7	0.0237	1.90	2.17	10.3	0.0585	3.29
50	×	20	×	3.0 RHS	2.83	0.130	45.8	4.67	14.7	361	0.0951	3.81	5.16	16.2	0.0212	2.12	2.63	7.67	0.0620	3.88
50	×	20	×	2.5 RHS	2.42	0.131	54.2	6.00	18.0	309	0.0848	3.39	4.51	16.6	0.0192	1.92	2.32	7.89	0.0550	3.49
50	×	20	×	2.0 RHS	1.99	0.133	66.8	8.00	23.0	254	0.0723	2.89	3.78	16.9	0.0167	1.67	1.96	8.11	0.0466	3.00
50	×	20	×	1.6 RHS	1.63	0.135	82.7	10.5	29.3	207	0.0608	2.43	3.14	17.1	0.0142	1.42	1.63	8.29	0.0389	2.55

NOTE: The calculation of sectional properties is based on the following corner geometry:

Size range	Inside corner radius mm	Outside corner radius mm
Thickness 3.0 mm and less	1.0*t*	2.0*t*
Thickness greater than 3.0 mm	1.5*t*	2.5*t*

FIGURE D3 (in part) RECTANGULAR HOLLOW SECTIONS



1					2	3	4	5	6	7	8	9	10	11	12	13
Designation						External surface area				About *x*, *y* and *n*- axes						
Depth		Width		Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d	×	*b*	×	*t*	*m*			$\frac{b-2t}{t}$	A_g	I_x, I_y	Z_x, Z_y	Z_n	S_x, S_y	r_x, r_y	*J*	*C*
mm	×	mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
250	×	250	×	9.0 SHS	65.9	0.961	14.6	25.8	8400	79.8	639	477	750	97.5	129	972
250	×	250	×	6.0 SHS	45.0	0.974	21.7	39.7	5730	56.2	450	330	521	99.0	88.7	681
200	×	200	×	9.0 SHS	51.8	0.761	14.7	20.2	6600	39.2	392	297	465	77.1	64.5	599
200	×	200	×	6.0 SHS	35.6	0.774	21.8	31.3	4530	28.0	280	207	327	78.6	44.8	425
200	×	200	×	5.0 SHS	29.9	0.779	26.0	38.0	3810	23.9	239	175	277	79.1	37.8	362
150	×	150	×	9.0 SHS	37.7	0.561	14.9	14.7	4800	15.4	205	159	248	56.6	26.1	316
150	×	150	×	6.0 SHS	26.2	0.574	22.0	23.0	3330	11.3	150	113	178	58.2	18.4	229
150	×	150	×	5.0 SHS	22.1	0.579	26.2	28.0	2810	9.70	129	96.1	151	58.7	15.6	197
125	×	125	×	9.0 SHS	30.6	0.461	15.1	11.9	3900	8.38	134	106	165	46.4	14.5	208
125	×	125	×	6.0 SHS	21.4	0.474	22.1	18.8	2730	6.29	101	76.5	120	48.0	10.4	154
125	×	125	×	5.0 SHS	18.2	0.479	26.3	23.0	2310	5.44	87.1	65.4	103	48.5	8.87	133
125	×	125	×	4.0 SHS	14.8	0.483	32.7	29.3	1880	4.52	72.3	53.6	84.5	49.0	7.25	110

FIGURE D4 (in part) SQUARE HOLLOW SECTIONS

1					2	3	4	5	6	7	8	9	10	11	12	13
Designation					Mass per unit length	External surface area		Ratio	Gross area of cross-section	About *x*, *y* and *n*- axes					Torsion constant	Torsion modulus
Depth		Width		Thickness		Per unit length	Per unit mass			Second moment of area	Elastic section modulus	Elastic section modulus	Plastic section modulus	Radius of gyration		
d	×	*b*	×	*t*	*m*			$\frac{b-2t}{t}$	A_g	I_x, I_y	Z_x, Z_y	Z_n	S_x, S_y	r_x, r_y	*J*	*C*
mm	×	mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
100	×	100	×	9.0 SHS	23.5	0.361	15.4	9.11	3000	3.91	78.1	63.6	98.6	36.1	7.00	123
100	×	100	×	6.0 SHS	16.7	0.374	22.4	14.7	2130	3.04	60.7	47.1	73.5	37.7	5.15	93.6
100	×	100	×	5.0 SHS	14.2	0.379	26.6	18.0	1810	2.66	53.1	40.5	63.5	38.3	4.42	81.4
100	×	100	×	4.0 SHS	11.6	0.383	32.9	23.0	1480	2.23	44.6	33.5	52.6	38.8	3.63	68.0
100	×	100	×	3.0 SHS	8.96	0.390	43.5	31.3	1140	1.77	35.4	26.0	41.2	39.4	2.79	53.2
89	×	89	×	6.0 SHS	14.6	0.330	22.5	12.8	1870	2.06	46.2	36.3	56.6	33.2	3.54	71.6
89	×	89	×	5.0 SHS	12.5	0.334	26.7	15.8	1590	1.81	40.7	31.4	49.1	33.7	3.05	62.7
89	×	89	×	3.5 SHS	9.06	0.341	37.6	23.4	1150	1.37	30.9	23.2	36.5	34.5	2.24	47.1
75	×	75	×	6.0 SHS	12.0	0.274	22.8	10.5	1530	1.16	30.9	24.7	38.4	27.5	2.04	48.2
75	×	75	×	5.0 SHS	10.3	0.279	27.0	13.0	1310	1.03	27.5	21.6	33.6	28.0	1.77	42.6
75	×	75	×	4.0 SHS	8.49	0.283	33.3	16.8	1080	0.882	23.5	18.0	28.2	28.6	1.48	36.1
75	×	75	×	3.5 SHS	7.53	0.285	37.9	19.4	959	0.797	21.3	16.1	25.3	28.8	1.32	32.5
75	×	75	×	3.0 SHS	6.60	0.290	43.9	23.0	841	0.716	19.1	14.2	22.5	29.2	1.15	28.7
75	×	75	×	2.5 SHS	5.56	0.291	52.4	28.0	709	0.614	16.4	12.0	19.1	29.4	0.971	24.6
65	×	65	×	3.0 SHS	5.66	0.250	44.1	19.7	721	0.454	14.0	10.4	16.6	25.1	0.733	21.0
65	×	65	×	2.5 SHS	4.78	0.251	52.6	24.0	609	0.391	12.0	8.91	14.1	25.3	0.624	18.1
65	×	65	×	2.0 SHS	3.88	0.253	65.3	30.5	494	0.323	9.94	7.29	11.6	25.6	0.509	14.9
50	×	50	×	4.0 SHS	5.35	0.183	34.2	10.5	681	0.229	9.15	7.33	11.4	18.3	0.403	14.3
50	×	50	×	3.0 SHS	4.25	0.190	44.7	14.7	541	0.195	7.79	5.92	9.39	19.0	0.321	11.8
50	×	50	×	2.5 SHS	3.60	0.191	53.1	18.0	459	0.169	6.78	5.09	8.07	19.2	0.275	10.2
50	×	50	×	2.0 SHS	2.93	0.193	65.8	23.0	374	0.141	5.66	4.20	6.66	19.5	0.226	8.51
50	×	50	×	1.6 SHS	2.38	0.195	81.7	29.3	303	0.117	4.68	3.44	5.46	19.6	0.185	7.03
40	×	40	×	4.0 SHS	4.09	0.143	34.9	8.00	521	0.105	5.26	4.36	6.74	14.2	0.192	8.33
40	×	40	×	2.5 SHS	2.82	0.151	53.7	14.0	359	0.082 2	4.11	3.13	4.97	15.1	0.136	6.21
40	×	40	×	2.0 SHS	2.31	0.153	66.4	18.0	294	0.069 4	3.47	2.61	4.13	15.4	0.113	5.23
40	×	40	×	1.6 SHS	1.88	0.155	82.3	23.0	239	0.057 9	2.90	2.15	3.41	15.6	0.092 7	4.36

FIGURE D4 (in part) SQUARE HOLLOW SECTIONS

1					2	3	4	5	6	7	8	9	10	11	12	13
Designation						External surface area				About *x*, *y* and *n*- axes						
Depth		Width		Thickness	Mass per unit length	Per unit length	Per unit mass	Ratio	Gross area of cross-section	Second moment of area	Elastic section modulus	Elastic section modulus	Plastic section modulus	Radius of gyration	Torsion constant	Torsion modulus
d	×	*b*	×	*t*	*m*			$\frac{b-2t}{t}$	A_g	I_x, I_y	Z_x, Z_y	Z_n	S_x, S_y	r_x, r_y	*J*	*C*
mm	×	mm	×	mm	kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3
35	×	35	×	3.0 SHS	2.83	0.130	45.8	9.67	361	0.0595	3.40	2.67	4.23	12.8	0.102	5.18
35	×	35	×	2.5 SHS	2.42	0.131	54.2	12.0	309	0.0529	3.02	2.33	3.69	13.1	0.0889	4.58
35	×	35	×	2.0 SHS	1.99	0.133	66.8	15.5	254	0.0451	2.58	1.95	3.09	13.3	0.0741	3.89
35	×	35	×	1.6 SHS	1.63	0.135	82.7	19.9	207	0.0379	2.16	1.62	2.57	13.5	0.0611	3.26
30	×	30	×	2.0 SHS	1.68	0.113	67.4	13.0	214	0.0272	1.81	1.39	2.21	11.3	0.0454	2.75
30	×	30	×	1.6 SHS	1.38	0.115	83.3	16.8	175	0.0231	1.54	1.16	1.84	11.5	0.0377	2.32
25	×	25	×	3.0 SHS	1.89	0.0897	47.4	6.33	241	0.0184	1.47	1.21	1.91	8.74	0.0333	2.27
25	×	25	×	2.5 SHS	1.64	0.0914	55.7	8.00	209	0.0169	1.35	1.08	1.71	8.99	0.0297	2.07
25	×	25	×	2.0 SHS	1.36	0.0931	68.3	10.5	174	0.0148	1.19	0.926	1.47	9.24	0.0253	1.80
25	×	25	×	1.6 SHS	1.12	0.0945	84.1	13.6	143	0.0128	1.02	0.780	1.24	9.44	0.0212	1.54
20	×	20	×	1.6 SHS	0.873	0.074 5	85.4	10.5	111	0.006 08	0.608	0.474	0.751	7.39	0.010 3	0.924

NOTE: The calculation of sectional properties is based on the following corner geometry:

Size range	Inside corner radius mm	Outside corner radius mm
Thickness 3.0 mm and less	1.0*t*	2.0*t*
Thickness greater than 3.0 mm	1.5*t*	2.5*t*

FIGURE D4 (in part) SQUARE HOLLOW SECTION

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