



Pressure vessels



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Australian Standard[®]

Pressure vessels

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and AS 1210 Supplement 2—1999.
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PREFACE

This Standard was prepared by the Australian members of Joint Standards Australia/Standards New Zealand Committee ME-001, Pressure Equipment, to supersede AS 1210—1997, *Pressure vessels*, AS 1210 Supplement 1—1990 and AS 1210 Supplement 2—1999. This Standard is referenced in AS/NZS 1200, which is the parent Standard for pressure equipment and outlines general requirements for boilers, pressure vessels, pressure piping and related matters.

This Standard incorporates Amendment No. 1 (November 2013) and Amendment No. 2 (July 2015). The changes required by the Amendments are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The issues discussed in Rulings RUL PE.3, RUL PE.4 and RUL PE.9 to PE.14 have been addressed in this revision, and those rulings will be withdrawn.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australia/New Zealand Standard.

The main changes in this edition are as follows:

- (a) Incorporation of Amendments 1 to 3 to AS 1210—1997.
- (b) Incorporation and review of Supplement 1 to AS 1210—1997 as Appendix H (on stress classification and limits), Appendix I (on finite element analysis) and Appendix M (on design against fatigue).
- (c) Incorporation and review of Supplement 2 to AS 1210—1997 as Appendix L (on cold-stretched vessels).
- (d) Revision of requirements for low temperature service, mainly in Clause 2.6.
- (e) Revision of design tensile strength Table B1 (previously Table 3.3.1).
- (f) Revision of Appendix A on design tensile strengths to align more closely with international practice.
- (g) Revision of application of safety factors for flanges and transportable vessels.
- (h) Deletion of the 400 mm manhole size from Table 3.20.9.
- (i) Revision of Appendix E on information to be supplied to the designer.
- (j) New Appendix G on failure modes.
- (k) New Appendix J on wind and seismic loadings.
- (l) New Appendix N on local non-pressure loads.

Minor changes have been made in the welding procedure, test plate, and postweld heat treatment requirements, principally to align with world practice. It is not intended that welding procedures already qualified will be invalidated by these changes or that the changes be applied retrospectively.

Amendment No. 2 to the 1997 edition reduced the factor of safety used to determine the material design stress from 4 to 3.5. This change is now confirmed in the Standard. The justifications for such a change included improvement in the quality of materials, improvement in the quality of welding and fabrication, improved inspection technology and better information on design, operation, maintenance and vessel failures.

Where other Standards refer to Supplements 1 and 2 to AS 1210—1997, this should now be taken as referring to this edition of AS 1210.

Statements expressed in mandatory terms in notes to tables and figures are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the Appendices. A ‘normative’ appendix is an integral part of this Standard and an ‘informative’ appendix is only for information and guidance.

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FOREWORD

Design, manufacturing and supply requirements: The requirements in this Standard are intended to provide reasonably certain protection of life and property, and to indicate where a margin for deterioration in service may be needed to give reasonably long, safe equipment life. The Standard takes into consideration advancements in design and materials, and the evidence of experience.

The Standard contains basic data necessary for design, including material specification, design parameters, requirements for fabrication, testing and inspection. These requirements are specified in terms of principles where possible, with further detail added for uniform interpretation of principles and guidance on best methods. In other areas the Standard indicates where caution is necessary but a direct prohibition would be unwise at the present level of local and international knowledge.

In principle this Standard follows other codes forming part of AS/NZS 1200 in giving guidance to designers, manufacturers, inspection bodies, purchasers and users in the form of minimum engineering requirements that are necessary for the safe design, manufacture and testing of pressure vessels. In special instances additional requirements may be necessary for adequate performance or safety.

The Standard classifies vessels based on different classes of construction, and gives basic principles to indicate where such classes should or are to be used. Four classes (1, 2A, 2B, 3) use a stress safety factor of 3.5, and four classes (i.e. 1H, 2H, and 1S and 2S using cold-stretching) use higher design stresses.

No rules for design and manufacture can be written in sufficient detail to ensure good workmanship in manufacture. Each vessel manufacturer is responsible for taking every necessary step to make sure the quality of manufacture is such as will ensure compliance with good engineering practice and design.

The user of pressure vessels will also need to consider many factors beyond those covered by this Standard in the final specification of a vessel and is cautioned that the Standard is not a complete design handbook and there is a need for competent engineering judgement.

Adaption for regulatory change: The Standard continues to be written largely for Australian conditions and to cater for recent moves in various States and Territories to objective or performance regulations rather than the earlier prescriptive ones. These moves also have lead to privatization of inspection functions such as design verification, manufacture and in-service inspection, and agreement by designers, manufacturers, purchasers and others involved.

Thus the Standard uses competent ‘inspection bodies’ (somewhat like ‘notified bodies’ in European practice) in place of the previous regulatory authority and is written as far as practical for clear interpretation and use in contracts to assist all parties and facilitate safety and trade.

Use of alternative methods: In addition to the flexibility provided for the various classes of vessels, provision is made for the use of specific alternative methods, materials, and the like where equivalent safety and performance is achieved and any departures from the Standard are clearly identified in all documentation and are agreed.

Use of international Standards: Acknowledgment is gratefully made to the American Society of Mechanical Engineers for permission to reproduce certain extracts from the *ASME Boiler and Pressure Vessel Code*. In addition, acknowledgment is made of the considerable assistance provided by British and other national Standards, recent EN Standards and the recent draft ISO Standards for pressure vessels. This takes advantage of world experience as well as Australian experience, and helps to align with these major Standards to optimize safety and standardization and facilitate trade.

Compliance with the appropriate class of this Standard will satisfy the technical requirements for equivalent vessels to the above national, regional and international Standards. However, compliance with regulatory and quality requirements of the country of use will need to be satisfied. For comparison of this Standard with the above Standards see AS/NZS 1200.

Effect on existing designs of vessels: The revised and new requirements in this edition of the Standard are not intended to require modifications to any existing vessels that were constructed to previous editions of the Standard. However, there may be cases where implementing the new requirements to an existing design could be advantageous. Existing designs for future vessels should be suitably revised.

STANDARDS AUSTRALIA

Australian Standard **Pressure vessels**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the materials, design, manufacture, testing, inspection, certification, documentation and dispatch of fired and unfired pressure vessels constructed in ferrous or non-ferrous metals by welding, brazing, casting, forging, or cladding and lining and includes the application of non-integral fittings required for safe and proper functioning of pressure vessels. This Standard also specifies requirements for non-metallic vessels and metallic vessels with non-metallic linings.

For detailed requirements for metallic materials, manufacture, testing and conformity assessment, reference is made to the relevant material Standards, AS 4458, AS 3920.1, AS/NZS 3992 and AS 4037.

The requirements of this Standard have been formulated on the basis that the required examinations and inspection during manufacture are performed and that appropriate care is taken during subsequent stages in the life of vessels. Appropriate care may include transport, installation (for guidance see AS 3892), operation and maintenance (for guidance see AS 3873), and in-service inspection (for guidance see AS/NZS 3788). Other standards or procedures may also be relevant.

Users of this Standard are reminded that it has no legal authority in its own right, but may acquire legal standing in one or more of the following circumstances:

- (a) Adoption by a government or other authority having jurisdiction.
- (b) Adoption by a purchaser as the required standard of construction when placing a contract.
- (c) Adoption where a manufacturer states that a vessel is in accordance with this Standard.

1.2 OBJECTIVE AND PERFORMANCE CRITERIA

1.2.1 Objective of the Standard

This Standard aims to specify clear, uniform, safe requirements that—

- (a) cover the materials, design, manufacture, testing, inspection, certification, documentation and dispatch of pressure vessels; and
- (b) facilitate the supply of pressure vessels which meet the purchaser's requirements.

1.2.2 Performance requirements

To meet the above objective, pressure vessels supplied to this Standard should satisfy the following performance criteria when produced and used in accordance with the contract, the designed service conditions and sound practice:

- (a) Provide reasonably certain protection of all persons involved in various stages of the vessel's life and of adjacent property and environment.

- (b) Provide appropriate economy, performance, reliability, operability, inspectability and maintainability over a reasonably long life.
- (c) Control risks to at least satisfy applicable safety, health and environment laws.
- (d) Comply with the safety recommendations of AS/NZS 1200, Appendix J.

NOTE: See Appendix ZZ for a comparison of the requirements of this Standard with Appendix J of AS/NZS 1200 and with ISO 16528-1.

The remainder of this Standard gives prescriptive requirements that satisfy the above criteria in the matters covered.

NOTE: As the competence of construction bodies and personnel is integral to satisfying the objectives of this Standard, guidance is given in Appendix P.

1.3 APPLICATION

This Standard is intended to apply to pressure vessels—

- (a) with design pressures above the curves in Figures 1.3.1 and 1.3.2 for welded, forged, brazed or cast metallic vessels or non-metallic vessels unless otherwise agreed by the parties concerned; and
- (b) with operating temperatures within the temperature limits for various materials and components as stated in the appropriate Section of this Standard.

In relation to pressure-containing parts, the following shall be included in the scope of this Standard:

- (i) Where external piping is to be connected to the vessel—
 - (A) the welding end connection for the circumferential joint for welded connections;
 - (B) the first threaded joint for screwed connections;
 - (C) the face of the first flange for bolted, flanged connections; and
 - (D) the first sealing surface for proprietary connections or fittings.
- (ii) Where a non-pressure part is attached directly to either the internal or external surface of a pressure vessel—
 - (A) the weld attaching the part to the vessel; and
 - (B) lifting lugs, support rings, straps and attached load-carrying brackets or cleats for items such as platforms, pipe supports, manhole davits, process internal supports, etc.
- (iii) Pressure-retaining covers for vessel openings such as manhole and handhole covers.
- (iv) Vessel supports, legs and skirts that form part of the vessel.
- (v) Protective devices, pressure relief valves and thermal protection where required by the purchaser.

The scope for attachments does not include items such as cranes, walkways, platforms etc., however any loads applied to the vessel by such items shall be considered in the vessel design.

This Standard is not intended to apply to liquid storage tanks, large low pressure gas storage tanks (such as are dealt with in API 620), nuclear vessels, machinery such as pump and compressor casings, or vessels subject to pressures caused only by static head of their contents, fire-tube, shell, water tube and miscellaneous boilers, water tube boilers, non-integral piping, and other plant under pressure excluded by AS/NZS 1200.

Related Standards that provide alternatives to the requirements in this Standard within the scope of their application are AS 2971 and AS/NZS 3509.

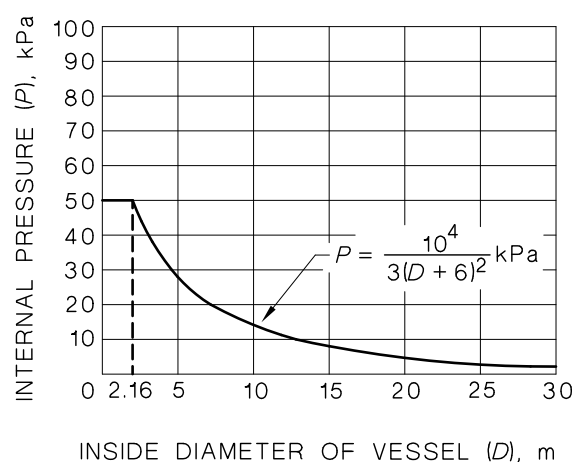


FIGURE 1.3.1 VESSELS SUBJECT TO INTERNAL PRESSURE

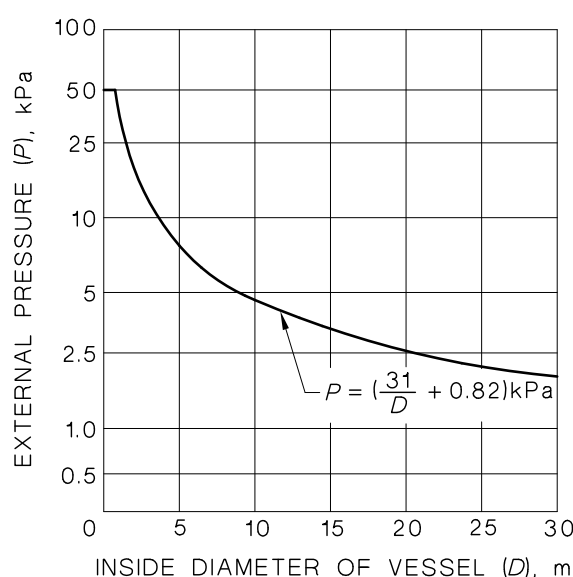


FIGURE 1.3.2 VESSELS SUBJECT TO EXTERNAL PRESSURE

1.4 INTERPRETATION OF STANDARD

For interpretation of this Standard refer to AS/NZS 1200.

1.5 NEW DESIGNS, MATERIALS AND MANUFACTURING METHODS

This Standard does not prohibit the use of materials or methods of design or manufacture that are not specifically referred to herein. (See AS/NZS 1200 for guidance).

1.6 CLASSES OF VESSEL CONSTRUCTION

Metallic vessels are classified according to the design, manufacture, testing and inspection requirements indicated in Table 1.6. Class 2 is subdivided into classifications 2A and 2B to enable the use of higher weld joint efficiency where spot non-destructive examination is used in addition to a production test plate.

For mixing of classes of welded construction, see Clause 1.7.2.

Cast iron and non-metallic vessels are not classified.

The range of materials permitted for vessels of Classes 1H, 2H, 1S and 2S construction (which permit higher design strength values) is limited by Clause 2.1.1.

The extent of non-destructive examination may be reduced from that required for Class 1H construction (see AS 4037) provided that criteria for design against fatigue failure, as appropriate for Class 2H, are fulfilled (see Appendix M).

TABLE 1.6
VESSEL CLASSIFICATION—SUMMARY (see Notes 1 and 2)

Item No.	Description and clause reference	Requirement of Class							
	Class	1H	2H	1S	2S	1	2A	2B	3
	General description	High stress, full NDE	High stress, part NDE	Cold stretched, full NDE	Cold stretched, part NDE	Medium stress, full NDE	Reduced stress, part NDE	Reduced stress, no NDE	Low stress, no NDE, no WPTP
1	CLASSES (Clause 1.7 and Table 1.7) Note 4								
2	MATERIALS (Section 2)								
2.1	Steel: plate, strip, forging and casting (for weldability see Table 1.7B)								
	–Pressure quality	Any	Excellent weldability	Austenitic stainless steel, e.g. Types 304, 316		Any	Good weldability		Excelent or good weldability
	–Structural quality	Not permitted		Not permitted		Any listed	Good weldability		Good weldability
2.2	Non-ferrous metals – pressure quality	Any		Not permitted		Any	Any		Any
2.3	Cast iron <i>Not classified</i>								
2.4	Non-metallic–pressure quality (See Section 10) <i>Not classified</i>								
3	DESIGN (Section 3)								
3.1	Design methods (Clause 3.1.3)								
	–by formula	Any (Clauses 3.7 to 3.32)							
	–by analysis	Any (Appendix H and I)							
	–by experiment	Any (Clause 5.12)							
	–by fracture mechanics	Any (Clause 3.1.3)							

(continued)

TABLE 1.6 (continued)

Item No.	Description and clause reference	Requirement of Class							
		Class	1H	2H	1S	2S	1	2A	2B
	General description	High stress, full NDE	High stress, part NDE	Cold stretched, full NDE	Cold stretched, part NDE	Medium stress, full NDE	Reduced stress, part NDE	Reduced stress, no NDE	Low stress, no NDE, no WPTP
3.2	Design strength (<i>f</i>) at design temperature <i>T</i> (Clause 3.3.1, Appendix A, B and L)								
3.2.1	Ductile metals other than structural quality and bolting. For bolting see Appendix A.	Below creep range, lowest of: $\frac{R_m}{2.35}; \frac{R_{mT}}{2.35} \left(\text{or } \frac{R_m}{2.5}; \frac{R_{mT}}{2.5} \text{ for austenitic steels} \right);$ $\frac{R_e}{1.5}; \frac{R_{eT}}{1.5}$ In creep range, for indefinite life, lowest of: $\frac{S_R}{1.5}; S'_c$ In creep range, for life of <i>t</i> hours, lowest of: $\frac{S_{Rt}}{1.3}; S_{ct}$				Below creep range, lowest of: $\frac{R_m}{3.5}; \frac{R_{mT}}{3.5}; \frac{R_e}{1.5}; \frac{R_{eT}}{1.5}$ In creep range, for indefinite life, lowest of: $\frac{S_R}{1.5}; S'_c$ In creep range, for life of <i>t</i> hours, lowest of: $\frac{S_{Rt}}{1.3}; S_{ct}$			
3.2.2	For Low ductility metals (<i>A</i> ₅ <15%)	Lowest of Item 3.2.1 (below creep range only), and $R_m(0.1 + 0.023A_5)$				Lowest of Item 3.2.1 (below creep range only), and $R_m(0.1 + 0.023A_5)$			
3.2.3	Structural quality	Not permitted				Values as for Item 3.2.1, multiplied by 0.92			
3.2.4	Non-metallic (Section 10)	As agreed by the parties concerned with the proviso that the design complies with the relevant vessel design Standard (e.g. AS 2971).							
3.3	Design quality factors								
3.3.1	Joint efficiency (η) (longitudinal)								
	–welded (Clause 3.5.1.7 and Table 3.5.1.7)	1.0	1.0	1.0	1.0	1.0	0.85	0.80	0.7
	–brazed (Clause 3.5.3.4)	Not permitted		Not permitted for joints A, B or D in vessel shell		1.0	1.0 or 0.5 depending on examination results		
	–soldered (Clause 3.5.4)	Not permitted				1.0	1.0 or 0.5 depending on examination results		
3.3.2	Casting quality factor (Clause 3.3.1.1)								
	–C, C-Mn, low alloy and high alloy steels	0.8, or 0.9 with additional testing		Not permitted		0.9	0.8, or 0.9 with additional testing		
	—Non-ferrous and ductile cast iron	0.8, or 0.9 with additional testing		Not permitted		0.9	0.8, or 0.9 with additional testing		
	–Grey cast iron	Not permitted		Not permitted		1.0 (not permitted for lethal or flammable fluids)			
3.4	Local load assessment	Required (See Appendix N)				Not typically required (See Appendix N)			
3.5	Fatigue assessment (Clause 3.1.4 and Appendix M)	Required for >500 full pressure cycles or equivalent				Recommended for >50 000 full pressure cycles	Recommended for >100 000 full pressure cycles		
	NOTE: A full cycle is pressure from 0 to <i>P</i> to 0 or equivalent stress range								
3.6	Accidental fire assessment	Required (See Clause 8.6)				Not required			
3.7	Collision assessment	Required (See Appendix N)				Not required			

(continued)

TABLE 1.6 (continued)

Item No.	Description and clause reference		Requirement of Class								
			Class	1H	2H	1S	2S	1	2A	2B	3
	General description	High stress, full NDE	High stress, part NDE	Cold stretched, full NDE	Cold stretched, part NDE	Medium stress, full NDE	Reduced stress, part NDE	Reduced stress, no NDE	Low stress, no NDE, no WPTP		
3.8	Welded nozzle connections										
	–Integral reinforcement (Clause 3.19.3)		Recommended		Recommended		As required by Clause 3.19				
	–Partial penetration welds		Analysis required		Analysis required		Permitted				
	–Threaded joints (Clause 3.19.4.2)		Permitted		Permitted		Permitted				
	–Brazed joints (Clause 3.5.3.1)		Permitted if design temperature ≤205°C		Not permitted (except for attached piping)		Permitted if design temperature ≤205°C				
	–Soldered joints (Clause 3.5.4)		Not permitted		Not permitted (except for attached piping)		Permitted if design temperature ≤50°C				
4	MANUFACTURE AND WELDING (Note 3) (Sections 4 and 5, AS 4458 and AS/NZS 3992)										
4.1	Welding procedure qualification		Required to AS/NZS 3992 (except as provided for in Item 4.2)								
4.2	Prequalified welding procedure		Permitted to AS/NZS 3992 but subject to partial requalification, e.g. welder qualification								
4.3	Criteria for weld quality (AS 4037)		Very high				High			Reduced	
4.4	Personnel requirements (See Clause 4.2.2)										
4.5	Postweld heat treatment (AS 4458) (also may be required to satisfy service conditions)										
	–C, C-Mn steels		Required if <i>t</i> >32 mm, or as per AS 4458	Not required			Typically not required (See AS 4458)		Not required, except required for Class 2A transportable vessels		
	–Low alloy steels		AS 4458								
	–Quenched and tempered steels		AS 4458								
	–Austenitic steels		Not required								
	–Non-ferrous		Not required								
5	EXAMINATION AND TESTING (See Section 5 and AS 4037)										
5.1	Visual		100%		100%		100%				
5.2	Penetrant (PT) or Magnetic particle (MT)		0-100%		0-20%		0-10%		Not required		
5.3	Radio-graphic (RT) or Ultra-sonic (UT) (AS 4037)	Weld: Long Circ.	100% 100%	100% 10% or 25% or 100%	100% 100%	100% 20%	100% 10% or 25% or 100%	2% or 10% 2% or 10%	Not required		
5.4	Production test plates (Clause 5.2 and AS/NZS 3992)		Required		Required		Required (some exceptions)	Required (some exceptions)	Required (limited testing)	Not required	
5.5	Hydrostatic test (Clause 5.10)		Required (except as provided for in Items 5.6 or 5.7)								
5.6	Pneumatic test (Clause 5.11)		Permitted by agreement								

(continued)



Documents

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TABLE 1.6 (continued)

Item No.	Description and clause reference	Requirement of Class							
	Class	1H	2H	1S	2S	1	2A	2B	3
	General description	High stress, full NDE	High stress, part NDE	Cold stretched, full NDE	Cold stretched, part NDE	Medium stress, full NDE	Reduced stress, part NDE	Reduced stress, no NDE	Low stress, no NDE, no WPTP
5.7	Proof test (Clause 5.12)	Required for special applications							
5.8	Leak test (Clause 5.13)	Required for special applications							
6	CONFORMITY ASSESSMENT (Section 6 and AS 3920.1)						Required		
7	MARKING (Section 7 and Clause 1.6)						Required		
8	PROTECTIVE DEVICES (Section 8)						Required		
9	DISPATCH (Section 9 and AS 4458) Required to be cleaned and protected for transport and storage as appropriate								

LEGEND:See Appendix A for A_5 , R_m , R_{mT} , R_e , R_{eT} notation. t = nominal thickness above which postweld heat treatment is required, in millimetres

NDE = non-destructive examination

WPTP = welded production test plate

NOTES:

- 1 This Table summarizes the requirements of this Standard as they apply to each Class. Reference should be made to the text for full details.
- 2 Materials, design, welding, qualification and testing, marking, dispatch and non-metallic vessels are shown as 'permitted' on the basis that such items comply in all other aspects with this Standard.
- 3 Welding is taken to include brazing and soldering unless otherwise specified. For detailed requirements, see AS 4458 and AS/NZS 3992.
- 4 Riveted construction is not permitted for Classes 1H, 2H, 1S and 2S vessels.

1.7 APPLICATION OF VESSEL CLASSES

1.7.1 General

The application of various classes of construction shall comply with Clause 1.7.2 and Tables 1.7A and 1.7B, and with any necessary additional risk assessment requirements.

1.7.2 Mixed classes of construction

Mixing of classes of construction is permitted, provided the following conditions apply:

- (a) The class of construction used for any part, component, or joint is not a lower class than that required by Tables 1.6, 1.7A and 1.7B, as applicable at the part or joint.
- (b) Where two classes join at a circumferential joint, and the longitudinal joints of a vessel are fully radiographed, Type B (see Clause 3.5.1.1) circumferential joints shall be spot radiographed in accordance with the relevant requirements for the Clause 'spot examination' of AS 4037.
- (c) The design, marking and manufacturer's data report record joint compliance.
- (d) The vessel shall be marked with the highest two classes of construction used in the main vessel shell.

Examples of pressure vessels where mixed classes of construction may be used are—

- (i) vessels having different sections exposed to different process conditions that warrant different classes of construction, e.g. major refinery towers and heat exchangers;
- (ii) vessels having different wall thicknesses over the length of the vessel owing to external load considerations (e.g. wind or self-weight) or different diameters; and
- (iii) Class 1 shell joined to a Class 1 end by a Class 2 weld that meets all the provisions and limitations for Class 2 construction.

TABLE 1.7A
APPLICATION OF VESSEL CLASSES FOR SERVICE CONDITIONS

		Service limit for vessel classes (see Note 1)									
Item No.	Service condition	1H (Note 4)	2H	1S (Note 4)	2S	1 (Note 4)	2A	2B	3	Low ductility A ₅ < 5% (Note 5)	Non-metallic
1	Fluid type (see AS 4343)										
	—Lethal (Notes 2 and 3)	No limit	Not permitted	No limit	Not permitted	No limit	Not permitted			Not permitted	As agreed
	—Other fluid types (Note 3)	No limit		No limit		No limit			No limit		
2	Design pressure (Clause 1.3)	No limit								See Notes to Table B1(c)	
3	Design temperature										
	—Maximum (Clause 2.7)	No limit, except for material selection and stress		400°C		No limit, except for material selection and stress					
	—Minimum (Clause 2.6)	No limit, except for material selection, stress and postweld heat treatment									
4	Shell thickness	Thickness of type A or B butt welds in Figure 3.5.1.1									
	—Maximum (Table 1.7B)	No limit	Table 1.7B	30 mm		No limit		Table 1.7B		As agreed	
	—Minimum (Clause 3.4)	Table 3.4.3									
5	Shell diameter	No limit									
6	Corrosion/erosion	No limit, except for material selection, fluid type, stress and corrosion allowance									
7	Fatigue service (Clause 3.1.4 and Appendix M)	Required for >500 full pressure cycles or equivalent				Recommended for >50 000–100 000 pressure cycles				Not normally required	As agreed
8	Transportable vessels, service (Clause 3.26.3)	No limit provided designed against fire, collision and fatigue. Not permitted for Group G steels	Not permitted	No limit provided designed against fire, collision and fatigue	Not permitted	No limit	See Clause 3.26.3.1	Not applicable	500 L max. with non-harmful fluid		

NOTES:

- 1 Applicable to welded, brazed, soldered, seamless, forged, cast metallic vessels and non-metallic vessels.
- 2 Vessels shall be forged, seamless or Class 1H or Class 1 construction.
- 3 Packed floating heat exchangers shall not be used when the fluid in contact with the joint is lethal or flammable, unless a risk assessment proves it to be satisfactory.
- 4 Classes 1H, 1S and 1 construction shall be used where it is not practicable to provide inspection openings for subsequent inspections (Clause 3.20.6(b)).
- 5 See Appendix A for A_5 .

TABLE 1.7B
NOMINAL SHELL THICKNESS REQUIRING VARIOUS CLASSES OF
CONSTRUCTION (Note 1)

Material (Notes 7 and 9)			Nominal shell thickness (Note 2)		
Group	Type	Typical standard or nominal composition	Class 1 & 1H construction mm	Class 2 & 2H construction mm	Other Classes
A1	Carbon and carbon-manganese steel (low strength)	AS 1548: 7-430, PT460	>32 (Note 3)	>20	See Notes 10 and 11
A2	Carbon and carbon-manganese steel (medium strength)	AS 1548: 5-490, 7-490	>32 (Note 3)	>12	
A3	Carbon and carbon-manganese steel (high yield strength)	AS 1548: PT490, PT540 AS/NZS 1594: XF 400, XF 500 API 5L: X52, 60, 65, 70	>32 (Note 3)	>20	
A4	Carbon and carbon-manganese steel (quenched and tempered)	JIS-G 3115 SPV490	>32	>12	
B	Alloy steel (alloy <¼)	C-½ Mo; ½ Cr-½ Mo; 1¼Mn-½Mo	>20	>10	
C	Alloy steel (¾ ≤ total alloy <3)	1 Cr-½ Mo; 1¼ Cr-½ Mo	>16	>6	
D1	Low alloy steel (vanadium type)	½ Cr-½ Mo-¼ V	All	—	
D2	Alloy steel (3 ≤ total alloy <10)	2¼ Cr-1 Mo; 5 Cr-½ Mo; 9 Cr-1Mo	All	—	
E	3½–5 Nickel steel	3½ Ni, 5Ni	>16	>6	
F	9 Nickel steel	9 Ni	All	—	
G	Alloy steel quenched and tempered	AS 3597: 700 PV	All	—	
H	Martensitic chromium steel	12 Cr (Type 410) 15 Cr (Type 429)	All	—	
J	Ferritic high chromium steel	12 Cr-Al (Type 405) (Note 4)	All	—	
		12 Cr-low C (Type 410S) (Note 5)	All	—	
		12 Cr-low C (Type 410S) (Note 6)	>38	>5	
K	Austenitic chromium-nickel steel	18 Cr-8Ni (Type 304) 18 Cr-12Ni-2.5 Mo (Type 316) 18 Cr-10Ni-Ti (Type 321)	>38	>10	
L	High chromium steel (>25 Cr)	27 Cr-0.5Ni-0.2C (S44627)	All	—	
M	Ferritic-austenitic chromium-nickel steel (Duplex and Super Duplex)	Various	>38	>5	
Non-ferrous metals	Aluminium and its alloys	Various	>12	≤12	
	Copper and its alloys	Various	>6	≤6	
	Nickel and its alloys	All grades except those below	>38	>5	
		Ni-Cr-Fe, Ni-Fe-Cr, Ni-Mo, Ni-Mo-Cr, Ni-Cr-Mo-Nb	>10	≤10	
	Other	Various	Note 8	Note 8	

* See Notes page 19.

NOTES TO TABLE 1.7B:

- 1 This Table does not prevent Class 1 and 1H or Class 2 and 2H construction below thickness shown. However, it nominates the minimum thickness over which these constructions must be used.
- 2 See also Clause 1.7, and for clad plate, see Clause 3.3.1.2.
- 3 This may be increased to 40 mm where a preheat of not less than 100°C is used or the steel used is made to fully killed fine grain practice with longitudinal impacts of 27 joules at –20°C.
- 4 Welded with straight chromium welding consumables.
- 5 Welded with any welding consumable other than in Note 6.
- 6 Welded with welding consumables that produce an austenitic chromium-nickel steel weld or a non-hardening nickel-chromium-iron deposit.
- 7 For basis of grouping of steels, see AS/NZS 3992 and for specific materials, see Table B1.
- 8 By agreement between the parties concerned.
- 9 Excellent weldability = Groups A1, A2, A3, A4 and K. Good weldability = Groups B, C, E and M.
- 10 For Classes 1S and 2S the maximum nominal shell thickness = 30 mm.
- 11 For Class 3 construction the nominal shell thickness shall be less than that for Class 2.

1.8 DEFINITIONS

For the purpose of this Standard, the definitions in AS 4942, AS 2812 (for welding terms and symbols) and the following apply.

1.8.1 Actual thickness

The actual measured thickness of the material used in the vessel part. It may also be taken as the nominal thickness, minus any applicable manufacturing under tolerance (see Clause 3.4.2(i)).

1.8.2 Cold-stretched plate

Plate, sheet or strip cold-stretched in a cold-stretching machine, after solution heat treatment, to a controlled 0.2% residual proof strength e.g. 350–450 MPa (or 400–500 MPa for nitrogen-alloyed steels).

1.8.3 Cold-stretched pressure vessel

A pressure vessel subjected to a calculated and controlled internal pressure (cold-stretching pressure) at ambient temperature during hydrostatic testing. This pressure stretches the steel, as necessary, and within limits to raise its proof strength and to ensure the actual thickness $\times$ proof strength satisfies the design. Also known as a ‘pressure strengthened vessel’.

NOTE: Vessels made of cold-stretched or work hardened plate will normally have very little plastic deformation during cold-stretching.

1.8.4 Construction

All of the main stages in the provision of pressure vessels. See Figure 1.8.4.

It includes all the tasks required to make and supply the vessel, excluding the specification, and including (but not limited to) design, selection and supply of materials or components, fabrication, provision of examination, testing and conformity assessment services.

NOTE: Any of these tasks might be provided by different parties, as agreed in the contract.

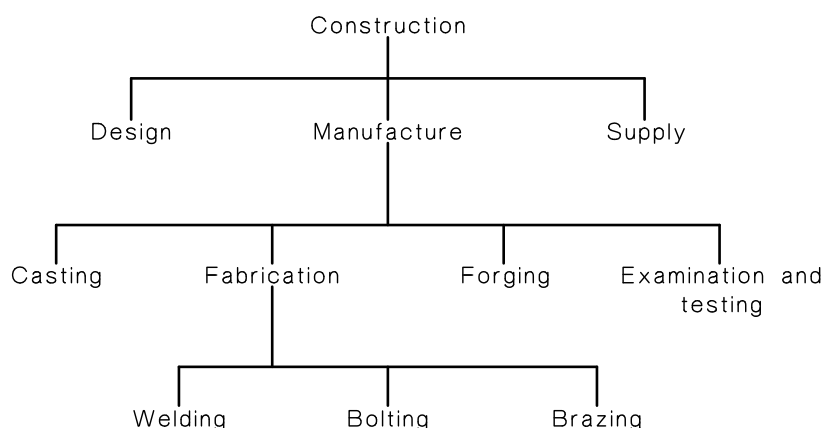


FIGURE 1.8.4 TERMS USED IN CONSTRUCTION

1.8.5 Design

Drawings, calculations, specifications, reports, purchaser requirements and all other information necessary for the complete description of the vessel and its manufacture.

1.8.6 Design life

The life specified in the design as agreed between the manufacturer and the purchaser for each component of pressure equipment.

NOTES:

- 1 Design life is expressed in—
 - (a) hours (or nominated as ‘indefinite’), for operating in the creep (high temperature) range;
 - (b) number of cycles, for fatigue; or
 - (c) years, for corrosion or other material degradation.
- 2 The design life relates to the performance of the relevant component and is not necessarily related to the life of the pressure equipment.

1.8.7 Design pressure

The maximum gauge pressure, at a designated temperature, which is allowed at the top of the vessel in its operating position. (Also known as ‘maximum allowable working pressure’.)

1.8.8 Design strength

The maximum allowable stress for use in the equations for the calculation of the minimum thickness or dimensions of pressure parts (see Clause 3.3).

1.8.9 Design temperature

The metal temperature at the coincident calculation pressure used to select the design strength for the vessel part under consideration (see Clause 3.2.2).

1.8.10 Fire condition

An unusual but foreseeable service condition where there is a significant hazard to a vessel due to exposure to a fire, or other similar source of heat.

The hazard may exist due to flammable or combustible contents, or where such materials are present in the surrounding area.

1.8.11 Harmful contents

A substance, which under the expected concentration and operating conditions, is classified as a *combustible liquid* or *fluid irritant* to humans, or is harmful to the environment, above 90°C, or below –30°C. (See AS 4343.)

1.8.12 Hazard level

A rating of the hazard associated with an application, as determined using AS 4343.

1.8.13 Ligament efficiency

The ratio (expressed as a decimal) of the lowest calculated working strength of the ligaments between holes, for any way in which any ligament might fail, to the calculated working strength of the solid plate adjacent.

1.8.14 Material design minimum temperature (T_R)

A characteristic minimum temperature of a material. It is used in design to select material with sufficient notch toughness to avoid brittle fracture and is the lowest temperature at which the material can be used at full design strength.

NOTE: The term 'material design minimum temperature' was denoted as 'MDMT' in previous editions of this Standard. The notation T_R has been adopted in this edition to allow for inclusion in various equations.

1.8.15 Maximum operating temperature (T_{max})

The highest metal temperature to which the vessel part under consideration is subjected under normal operation. It is determined by the technical requirements of the process (see Clause 3.2.2.4 for maximum service temperature for liquefied gas).

1.8.16 Maximum operating pressure

The highest pressure to which the vessel part under consideration is subjected under normal operation. It is determined by the technical requirements of the process (see Clause 3.2.1).

1.8.17 May

Indicates the existence of an option.

1.8.18 Minimum calculated thickness

The minimum thickness calculated according to the equations to resist loadings, before corrosion or other allowances are added.

1.8.19 Minimum operating temperature (T_{min})

The lowest temperature to which the vessel part under consideration is subjected during normal operation. It is determined by the technical requirements of the process or a lower temperature where specified by the purchaser.

NOTE: The term 'minimum operating temperature' was denoted as 'MOT' in previous editions of this Standard. The notation T_{min} has been adopted in this edition to allow for inclusion in various equations.

1.8.20 Minimum required thickness

The minimum thickness required, which is equal to the minimum calculated thickness plus corrosion and other allowances.

1.8.21 Nominal thickness

The nominal thickness of material selected as commercially available (and to which specified manufacturing tolerances are applicable).

1.8.22 Parties concerned

The purchaser, designer, fabricator, manufacturer, design verifier, inspection body, supplier, installer and owner as appropriate.

1.8.23 Pressure, calculation

The pressure (internal or external) used in conjunction with the design temperature to determine the minimum thickness or dimensions of the vessel part under consideration (see Clause 3.2.1).

1.8.24 Pressures

Unless otherwise noted, all pressures used in this Standard are gauge pressures or the difference in pressures on the opposite sides of the vessel part.

1.8.25 Pressure vessel

A vessel subject to internal or external pressure. It includes interconnected parts and components, valves, gauges and other fittings up to the first point of connection to connecting piping. It also includes fired heaters and gas cylinders, but excludes any vessel that falls within the definition of a boiler or pressure piping in AS/NZS 1200.

NOTES:

- 1 Gas cylinders are not covered by this Standard. It is intended that the above definition includes vessels, such as heat exchangers, evaporators, air receivers, steam type digesters, steam type sterilizers, autoclaves, reactors, calorifiers and pressure piping components, i.e. separators, strainers and the like. See Clause 1.3 for vessels specifically included and excluded.
- 2 Throughout this Standard 'pressure vessels' are referred to as 'vessels'.

1.8.26 Qualified welding procedure

A welding procedure satisfying the requirements of AS/NZS 3992.

1.8.27 Shall

Indicates that a statement is mandatory.

1.8.28 Should

Indicates a recommendation.

1.8.29 Pressure piping

An assembly of pipes, pipe fittings, valves and piping accessories subject to internal pressure, external pressure, or both, and used to contain or convey fluid or to transmit fluid pressure. It includes distribution headers, bolting, gaskets, pipe supports and pressure-retaining accessories.

1.9 UNITS

Except where specifically noted, units used in the Standard are based on newtons, millimetres and degrees Celsius.

1.10 NOTATION

Symbols used in equations in this Standard are shown in Table 1.10.

Symbols not shown in Table 1.10 are defined in relation to the particular equations in which they occur.

1.11 PURCHASER AND MANUFACTURER

This Standard is written on the basis that the purchaser provides a suitable specification for the vessel, and the manufacturer performs all tasks required to construct the vessel according to the specification and to the requirements of this Standard. It is intended that, so long as the requirements of the Standard are met, the parties concerned can come to a documented agreement that certain tasks be performed by alternative parties.

NOTE: All parties should note that various laws, regulations, codes of practice and other requirements apply to pressure vessels in Australia.

Appendices E and F summarize the information required in various Clauses to be supplied by the purchaser and manufacturer, respectively.

A2

1.12 REFERENCED DOCUMENTS

A list with titles of the documents referred to in this Standard, is given in Appendix R.

Where reference is made to a Standard by its number only, the reference applies to the current edition of the Standard, including amendments, unless otherwise agreed by the parties concerned. Where reference is made to a Standard by number, year and, where relevant, an amendment number, the reference applies to that specific document.

TABLE 1.10
MAIN SYMBOLS AND UNITS USED IN EQUATIONS

Description	Symbol	Units
Area	A	mm^2
Charpy–V rupture energy	C_v	J
Corrosion or erosion allowance	c	mm
Cycles–number of	N, n	—
Density	ρ	g/mm^3 or kg/m^3
Diameter	D, d	mm
Dimensions	English alphabet letters	—
Elongation at rupture	A_5	%
Force	F	N
Hardness	HB, HV	—
Joint factor (efficiency)	η	decimal
Length	L, l	mm
Linear expansion coefficient	α	$\mu\text{m/m}^\circ\text{C}$
Mass	m	kg or tonne
Moment	M	Nm or Nmm
Plane angle	Any Greek letter	—
Poisson's ratio	ν	—
Pressure–design (or calculation)	P	MPa
Pressure–test	P_t	MPa
Radius	R, r	mm
Safety factor	S	—
Second moment of area	I	mm^4
Section modulus	Z	mm^3
Shear modulus	G	MPa
Strain	ϵ	%
Strength*–0.2% proof	$R_{p0.2}$	MPa

(continued)

TABLE 1.10 (continued)

Description	Symbol	Units
Strength*–0.2% proof – at temperature T	$R_{p0.2/T}$	MPa
Strength*–1% proof	$R_{p1.0}$	MPa
Strength*–1% proof – at temperature T	$R_{p1.0/T}$	MPa
Strength–creep rupture – for t hours at temperature T	S_{RT}	MPa
Strength–design	f	MPa
Strength*–tensile	R_m	MPa
Strength*–tensile–at temperature T	R_{mT}	MPa
Strength*–upper yield	R_{eH}	MPa
Strength*–yield	R_e	MPa
Strength*–yield–at temperature T	R_{eT}	MPa
Stress–normal	σ	MPa
Stress–shear	τ	MPa
Temperature	T	°C or K
Temperature–material design minimum	T_R	°C
Temperature–maximum allowable	T_{max}	°C
Temperature–minimum allowable	T_{min}	°C
Temperature–test	T_{test}	°C
Thickness–minimum calculated	t	mm
Thickness–minimum	t_{min}	mm
Thickness–nominal	t_n	mm
Time	t	s, min or h
Volume	V	mm ³ , m ³ or L
Weight	W	N or kN
Young's modulus	E	MPa

* Specified minimum strengths

SECTION 2 MATERIALS

2.1 MATERIAL SPECIFICATIONS

2.1.1 General

Parent materials and components used in the construction of vessels shall comply with one of the following:

- (a) Appropriate Standards listed in Tables B1, B2, 1.7B or Clause 2.2.
- (b) Standards listed in AS 1228 or AS 4041.
- (c) Material Standards published by ISO, ASTM (as listed in ASME BPV-VIII) or CEN for use in boilers, pressure vessels, or pressure piping.
- (d) Other materials, in compliance with Clause 2.3.

Such materials shall be used within the limits given in the material or component Standard, and in this Standard.

NOTE: In some cases, material selection might be a matter for discussion between the parties concerned.

Piping and piping components used in pressure vessels shall have a construction suitable for the class of vessel.

NOTE: For example, if the joint efficiency of a piping grade is less than 1, it would be unsuitable for a Class 1 pressure vessel design.

Table 1.7B indicates the vessel Class limits for materials.

2.1.2 Grades

Only those material grades that are suitable for pressure containing parts and their integral attachments, for fabrication and for the conditions of operation for which the vessel is designed, shall be used.

Materials used in the manufacture of welded vessels shall be of satisfactory welding quality. Qualification of welding procedures in accordance with AS/NZS 3992 shall be considered as a minimum proof of satisfactory welding quality of the material. Materials used in the manufacture of brazed vessels shall be of satisfactory brazing quality. Qualification of brazing procedures in accordance with AS/NZS 3992 shall be considered as a minimum proof of satisfactory brazing quality of the material.

Steels of Groups A to E, inclusive (see Table 1.7B), used in the manufacture of welded pressure vessels that will be subjected to prolonged holding at temperature during postweld heat treatment(s) (e.g. exceeding 6 h total holding time) shall have representative test pieces subjected to the total simulated postweld heat treatment cycle(s). Such test pieces shall be subjected to mechanical testing requirements of the parent metal specification to ensure that any degradation in material properties from such heat treatment has not resulted in the material not meeting specification requirements.

Alloy steels may be selected for either creep or corrosion service. This will normally entail tempering temperatures at the bottom range for creep service and at the upper range for corrosion service. Such variations in tempering temperatures shall be taken into account in the selection of materials.

Plate materials that are used as a base in the manufacture of vessels with integrally clad plate or having applied corrosion-resistant linings, shall comply with the requirements of materials given in Table B1. Metal used for applied corrosion resistant lining may be any metallic material of weldable quality that is suitable for the intended service and acceptable to the purchaser.

Materials used for supporting lugs, saddles, skirts, baffles and similar non-pressure parts welded to vessels shall be of weldable quality and suitable in other respects for the intended service.

For Group F steels, see Clause 2.5.4.

2.2 STANDARD COMPONENTS AND INTEGRALLY CLAD METALS

Standard components, e.g. flanges, nozzles, pipe fittings, bolting and valves, and integrally clad metals used in vessel manufacture shall comply with the requirements of the following relevant Standards, except as provided in Clause 2.3.

- (a) *Pipe fittings* ASME B16.9, ASME B16.11, AS/NZS 4331.
- (b) *Pipe flanges* AS 2129, AS/NZS 4331, BS 3293, EN 1092, ASME B16.47, ASME B16.5.
- (c) *Bolting* AS 1110 (series), AS 1111 (series), AS 1112 (series), AS/NZS 2451, AS/NZS 2465, AS 2528, AS B148, BS 2693.1, BS 4439, BS 4882, ASTM A 193, ASTM A 194, ASTM A 320.
- (d) *Pipe threads* AS ISO 7.1, AS 1722.2, ASME B1.20.1, ASME B1.20.3, API Std 5B.
- (e) *Valves* AS 1271, ASME B16.34.
- (f) *Integrally clad plate* ASTM A 263, ASTM A 264, ASTM A 265, ASTM B 898.

NOTES:

- 1 These materials are required where design calculations are based on the total thickness, including cladding.
- 2 Bonding strength to be established in accordance with these specifications.
- 3 Where any part of the cladding thickness is specified as a corrosion allowance, such added thickness should be removed before tensile tests are carried out.

2.3 ALTERNATIVE MATERIAL AND COMPONENT SPECIFICATIONS

2.3.1 General

Where a material or component conforming to one of the specifications permitted by Clauses 2.1 or 2.2 is not available or desired, alternative materials and components may be used provided they comply with the requirements of AS/NZS 1200 for new or alternative materials.

Materials and components that are acceptable under ISO, British, American or European pressure equipment Standards are acceptable for use with this Standard (AS 1210).

2.3.2 Alternative product form

When there is no specification covering a particular product form of a wrought material for which there are specifications covering other product forms, such a product form may be used, provided the following conditions apply:

- (a) The chemical, mechanical and physical properties, scope of testing, heat treatment requirements, and deoxidation or grain size requirements conform to specifications included in Table B1 or B2. The strength values for that specification, listed in Table B1 or B2, shall be used.
- (b) The manufacturing procedures, tolerances, tests and marking are in accordance with the specification covering the same product form of a similar material.
- (c) The two conditions in Items (a) and (b) are compatible in all respects, e.g. welding and testing requirements in Item (b) are appropriate for the material specified in Item (a).

- (d) For welded pipe and tube made from plate, sheet or strip, without the addition of filler metal, 0.85 times the appropriate design strength, as listed in Table B1 or B2 or as derived in accordance with Appendix A, is used.
- (e) Material manufacturer's test certificates reference the specifications used in producing the material.

2.3.3 Use of structural and similar quality steels for pressure parts

Structural and similar quality carbon and carbon-manganese steel plates and sheets, tubes, bars and sections not listed in Table B1, may only be used for pressure parts of Class 3 vessels, provided the following conditions are fulfilled:

- (a) The specified minimum tensile strength of the steel is no greater than 460 MPa.
- (b) The ladle analysis does not exceed the following:

Carbon.....	0.25%.
Phosphorus	0.040%.
Sulfur	0.040%.
Carbon equivalent based on: $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$	0.45%.
- (c) Test certificates (or equivalent) identifying the steel to a national Standard are provided and the steel is suitably marked or labelled.
- (d) Plate used for flanges is not greater than 40 mm thick and the steel is not greater than 16 mm thick for tubes, sections and machined sockets and bosses, or 40 mm diameter for bars.
- (e) Welded tube complies with a specification that requires hydrostatic testing of the tube. Regardless of the vessel classification, a maximum weld joint efficiency of 0.65 is to be used for welded tubes. Factor 0.85 in Clause 2.3.2(d) and factor 0.92 in Item (f) do not apply.
- (f) The design strength for calculation purposes is determined in accordance with Appendix A and multiplied by a factor of 0.92.
- (g) All weld preparations, openings, tubes, bars and sections shall be visually examined for evidence of lamination that may render the plate unacceptable (see 'Defects in materials' in AS 4458).
- (h) The design temperature of the vessel is between 0°C and 250°C.
- (i) The vessel is not used for applications with high risk of lamellar tearing or hydrogen blistering.
- (j) If the steel is to be hot-formed above 650°C or normalized during fabrication, the specified properties of the material shall be verified by tests on a specimen subjected to a simulated heat treatment equivalent to that which the steel is to be subjected.
- (k) Bars and sections that have been manufactured by a cold forming process are not acceptable unless an appropriate heat treatment is used, e.g. normalizing.

2.3.4 Specifically tested materials

The use of steel outside the limits of Clause 2.3.3 or other materials is permitted for pressure parts and attachments, provided—

- (a) the material is shown by special tests to be equally suitable for the particular application as a similar material listed in Table B1; and
- (b) agreement is given by the parties concerned.

These special tests may include chemical analysis, mechanical tests and non-destructive examination.

2.4 MATERIAL IDENTIFICATION

Material identification shall comply with the requirements of the material or component Standard and AS 4458.

2.5 LIMITS OF APPLICATION OF MATERIALS AND COMPONENTS

2.5.1 Maximum pressure limits

The maximum pressure for cast iron pressure parts should be in accordance with Notes 2 and 3 to Table B1(D).

Components shall be limited to the maximum pressures for which they are rated by the component specification and by the requirements in this Standard for the specific type of component.

2.5.2 Temperature limits

For low and high temperature limits, see Clauses 2.6 and 2.7, respectively.

2.5.3 Service limits

2.5.3.1 *Cast iron*

Grey and malleable cast irons and ductile cast irons*, with elongation less than 14% (on a gauge length of $5.65\sqrt{\text{area}}$), shall not be used for vessels containing lethal or flammable fluids.

2.5.3.2 *Low melting point metals*

The low melting points of copper and aluminium and some of their alloys shall be taken into account where vessels will contain flammable fluid.

Materials for which no design strengths are given above 350°C in this Standard shall not be used for transportable vessels containing lethal substances, nor those containing flammable substances unless the vessel is insulated in accordance with Clause 3.26.

2.5.3.3 *Corrosion resistance*

In selecting material for vessels, consideration shall be given to the possibility of general or local wastage, corrosion, stress corrosion, corrosion fatigue, abrasion, erosion, and the like.

NOTE: For recommended corrosion practice, see Clause 2.9 and Appendix D.

2.5.4 Structural attachments and stiffening rings

Where pressure parts are constructed of Group F steel, all permanent structural attachments and stiffening rings welded directly to the pressure part shall be of nine percent nickel steel or an austenitic stainless steel which cannot be hardened by heat treatment. Where austenitic stainless steel is used for attachments, consideration shall be given to the greater coefficient of expansion of the austenitic stainless steel.

* Alternative names for ductile cast iron are 'spheroidal graphite iron', 'SG iron' and 'nodular graphite iron'.

2.6 MATERIAL FOR LOW TEMPERATURE SERVICE

2.6.1 General

Materials and components for pressure parts (and for non-pressure parts welded directly to pressure parts) for low temperature service, or where it is required to guard against brittle fracture, shall comply with the appropriate requirements of this Clause (2.6). These requirements do not apply to non-pressure parts such as internal baffles, trays, supports, and the like where these are not attached to a pressure part by welding and are not otherwise an integral part of a pressure part.

The following methods may be used to establish requirements to guard against low temperature brittle fracture:

- (a) Method 1: Technical requirements in Clauses 2.6.2 to 2.6.5, developed from testing, operating experience and fracture mechanics principles using Charpy V values to characterize metal toughness.
- (b) Method 2: Fracture mechanics analysis in accordance with Clause 2.6.6, by agreement of the parties concerned.

See Clause 3.21.5 for requirements for steel bolting for low temperatures.

Unless otherwise noted, metal temperatures are mean values.

2.6.2 Selection of material

2.6.2.1 General

To select suitable material for each part of the vessel, the following procedure may be used:

- (a) For carbon, carbon-manganese and low alloy wrought or cast steels but excluding bolting, either see Clauses 2.6.2.2, 2.6.2.3 and 2.6.2.4, or determine the following:
 - (i) The minimum operating temperature ($T_{\min}$) for the part from Clause 2.6.3.1;
 - (ii) The required material design minimum temperature* (T_R) from Clause 2.6.3.2;
 - (iii) The material reference thickness (t_R) from Clauses 2.6.4;
 - (iv) The impact test temperature (T_{cv}); and
 - (v) Select a suitable steel from Table 2.6.2.
- (b) For metals other than carbon, carbon-manganese and low alloy wrought or cast steel and excluding steel bolting—
 - (i) determine the $T_{\min}$ for the part in accordance with Clauses 2.6.3.1; and
 - (ii) from Table 2.6.3, select the permitted material (and any necessary impact tests) having a required T_R equal to or less than $T_{\min}$.

NOTE: Where reference is made in Table 2.6.3 to Figure 2.6.2(A) or Figure 2.6.2(B), see Item (a) for guidance.

- (c) For non-metallic materials, see Clause 2.6.7.

The sequence in items (a) and (b) may be changed as appropriate to determine $T_{\min}$, T_R or t_R .

2.6.2.2 Thin-walled carbon and carbon-manganese steel tubes (seamless and welded)

Heat exchanger tubes of carbon and carbon-manganese and low alloy steels with less than 0.25% carbon and a specified minimum tensile strength of less than 450 MPa, may be used at $T_{\min}$ as shown in Table 2.6.2.2 provided—

* The ‘material design minimum temperature’ was denoted as ‘MDMT’ in previous editions of this Standard. The notation T_R has been adopted in this edition to allow for inclusion in various equations.

- (a) the tubes are used in heat exchangers of the floating head type;
- (b) the tubes used in U-tube type heat exchangers are heat-treated after cold bending where required by AS 4458; or
- (c) for fixed tubeplate type heat exchangers, it is demonstrated that tensile stresses in the tubes due to differential thermal expansion are low, e.g. where spiral-wound tubes or expansion bellows are used, or calculated tensile stresses are less than 50 MPa.

TABLE 2.6.2.2
MATERIAL DESIGN MINIMUM TEMPERATURE
FOR HEAT EXCHANGER TUBES

Thickness mm	Tube to tubesheet attachment method		
	As welded °C	Welded and PWHT °C	Unwelded °C
10	−15	−30	−70
8	−20	−35	−75
6	−25	−40	−80
4	−40	−55	−95
2	−55	−70	−110

2.6.2.3 Thin materials

Materials having a thickness insufficient to obtain a 2.5 mm Charpy V-notch specimen may be used at a temperature no less than that permitted for non-impact tested material of similar type, or as provided in Clause 2.6.2.2 and Clause 2.6.2.4, or as established by tests agreed by the parties concerned.

2.6.2.4 Metals not requiring impact testing

Impact testing of metals is not required for the following:

- (a) Steels covered by curves $T_{cv} = 0^\circ$, 20° and 30° of Figures 2.6.2(A) or (B), for the appropriate T_R and service conditions.
- (b) Steels covered by curves $T_{cv} = -20^\circ$ and -40° , for T_R 10°C above that from Figures 2.6.2(A) and (B).
- (c) Carbon and carbon-manganese steels Groups A1, A2 and A3 with specified carbon content above 0.25% covered by curves $T_{cv} = 0^\circ$, 20° and 40° , for T_R 10°C above that from Figures 2.6.2(A) and (B).
- (d) Steels covered by curves $T_{cv} = 20^\circ$, 40° and 50° thinner than 3.0 mm, provided they are used at design metal temperatures not colder than -50°C .

See also Table 2.6.2.2 and Note 5 to Table 2.6.2.

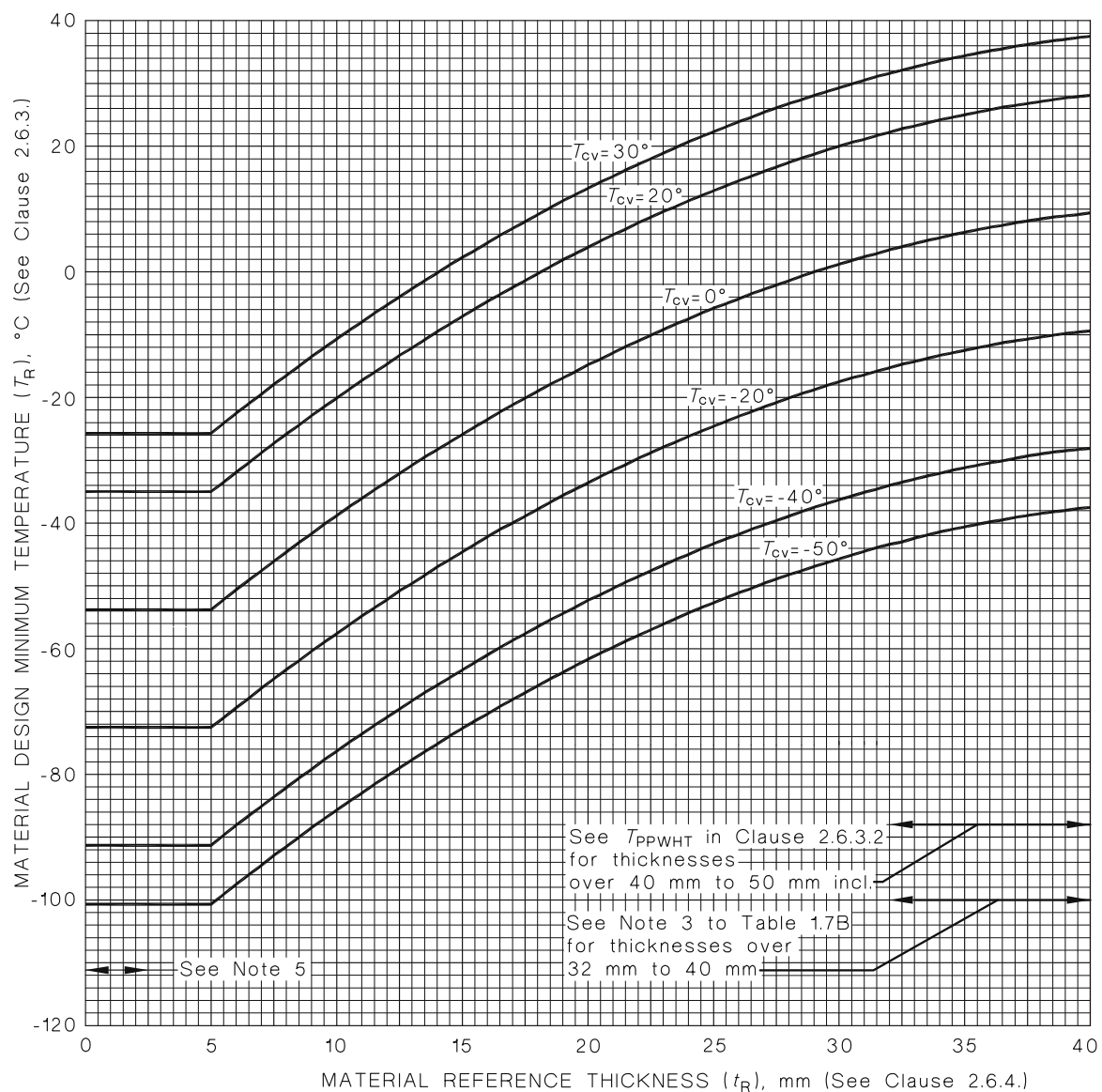
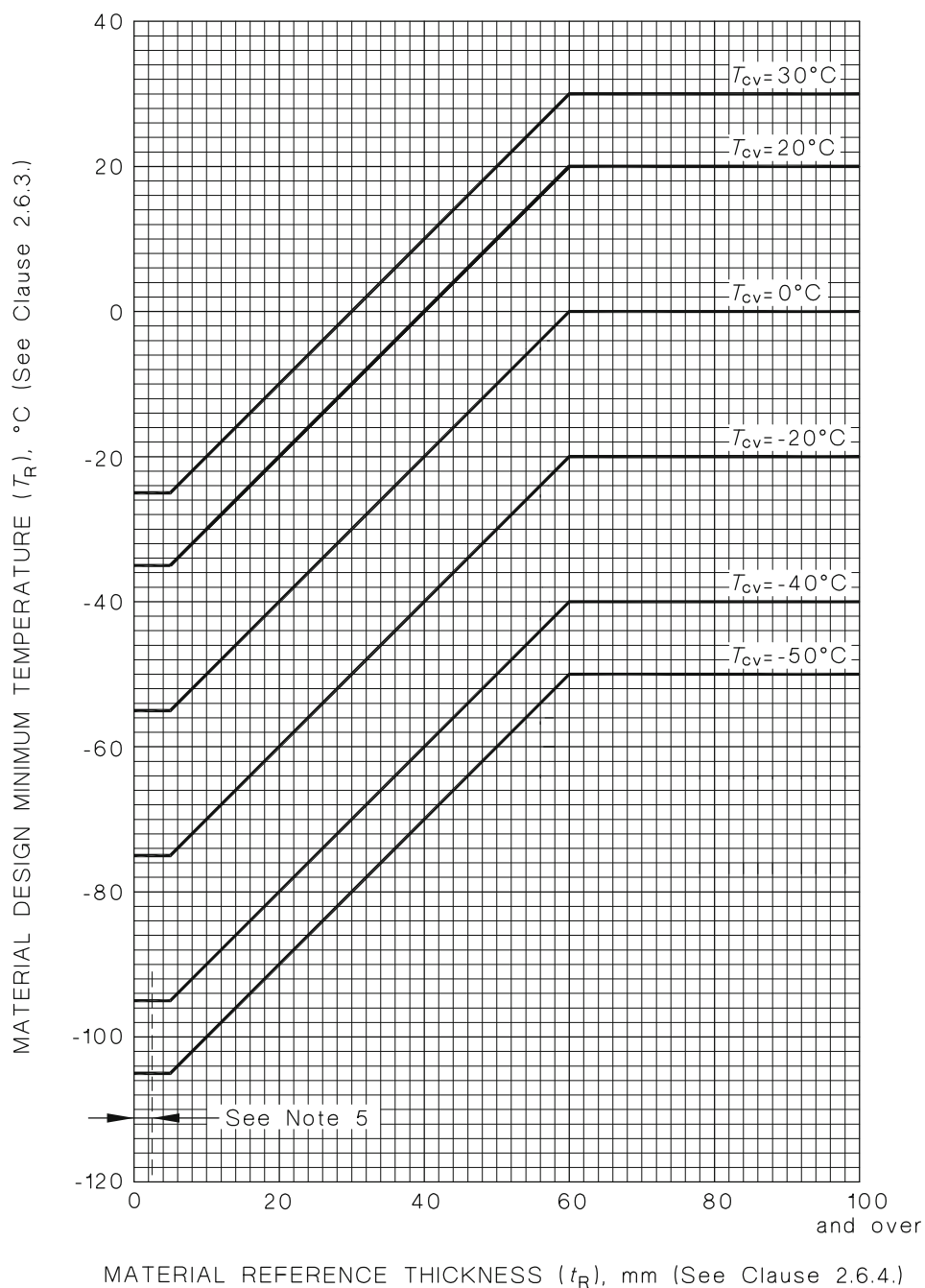


FIGURE 2.6.2(A) WROUGHT CARBON, CARBON-MANGANESE AND LOW ALLOY STEELS—SELECTION OF MATERIAL FOR LOW TEMPERATURE SERVICE —AS WELDED



*Notes to this figure follow Table 2.6.2.

FIGURE 2.6.2(B) WROUGHT CARBON, CARBON-MANGANESE AND LOW ALLOY STEELS—SELECTION OF MATERIAL FOR LOW TEMPERATURE SERVICE—POSTWELD HEAT TREATED AND UNWELDED

TABLE 2.6.2
BASIS FOR CURVES ON FIGURES 2.6.2(A) AND 2.6.2(B)

Curve $T_{cv}^{\circ}C$ (Notes 5 and 6)	Standard impact test value (J) Specified minimum yield strength, MPa			Steels represented by curves	
	$R_e \leq 310$	$310 < R_e \leq 360$	$360 < R_e \leq 450$	Type (Note 8)	AS 1548 Grades
30 No test (Note 7)	—	—	—	All, C < 0.35%	All
20 No test (Note 7)	—	—	—	All, C ≤ 0.25%	All
0 (Note 1)	27	31	40 (Note 3)	All, C < 0.25%	All
0 No test (Note 7)	—	—	(Note 4)	Fine grained C-Mn steel	PT430 L0 to L40 PT460 L0 to L50 PT490 All designations PT540 All designations
-10 (Note 1)	27	31	40 (Note 3)	Fine grained C-Mn steel (Note 2)	PT430 L0 to L40 PT460 L0 to L50 PT490 All designations PT540 All designations
-20 (Note 1)	27	31	40 (Note 3)	Fine grained C-Mn steel (Note 2)	PT430 L0 to L40 PT460 L0 to L50 PT490 All designations PT540 All designations
-40 (Note 1)	27	31	40 (Note 3)	Fine grained C-Mn steel (Note 2)	PT430 L20, L40 PT460 L20-L50 PT490 L20-L50 PT540 L40, L50
-50 (Note 1)	27	31	40 (Note 3)	Fine grained C-Mn steel (Note 2)	PT430 L0 to L40 PT460 L0 to L50 PT490 All designations PT540 All designations

NOTES TO FIGURES 2.6.2(A), 2.6.2(B), AND TABLE 2.6.2:

- 1 Tested by steelmaker or manufacturer.
- 2 Steels produced to fine grained practice, i.e.—
 - (a) normalized steel where the actual Mn% divided by the actual C% ≥ 4;
 - (b) controlled rolled;
 - (c) thermo-mechanically controlled rolled;
 - (d) grain refining elements added, e.g. aluminium or titanium (or both) 0.01% minimum. Examples are AS 1548 and AS/NZS 1594 grade HU 300/1; or
 - (e) ferritic grain size is 6 or finer, when tested to ISO 643.

- 3 For steel with impact test values equal to or greater than 27 J and less than 40 J, material design minimum temperatures 10°C above the curve will apply. Where a Standard does not specify the temperature corresponding to 27 J (or 31 J or 40 J) Charpy V energy, the value specified may be converted to the 27 J (or 31 J or 40 J) temperature on the basis of 1.5 J/°C. This conversion shall be permitted in the range of Charpy V energy 18 J to 50 J. For example, AS 1548 Grade PT460 giving 47 J at –20°C may be regarded as equivalent to 27 J at –33°C.
- 4 Applicable only to steel with specified minimum tensile strength equal to or less than 490 MPa.
- 5 Impact tests are not required for material thinner than 3 mm or where it is impracticable to obtain a 10 mm × 2.5 mm specimen. (See also Clause 2.6.2.3). Material specifications might not require impact tests on Charpy specimens smaller than 10 mm × 5 mm without special negotiation and thus impact tested material thinner than 7 mm might not be readily available. Extrapolation of curves from 5 mm to 2.5 mm, where agreed between the parties concerned, should be supported by suitable testing.
- 6 Values at intermediate test temperatures may be obtained by linear interpolation.
- 7 Where impact testing is not required and the vessel is classified as a hazard level A or B to AS 4343 and ferritic steels are purchased from an unproven supplier, a Charpy-V-impact test should be performed on at least one item of product to satisfy curves $T_{cv} = 20^{\circ}$, 30° and 40° of Figure 2.6.2(B) at these test temperatures.
- 8 The maximum permitted carbon content (C) by cast analysis is 0.25 % for curves $T_{cv} = -20^{\circ}$, -40° and -50° . This limit may require restriction of the normally specified carbon content in some steel specifications permitted by this Standard.

TABLE 2.6.3
MATERIAL DESIGN MINIMUM TEMPERATURE (T_R)

Material		Typical specification or nominal composition		Material design minimum temperature (T_R), °C (Note 1)	
Steel group (Note 3)	General type	Standard of specification	Grade or type	Not impact tested	Impact tested (Note 4)
CARBON AND CARBON-MANGANESE STEEL (all forms excluding weld metal and bolting)					
A1	C, C-Mn (low strength)	AS 1548	PT430, PT460	See Clauses 2.6.2 and 2.6.3.2	See Clauses 2.6.2 and 2.6.3.2 and Note 5
A2	C, C-Mn (medium strength)	AS 1548	PT490, PT490		
A3	C, C-Mn (high-yield strength)	AS 1548 AS/NZS 1594	PT540 XF 400, XF 500		
A4	C, C-Mn (high-yield strength) Quenched and tempered, with or without boron	JIS-G3115	ASME Group P1.4 EN Group 1.3 SPV 490		
LOW ALLOY STEEL (all forms, excluding weld metal and bolting) (Note 2)					
B	Cr or Mo < ¾	—	C - ½Mo, ½Cr - ½Mo	T_R for curve $T_{cv} = 20^\circ$ in Figure 2.6.2 (A) or (B) as appropriate but not lower than 0°C	Use the appropriate curve in Figures 2.6.2(A) and (B)
C	¾ ≤ Total alloy ≤ 3	—	1Cr - ½Mo		
D1	Vanadium	—	½Cr - ½Mo - ¼V		
D2	3 ≤ Total alloy ≤ 10	—	2¼Cr-1Mo		
E	1½-5 Ni	ASTM A 203	D E	-30 or T_R for curve $T_{cv} = 0^\circ$ in Figure 2.6.2 (A) or (B), whichever is less	Test temperature giving $C_v \geq 27$ J
F	9 Ni	ASTM A 353	A, B, C, D, E, F, J, P 700 PV	Not permitted	Test temperature giving $C_v \geq 20$ J
G	Quenched and tempered	ASTM A 517, AS 3597			Test temperature giving lateral expansion ≥0.38 mm for each specimen (Note 9) and NDTT (Note 6)

(continued)

TABLE 2.6.3 (continued)

Material		Typical specification or nominal composition		Material design minimum temperature (T_R), °C (Note 1)		
Steel group (Note 3)	General type	Standard of specification	Grade or type	Not impact tested	Impact tested (Note 4)	
HIGH ALLOY STEEL (all forms, excluding castings, weld metal and bolting)						
H	Martensitic chromium Types 12 Cr and 15 Cr	ASTM A 240	410, 429	T_R as for curve $T_{cv} = 20^\circ$ in Figure 2.6.2 (A) or (B) as appropriate but not lower than -30°		
J	Ferritic high chromium types 12 Cr-Al or 12 Cr low C	ASTM A 240	405, 410S			
K	Austenitic chromium nickel types (only plate specifications shown) (See Note 10):					
	18 Cr-8 Ni	ASTM A 240	304	-255 -255 -255 -200 -200 -200 -200 -200 (Note 7)		Test temperature giving lateral expansion ≥ 0.38 mm for each specimen or Test temperature giving $C_v \geq 27$ J where $R_e \leq 310$ MPa; 40J where $310 \text{ MPa} < R_e < 650 \text{ MPa}$
	18 Cr-8 Ni (Low C)	ASTM A 240	304L			
	18 Cr-8 Ni-Nb	ASTM A 240	347			
	18 Cr-10 Ni-Ti	ASTM A 240	321			
	18 Cr-10 Ni-2 Mo	ASTM A 240	316			
	18 Cr-10 Ni-2 Mo(Low C)	ASTM A 240	316L			
	19 Cr-13 Ni-3 Mo	ASTM A 240	317			
	25 Cr-20 Ni	ASTM A 240	310S			
	Selected Austenitic types postweld heat treated below 900°C	ASTM A 240	309, 310, 316 309Cb, 310Cb, 316Cb	Not permitted		
	Any type with C > 0.10%	ASTM A 240	302	-30		

(continued)

TABLE 2.6.3 (continued)

Material		Typical specification or nominal composition		Material design minimum temperature, °C (Note 1)	
Steel group (Note 3)	General type	Standard of specification	Grade or type	Not impact tested	Impact tested (Note 4)
L	High chromium	ASTM A 240	442,446	Not permitted	
M	Ferritic-austenitic chromium nickel	ASTM A 789	S31803	T_R as for curve $T_{cv} = 20^\circ$ in Figure 2.6.2 (A) or (B) as appropriate but not lower than -30 . For unwelded material ≤ 5 mm thickness, the $T_R \geq -50^\circ\text{C}$.	
HIGH ALLOY STEEL (Castings)					
All types (H to M)		—	—	As for Group H steels	Test temperature giving $C_v \geq 20$ J
CAST IRONS					
	Grey iron	AS 1830	T-150 to T-400	-30	Note 8
	Spheroidal graphite	AS 1831	500-7 and 400-12		
	Malleable iron	AS 1831	370-17	T_R as for curve $T_{cv} = 20^\circ$ in Figure 2.6.2 (B) but not lower than -30°	Test temperature giving $C_v \geq 20$ J
	Austenitic iron	AS 1832	All whiteheart and blackheart	-30	Note 8
	Austenitic iron	AS 1833	All spheroidal graphite	-30	Test temperature giving $C_v \geq 20$ J
NON-FERROUS METALS					
All types except Titanium and its alloys		See Tables B1, (D), (E), (F) and (H)		No Limit	Impact test not required
Titanium and its alloys		ASTM B 265		-60	Test temperature giving $C_v \geq 20$ J

LEGEND:

C_v = Charpy V impact test values; R_e = specified minimum yield strength

NOTES TO TABLE 2.6.3:

- 1 See Clause 2.6.3.2 for adjustments permitted or required.
- 2 Low alloy steels not listed in or not equivalent to those in the table shall meet the requirements specified for Group B steels.
- 3 For steel groups, see Table 1.7 and AS/NZS 3992.
- 4 Where Charpy V energy values are quoted, the values are the minimum average values for each set of three 10 mm × 10 mm specimens.
- 5 For variations permitted for different energy values and test temperatures, see Note 3 to Figures 2.6.2(A) and 2.6.2(B).
- 6 In addition to Charpy V impact test, dropweight tests are required for—
 - (a) Group F steels ≥ 16 mm thick for use at minimum operating temperature (T_{min}) below -170°C ; and
 - (b) Group G steels ≥ 16 mm thick for use at T_{min} below -30°C .
- 7 Impact testing for these high alloy steels is not required below the temperature listed when the calculated primary general membrane stress used for determining thickness does not exceed 50 MPa.
- 8 These cast irons may be used below -30°C by agreement of the parties concerned, on the basis of suitable testing or successful past experience.
- 9 For Group F and Group G steels, the maximum test temperature is 0°C .
- 10 For austenitic stainless steels, the T_R listed here applies to material in the solution-annealed condition only.

2.6.2.5 Use of fracture mechanics

Materials may be used at temperatures lower than otherwise required by Clauses 2.6.2 to 2.6.5, provided that suitable fracture mechanics analysis (see Clause 2.6.6) and tests justifying the lower temperatures are carried out.

2.6.2.6 Welded material

Where materials are welded, the following shall apply:

- (a) The heat affected zones and weld metal of each weld shall meet the temperature limits and impact requirements for the component with the higher T_R , as specified in this Standard and in AS/NZS 3992.
- (b) The weld procedure shall be qualified according to AS/NZS 3992.
- (c) Weld production test plates shall be prepared in compliance with this Standard (see Clause 5.2.2) and AS/NZS 3992.

2.6.3 Minimum temperatures**2.6.3.1 Minimum operating temperature (T_{min}) ***

T_{min} shall be the lowest metal temperature of the part under consideration during normal operation including normal process fluctuations and during properly conducted start-up and shutdown. T_{min} shall be the lowest of the following:

- (a) For vessels thermally insulated externally—the minimum temperature of contacting contents.
- (b) For vessels not thermally insulated—the lower of—
 - (i) the lowest one day mean ambient temperature (LODMAT)[†] plus 10°C , where the metal can be subjected to this temperature while the shell is under pressure; and

* Minimum operating temperature was denoted as 'MOT' in previous edition of this Standard. The notation T_{min} has been adopted to allow its inclusion in various equations in this edition of this Standard.

[†] See Appendix K.

- (ii) the minimum temperature of the contacting contents except that for Groups A1, A2, A3, A4, B, C, D1, D2, and G steels in vessels containing fluids at temperatures governed by atmospheric conditions only and whose vapour pressure reduces with decreasing temperature, the temperature corresponding to the vapour pressure obtained by dividing the vessel design pressure by 2.5 may be used.
- (c) If there is evidence to show that because of radiation, adiabatic expansion or other effects, the above will not provide a reliable estimate of temperature, the method to be used in assessing the temperature shall be agreed. Allowance shall be made for any sub-cooling during pressure reduction (see Clause 2.6.3.2).
- (d) A lower temperature than that determined from Items (a), (b) or (c) where so specified by the purchaser or an application Standard.

2.6.3.2 Material design minimum temperature (T_R) for Group A to E steels

For Group A to E steels, the required T_R (in degrees Celsius) shall be calculated using the following equation:

$$A1 \quad T_R = T_{\min} + T_S - T_L + T_{PPWHT} - T_{SHOCK} - T_C - T_{STRAIN} - T_H \quad \dots 2.6.3$$

where

$T_{\min}$ = minimum operating temperature, in degrees Celsius, from Clause 2.6.3.1

T_S = temperature adjustment for stress

- = 0°C for post weld heat treated (Note 1) and $k_s > 75\%$;
- = 10°C for post weld heat treated (Note 1) and $50\% < k_s \leq 75\%$;
- = 25°C for post weld heat treated (Note 1) and $k_s \leq 50\%$;
- = 50°C for post weld heat treated (Note 1) and membrane stress ≤ 50 MPa (Note 2);
- = 0°C for as-welded condition, membrane stress > 50 MPa (Note 2) and $t_R < 30$ mm; or
- = 40°C for as-welded condition, and membrane stress ≤ 50 MPa (Note 2) and $t_R < 30$ mm.

NOTES:

- 1 Also applies to non-welded parts and vessels where nozzles and non-temporary attachments are post weld heat treated, before assembly into the vessel with butt welds which are not subsequently post weld heat treated.
- 2 This membrane stress must take account of internal and external pressure and dead weight. For walls and pipes of heat exchangers the restraint of free end displacement of the heat exchanger pipes should also be taken into account.

k_s = ratio of pressure induced principal membrane stress and design strength for Class 1H vessels, f .

f = highest design stress for material under Class 1H, in megapascals

NOTE: The Class 1H value is to be used here for all Classes.

η = weld efficiency (for castings this shall be 0.8 max)

σ_m = calculated primary membrane stress in the corroded condition, in megapascals

- T_L = 15°C for lethal vessel contents; or
0°C otherwise.
- T_{PPWHT} = 15°C for partially post-weld heat treated parts where plates containing nozzles, supports or other welded attachments are postweld heat-treated before they are butt-welded to the shell, but the main joints are not postweld heat-treated, and where the minimum distance from the edge of the welds of the attachments to the main welded joints is not less than the lesser of $3t_{shell}$ and 150 mm; or
0°C otherwise.
- T_{SHOCK} = 15°C for transportable vessels or other vessels subject to similar shock loadings; or
0°C otherwise.
- T_C = 10°C for Class 2H vessels containing liquefied gas; or
0°C otherwise.
- T_{STRAIN} = 1°C for each 1% cold forming strain greater than 5% for any part that is not subsequently heat treated
- T_H = 10°C for vessels not subject to a full pressure test; or
0°C otherwise.

The calculated stresses shall take into account all loadings, such as internal and external pressures, thermal stress and external loads arising from connecting pipes. Where such a vessel will also be subject to a higher pressure at higher temperature, e.g. in a refrigeration system with liquefied gas, the material and design shall be suitable for all expected combinations of operating pressures and temperatures.

Where the vessel might be subject to cooling due to a pressure drop followed by a significant pressure increase while still cold, it is recommended the required T_R be equal to the atmospheric boiling point, for a liquefied gas, or the estimated minimum metal temperature, for a permanent gas.

2.6.3.3 T_R for metals other than Group A to E steels

For metals other than Group A to E steels, the required T_R shall be as specified in Clause 2.6.2.1.

2.6.4 Material reference thickness

A2 | The reference thickness (t_R) used in applying Figures 2.6.2(A) and 2.6.2(B) shall be determined from Table 2.6.4 and as follows:

- (a) *Butt welded shell components* The reference thickness of each component shall be taken as the actual thickness of the component under consideration at the edge of the weld preparation.
- (b) *Weld neck flanges, plate and slip-on (or hubbed) flanges, flat tubeplates and flat ends* The reference thickness shall be the greater of one-quarter the actual thickness of the flange, tubeplate or flat end, or the thickness of the nozzle or shell attached thereto.

If the distance from the flange, tubeplate or flat end to the butt weld is not less than four times the thickness of the butt weld, the reference thickness for the as-welded condition shall be the thickness at the edge of the weld preparation.

The reference thickness of tubeplates having tubes attached by welding shall be taken as not less than tube thickness.

NOTE: Where the shell to tubeplate joint is stress relieved but the tube/tubeplate joint is as-welded, this may affect the selection of materials for the tubeplate.

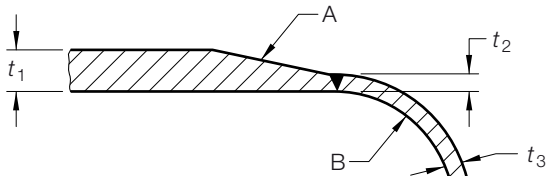
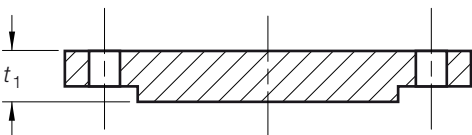
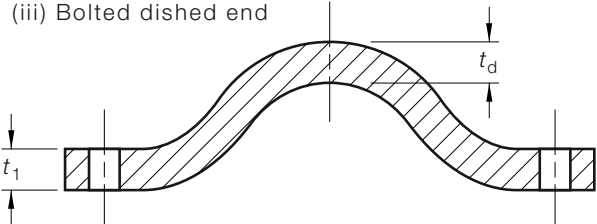
- (c) *Nozzles and compensating plates* The reference thickness of each welded component shall be determined separately by considering only the actual thickness of that component. Where butt-welded inserts are used, the reference thickness shall correspond to the thickness at the edge of the weld preparation.
- (d) *Tubes* The reference thickness shall be that of the actual thickness of the tube.
- (e) *Attachments* Attachments welded directly to a pressure component shall be regarded as part of the pressure component, and the reference thickness shall be the thickness as shown in Table 2.6.4. Intermediate attachments (see Table 2.6.4, Item (g) Attachments) shall be employed where it is required to attach non-critical components to the shell.
- (f) *Welds* The reference thickness for welds shall be the following:
- (i) For welds in shells or nozzles, or attachments directly welded to shells or nozzles—the maximum thickness of the parts joined.
 - (ii) For welds in flanges, flat ends and flat tube plates—the minimum thickness of the parts joined.
- (g) *Castings* The reference thickness shall be the maximum nominal thickness.
- (h) *Unwelded components* Unwelded components shall be taken as postweld heat treated and the reference thickness shall be taken as one-quarter of the thickness of the item.
- (i) The thickness above used as a basis for the reference thickness shall be the nominal thickness and shall be not less than the minimum calculated thickness plus corrosion and other allowances.

The reference thickness (t_R) and condition used to determine T_R for a component shall be the thickness and condition giving the warmest T_R .

NOTE: t_R is approximately equivalent to the thickness of a cylindrical shell with an assumed longitudinal weld defect, and with residual and applied stresses.

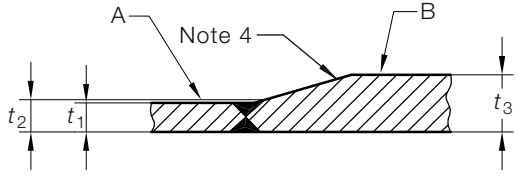
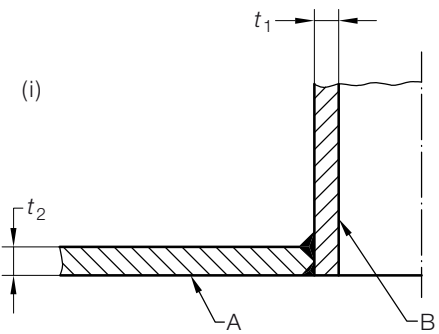
TABLE 2.6.4

DETERMINATION OF MATERIAL REFERENCE THICKNESS (t_R)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
(a) Unwelded components					
(i) Seamless cylinder	AW	Max of t_2 and $t_1/4$ in Figure 2.6.2(B)	t_2	t_3	—
	PWHT	Max of t_2 and $t_1/4$	t_2	t_3	—
(ii) Seamless flat plate	Treat as PWHT	$t_1/4$	—	—	—
					
(iii) Bolted dished end	Treat as PWHT	Max. of $(t_1/4)$ and $t_d/4$	—	—	—
					

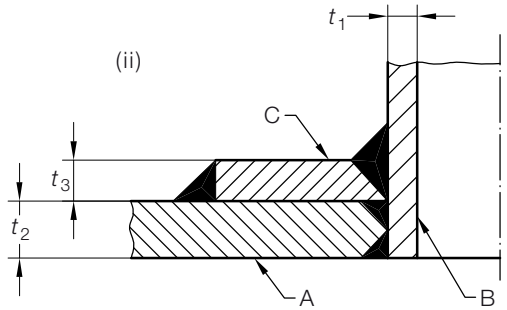
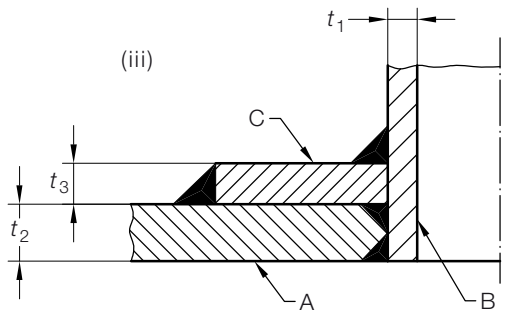
(continued)

TABLE 2.6.4 (continued)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
(b) Butt-welded shell components – circumferential and longitudinal welds 	AW	t_1	t_2	Max of t_2 and $t_3/4$ in Figure 2.6.2(B)	—
	PWHT	t_1	t_2	Max of t_2 and $t_3/4$	—
(c) Nozzles (i) 	AW	t_2	t_2	t_1	—
	PWHT	t_2	t_2	t_1	—

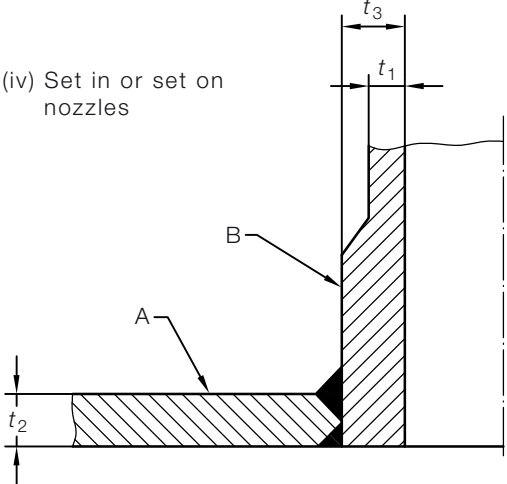
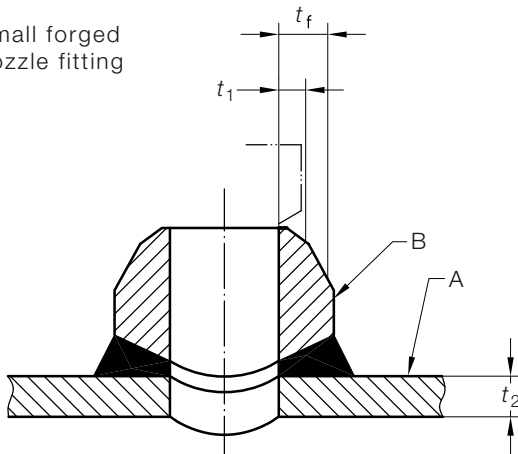
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TABLE 2.6.4 (continued)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
	AW	t_2	Max. of t_2 and t_3	t_1	t_3
	PWHT	t_2	Max. of t_2 and t_3	t_1	t_3
	AW	t_2	Max. of t_2 and t_3	t_1	t_3
	PWHT	t_2	Max. of t_2 and t_3	t_1	t_3

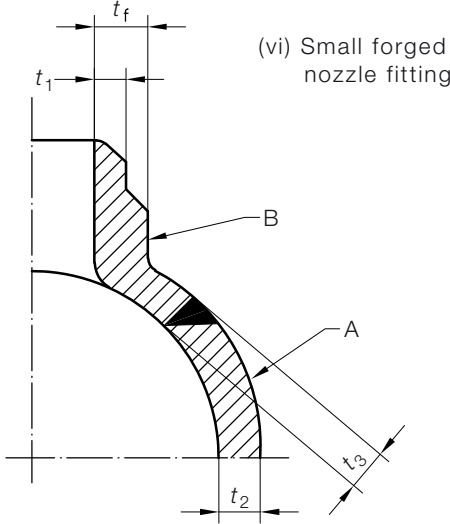
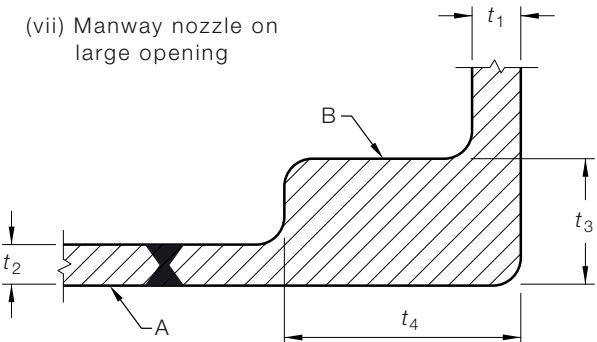
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TABLE 2.6.4 (continued)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
(iv) Set in or set on nozzles 	AW	t_2	Max. of t_2 and t_3	t_3	—
	PWHT	t_2	Max. of t_2 and t_3	t_3	—
(v) Small forged nozzle fitting 	AW	t_2	t_2	Max. of t_1 and $t_f/4$	—
	PWHT	t_2	t_2	Max. of t_1 and $t_f/4$. If necessary, check t_1 in Figure 2.6.2(A).	—

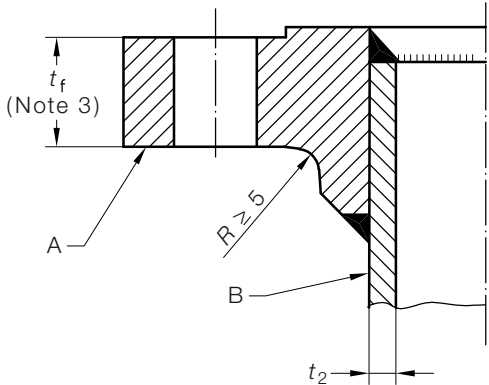
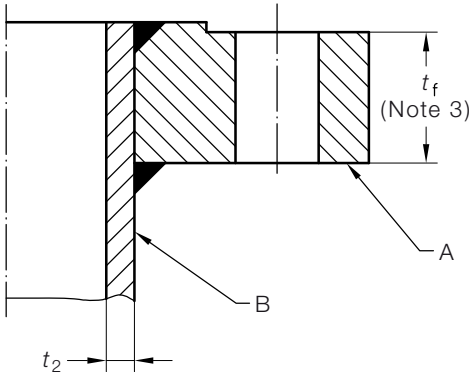
(continued)

TABLE 2.6.4 (continued)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
 (vi) Small forged nozzle fitting	AW	t_2	t_3	Max. of t_3 and $t_f/4$	—
	PWHT	t_2	t_3	Max. of t_3 and $t_f/4$. If necessary, check t_1 in Figure 2.6.2(A).	—
 (vii) Manway nozzle on large opening	AW	t_2	t_2	Max of t_1 ; t_2 ; and the lesser of $t_3/4$ and $t_4/4$ in Figure 2.6.2(B)	—
	PWHT	t_2	t_2	Max of t_1 ; t_2 ; and the lesser of $t_3/4$ and $t_4/4$	—

(continued)

TABLE 2.6.4 (continued)

Construction details	Condition (Note 1)	Reference thickness, t_R (Note 2)			
		Part A	Weld	Part B	Part C
(d) Flanges (i) Slip-on flange 	AW	$t_f/4$	t_2 for both welds	t_2	—
	PWHT	$t_f/4$	t_2 for both welds	t_2	—
(ii) Plate flange 	AW	$t_f/4$	t_2 for both welds	t_2	—
	PWHT	$t_f/4$	t_2 for both welds	t_2	—

(continued)