

Australian Standard[®]

Pressure piping



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-

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STANDARDS AUSTRALIA

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OF

AS 4041—2006

Pressure piping

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NOTES

Australian Standard[®]

Pressure piping

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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 4041—1998, *Pressure piping*. 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 Australian/New Zealand Standard.

Consensus means general agreement by all interested parties. Consensus includes an attempt to remove all objection and implies much more than the concept of a simple majority, but not necessarily unanimity. It is consistent with this meaning that a member may be included in the Committee list and yet not be in full agreement with all clauses of this Standard.

This Standard makes use of current American Standards such as ASME B31.3, *Process piping*, as well as Australian Standards. This has been done where practicable to align with international practices to provide flexibility in design and to enable current proven computer programs for the above Standard to be used to satisfy the design requirements of this Standard (see Clause 1.6). BS 806, *Specification for the design and construction of ferrous piping installations for and in connection with land boilers* was originally used as the basis for much of this Standard and even though BS 806 has been withdrawn the parts of this Standard where BS 806 was used are still considered valid and relevant and have been retained. BS 806 was superseded by the European Standard EN 13480, *Metallic industrial piping*.

Comparison of this Standard with ASME B31.1, *Power piping* and ASME B31.3 shows that for the same pressure and application, piping to this Standard may be thinner than piping to the two American Standards at low to medium temperatures. These two American Standards have been consulted as a major source of material.

The extension of scope in this edition to embrace room-temperature-safe fluids brings into contrast three different traditions of steel pipe engineering which exist side by side in Australia. All are successful in their particular scope of application.

The first tradition is that of power and process piping using steam and other hazardous fluids. This tradition is noted for higher safety factors, thick pipe, and the greater use of pre- and post-weld heat treatment and sophisticated quality assurance.

Another tradition is the non-code tradition for room temperature safe fluids. This is more influenced by the third tradition than by the first. It uses thick or thin pipe and rarely applies postweld heat treatment and only uses limited quality assurance.

The third pipe tradition is that of petroleum and natural gas pipelines. This tradition uses lower safety factors, thin pipe, rarely applies preheat and rarely uses postweld heat treatment but has adequate quality assurance.

The extension of scope that joined tradition 1 and 2 (and possibly tradition 3 in special cases) presented the Committee with a difficulty in preventing unnecessary increases in costs for the present non-code piping systems in Australia while maintaining safety. The more conservative requirements of tradition 1, and ASME B31.3 are not appropriate for applying these features to room-temperature safe fluids in modern low carbon equivalent pipe steels. Hence a four-tier pipe classification system is introduced to ensure adequate safety, performance and economy of piping systems for the wider range of industrial applications from critical pipe used in power stations to low hazard piping found in small industrial plant. In summary this edition will generally permit thinner steel pipe to be used for a given pressure than previously. Also there is a change to some of its pressure testing equations for steel pipe. The traditional value of $1.5 P$ applies for steam and water piping for steam boilers only.

This Standard is arranged similarly to AS 1210, *Pressure vessels*, including Supplement 1, *Unfired Pressure Vessels—Advance design and construction (Supplement to AS 1210—1997)*, and its class system parallels that of these Standards. Without inferring equality of the safety factor, the alignment of classes is approximately as follows:

AS 4041 Class	AS 1210 Class
1	1H
2A	2H
2P	—
3	3

Australian, American, and European material and component Standards which are used to a considerable extent in Australia have been listed. This Standard now provides for a wider range of materials than previously covered. A basis for specifying non-metallic pressure piping is given by reference to ASME B31.3 but with provision for substitution of equivalent Australian Standards.

The Standard follows in principle other Standards forming part of AS/NZS 1200, *Pressure equipment*, in providing guidance for owners, designers, manufacturers, inspection bodies and users in the form of minimum engineering requirements for the safe design, fabrication, installation, testing, and commissioning of pressure piping based on world-wide advances and experience. It also provides basic requirements and references for welding qualification, non-destructive testing, operation, maintenance and in-service inspection.

The principle objective of this Standard is to provide clear uniform national requirements which will result in reasonably certain protection of the general public, persons installing and operating the piping, and of adjacent property and environment, which give economic piping, and which show where a margin for deterioration may be necessary to give adequate and safe service life. Additional requirements may be necessary to prevent damage from unusual conditions, third parties and abnormal forces.

The Standard provides an authoritative source of important principles, data, and practical guidelines to be used by responsible and competent persons. It is not practicable nor indeed desirable for the Standard to specify every aspect of piping design and fabrication. It is neither an instruction manual nor a complete design or construction specification. The Standard does not replace the need for appropriate experience, competent engineering judgement, and the application of fundamental engineering principles.

Acknowledgment is gratefully made to the American Society of Mechanical Engineers and the British Standards Institution for the considerable assistance provided by the above referenced national Standards.

Statements expressed in mandatory terms in notes and footnotes 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 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

Australian Standard
Pressure piping

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the materials, design, fabrication, testing, inspection, reports and pre-commissioning of piping subject to internal pressure or external pressure or both. Specific requirements are given for piping constructed of carbon, carbon-manganese, low alloy and high alloy steels, ductile and cast iron, copper, aluminium, nickel, titanium and alloys of these materials. General requirements and reference to Standards for non-metallic piping are included.

The Standard makes extensive use of AS/NZS 3992, AS 4037 and AS 4458.

This Standard applies specifically to pressure piping, i.e. piping which may present a significant risk of injury to people, property or the environment owing to hazards arising from—

- (a) the effects of pressure, either as a result of internal pressure causing an explosion or projectile, or as a result of external pressure causing buckling and collapse;
- (b) release of contents which are lethal, toxic, harmful to human tissue (e.g. hot, cold, corrosive) flammable, combustible or are otherwise hazardous; or
- (c) release of contents which directly or indirectly result in injury or damage e.g. piping for pollutants, fire-fighting purposes or cooling purposes.

This Standard is intended to apply to the following piping except when varied by the relevant Standard:

- (i) Piping for land steam boilers, prime-movers, refrigerant and other industrial plant except where the piping forms an integral part of a boiler or pressure vessel and the requirements of AS 1210 or AS 1228 apply.
- (ii) Hydraulic piping, water piping (including feed water piping), process piping and water piping forming part of a fire protection system (see AS 4118 and AS 4214). See also Items (A) to (F) of this Clause.
- (iii) Piping within boundaries of chemical manufacturing or processing installations, petroleum refineries, petrochemical plant, gas process plant, refinery tank farms, terminals and bulk handling plants.
- (iv) Oil fuel piping within the scope of AS 1375, AS 1692 and AS 1940.
- (v) Liquefied petroleum gas piping within the scope of AS/NZS 1596.
- (vi) Anhydrous ammonia within the scope of AS/NZS 2022.
- (vii) Low-temperature and refrigeration piping within the scope of AS/NZS 1677.
- (viii) Piping for road tank vehicles within the scope of AS 2809.
- (ix) Compressed air piping, the design pressure of which exceeds 70 kPa (internal) or 32 kPa (external).
- (x) Piping for low pressure gas systems complying with AS 5601.

- (xi) Other piping covered by Standards Australia Standards which require compliance with this Standard.

This Standard may be applied beyond the limits of application of Items (i) to (xi) where specified by the purchaser. Unless suitably referenced this Standard is not intended to apply to the following:

- (A) Gas and liquid petroleum pipelines covered by AS 2885.
- (B) Gas distribution pipelines covered by AS 1697 for Australia or NZS 5258 for New Zealand.
- (C) Piping on shipping and aircraft.
- (D) Piping used for roof or floor drains, plumbing services, sewers, domestic water and gas reticulation, and low pressure ventilation ducting.
- (E) Mineral slurry pipelines which are covered by ASME B31.11.
- (F) Nuclear piping.

Guidance on the scope of this Standard is given in Figure 1.1.

NOTE: Users of this Standard are reminded that it has no intrinsic legal authority, 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 piping is in accordance with this Standard.

1.2 RESPONSIBILITIES

This Standard assumes the basic responsibilities of those parties normally involved with pressure piping to be as follows:

- (a) *The owner* The overall responsibility for compliance with this Standard, and for the establishment of the requirements for design, manufacture, examination, inspection, testing, operation, and maintenance of the piping.
- (b) *The designer* Responsible to the owner for assurance that the engineering design of piping is in compliance with this Standard and with any additional requirements specified by the owner.
- (c) *The manufacturer and fabricator* Responsible to the owner for assurance that materials, components, workmanship, examination, and testing are in compliance with this Standard and the engineering design. See also Clause 6.2.
- (d) *The owner's inspector* Responsible to the owner for ensuring that the requirements of Section 8, and any additional responsibilities specified by the owner are met.
- (e) *The inspection body* Responsible to the owner for carrying out inspections for piping to hazard level A and B to AS 4343 piping, and required certification.

1.3 NOT ALLOCATED

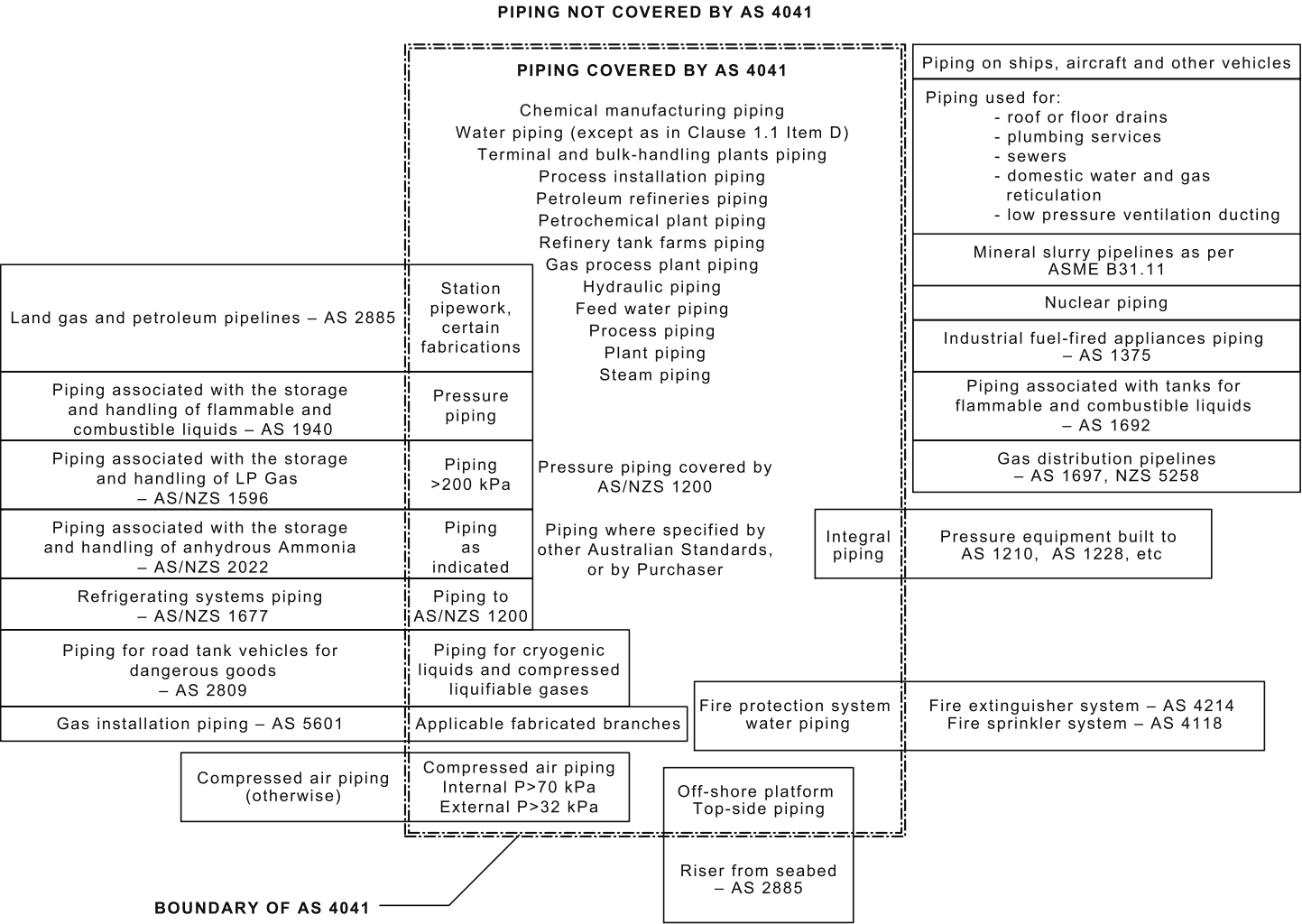


FIGURE 1.1 SCOPE OF PIPING TO AS 4041

1.4 APPLICATION OF PIPING CLASSES FOR SERVICE CONDITIONS

Metallic piping specified in this Standard is classified according to the material, design, welding, examination and testing and inspection criteria given in Table 1.5. Non-metallic piping is not classified. Class 2 is subdivided into subclasses 2A and 2P. Where the text refers to Class 2, Class 2A and 2P are included.

The application of piping classes for service conditions is shown in Table 1.4.

TABLE 1.4
APPLICATION OF PIPING CLASSES FOR SERVICE CONDITIONS

Service conditions (see AS 4343)			Service limits for following classes			
			Class 1	Class 2A	Class 2P	Class 3 (see Note 1)
Design pressure for fluid type (see Note 2 and Clause 3.2)	Lethal	Gas	No service limit	Prohibited		
		Liquid				
	Very harmful	Gas	No service limit	10.4 MPa max.	Prohibited	2.0 MPa max.
		Liquid		10.4 MPa max.		
	Harmful	Gas	No service limit	10.4 MPa max.	Prohibited	4.0 MPa max.
		Liquid		No service limit		No service limit
	Non-harmful	Gas	No service limit	No service limit	Prohibited	No service limit
		Liquid			No service limit	No service limit
Design temperature (see Clause 3.3)	Maximum		No service limit	400°C	99°C	180°C
	Minimum		No service limit (see Item 2.1 Table 1.5)	No service limit (see Item 2.1 Table 1.5)	0°C	−100°C (see Item 2.1 Table 1.5)
Nominal size (see Clause 1.7.27)	All material		No service limit	No service limit	No service limit	No service limit except DN 150 max. for very harmful fluid
Nominal wall thickness (see Clause 3.14.2)	Max.	Carbon steel Low alloy steel High alloy steel Non-ferrous metal	No service limit	See Table 3.14.2		
	Min.	Carbon steel Low alloy steel High alloy steel Non-ferrous metal	See Clause 3.14.2(a)	See Clause 3.14.2(b)		
		Ductile and cast iron	Prohibited			No service limit

NOTES:

- See Clause 3.24.2.6 for relaxation for low hazard service.
- Fluid types shall be as given AS 4343.

1.5 SELECTION OF PIPING CLASS

1.5.1 Basic requirements

NOTE: Appendix V provides guidance on the process for selecting the primary piping class in accordance with the criteria specified in this Standard.

The class of metallic piping selected for a particular application shall be determined in accordance with Table 1.4.

The requirements of Table 1.4 are intended to give a high level of assurance of reliable performance and of adequate protection to life and property for the service conditions listed. However, it is not practicable to include all details of the various service applications. Therefore in selection of the class of piping, the following shall be taken into account:

- (a) The possibility of piping failure under expected service conditions.
- (b) Consequence of failure of piping on human life, property and the environment.
- (c) Proximity of the piping to members of the general public and workers.
- (d) Properties of any released contents including temperature, corrosiveness, flammability, and toxicity and radioactive properties.
- (e) Pressure energy (pressure times volume) of the contents.
- (f) Service conditions.
- (g) Design life.
- (h) Adequacy of materials (e.g. weldability, corrosive resistance) adequacy of design, fabrication, installation, examination, testing, inspection, protection, operation, and maintenance.
- (i) Economics of carrying out repairs and replacements.
- (j) Minimization of the number of classes of piping for the same conditions in any one plant or for any one product.
- (k) Where there is doubt about a precise classification, the classification is a matter of agreement by the parties concerned.

TABLE 1.5
PIPING CLASSIFICATION (See Notes 1 and 2)

Item No.	Description and Clause reference	Limit or requirement			
		Class 1 piping	Class 2 piping		Class 3 piping
			2A	2P	
1 MATERIALS (Section 2)					
1.1	Steels designated for pressure purposes	Any	C, C-Mn austenitic and ferritic-austenitic stainless steel, 3½% Ni, 1Cr-½Mo	C, C-Mn	C, C-Mn, austenitic and ferritic-austenitic stainless steel
	Ductile iron (Clause 2.6.3.4)	See Table 2.6.3.4			
	Non-ferrous metals (Clauses 2.6.3.5 to 2.6.3.8)	Any	Any	Not permitted	Any
	Structural pipe and structural steel (Clause 2.2.4)	Not permitted	Not permitted		Any with appropriate tests
1.2	Seamless, hot finished (HFS), or cold finished (CPS)	Both permitted			
1.3	Continuous welded (CW) (In USA this is called BW) (Clause 2.6.10) (Weld Joint Factor Table 3.12.2)	Not permitted	Permitted to 250°C (see Clause 2.6.10)	Permitted	Permitted
1.4	Electric resistance welded (ERW) Cold-drawn electric-resistance-welded (CEW)	Permitted with weld joint factor listed in Clause 3.12.2			
1.5	Welds with filler metal added	Permitted with weld joint factor listed in Clause 3.12.2			
1.6	Non-Metallic Piping	Refer to Clause 1.14			
2 DESIGN (Section 3)					
2.1	Design temperature (excluding material limitations) °C:				
	(a) Maximum	None	400°C	99°C	180°C
	(b) Minimum (MDMT see Clause 2.11)	≥ MDMT	≥ MDMT	0°C	≥ MDMT + 20°C; and ≥ -100°C
	Determination (Clauses 3.3, 3.9.5, 3.9.6, 3.9.8, 3.10.6, 3.10.7, 3.10.8, 3.10.9)				
2.2	Design pressure (excluding material limitations) MPa	Pressure limits across classes depends upon the fluid type (see Table 1.4) Determination of design pressure (see Clauses 3.2, 3.9.1, 3.9.2, 3.9.4, 3.9.6, 3.10.4, 3.10.5, 3.10.7.1, 3.10.8.1)			
2.3	Design strength at room temperature for C and C-Mn steels (See Note 5) (Clause 3.11)	Lower of: $\frac{R_e}{1.5}$ or $\frac{R_m}{2.35}$	Lower of: $\frac{R_e}{1.5}$ or $\frac{R_m}{2.35}$	0.72 R_e	Lower of: $\frac{R_e}{1.5}$ or $\frac{R_m}{2.35}$
2.4	Design factors (Clause 3.12)				
	(a) Class design factor, (M)	1	1		0.7 1.0 (Item 7 in this Table) (Note 7)
	(b) Weld joint factor, (e)	1.0 min.	0.85 min		0.6 min. (Clause 3.14.3(a))
2.5	Flexibility assessment (Clauses 3.4 to 3.8 and 3.27.2.2)	Required		Required	
	Analysis (Clause 3.11 and 3.27)	If required		If required	

(continued)

TABLE 1.5 (continued)

Item No.	Description and Clause reference	Limit or requirement					
		Class 1 piping	Class 2 piping		Class 3 piping		
			2A	2P			
2.6	Fatigue assessment (Clauses 3.4 to 3.8)	Required		Required	Not required		
	Analysis (Clauses 3.11.7, 3.11.8)	If required		If required			
2.7	Welded branch connections (Clauses 3.19, 3.20)						
	Minimum included angle (Clause 3.19.1)	60° (or 45° when agreed)	45°				
	External non-integral reinforcement (Clause 3.19.8.1, 3.20.3)	Not permitted without detailed analysis	Permitted				
	Partial penetration or fillet weld (Clause 3.20.3.2)	Not permitted without detailed analysis	Not permitted without detailed analysis	Permitted by agreement	Permitted		
2.8	Pipe joints (Note 6) (Clause 3.24)						
	Butt weld (Clause 3.24.2.1)	Permitted					
	Partial penetration butt welds (Clause 3.24.2.6)	Not permitted		Not permitted	Permitted		
	Socket weld (Clause 3.24.2.3)	Permitted below DN 65		Permitted			
	Sleeve weld (Clause 3.24.2.4)	Not permitted	Permitted				
	Bell and spigot (Clause 3.24.2.5)	Not permitted	Permitted				
	Threaded joints (Clause 3.24.3)	Permitted $T \leq 495^{\circ}\text{C}$ Permitted by agreement $T > 495^{\circ}\text{C}$	Permitted				
	Flanged (Clause 3.24.4)	Permitted					
	Flared, flareless and compression fittings (Clause 3.24.5)	Permitted when used within manufacturer's recommendations, DN 25 practical upper limit					
	Caulked (Clause 3.24.6)	Not permitted	Permitted				
	Soldered (Clause 3.24.7)	Not permitted	Permitted below 75°C	Not permitted	Permitted below 75°C		
	Brazed (Clause 3.24.8)	Permitted up to 200°C					
	2.9	Bends (Clause 3.15)					
		Mitre (Clause 3.15.4)	Permitted cut $\leq 15^{\circ}$	Permitted			
Cut and shut (Clause 3.15.5)		Not permitted			Permitted		
Wrinkle (Clause 3.15.3)		Not permitted			Permitted		
Ovality (Clause 3.15.2.3)		$\leq 10\%$			$\leq 12\%$		
2.10	Non-pressure attachments (Clause 3.23)						
	Partial penetration or fillet weld	Not permitted without detailed analysis $T > 250^{\circ}\text{C}$	Permitted by agreement $T > 250^{\circ}\text{C}$	Permitted			
3 WELDING (Includes brazing, see AS 4458, AS/NZS 3992 and Note 3)							
3.1	Personnel requirements	Option 1	or	Option 2	Option 1	or	Option 2
	Welder certification (AS 1796)	Required		Not required	Not required		Required
	Welder qualification (Clause 6.3)	Required		Required	Required		Not required
	Welding supervisor (AS 1796)	Not required		Required	Not required		Not required

(continued)

TABLE 1.5 (continued)

Item No.	Description and Clause reference	Limit or requirement			
		Class 1 piping	Class 2 piping		Class 3 piping
			2A	2P	
3.2	Welding procedure qualification (Clause 6.3)	Required (except as provided for in Item 3.3)			
3.3	Prequalified welding procedure	Permitted but be subject to partial re-qualification e.g. welder qualification			
3.4	Permanent backing ring (Clauses 2.9.1, 3.20.3.4, 3.24.2.1)	Not permitted	Permitted		
3.5	Fit-up (AS 4458)	Close limits	Medium limits	Wide limits	
3.6	Criteria for weld quality	Very high	High	Reduced	
3.7	Dissimilar joints	Permitted			
4 EXAMINATION AND TESTING (See Section 6)					
4.1	Visual	100%			
4.2	Penetrant	0 to 100%	0 to 10%	Not required	
4.3	Magnetic particle	0 to 100%	0 to 10%	Not required	
4.4	Radiographic or ultrasonic Including TOFd	10 to 100% (Refer to AS 4037)	0 to 10% (Refer to AS 4037)	Not required	
4.5	Pressure tests: (Clause 6.6) Hydrostatic pressure test (Clause 6.7)	Normally required (for alternatives see Clause 6.8)		Alternatives to Item 4.5 include Items 4.6, 4.7 and 4.8)	
4.6	Pneumatic pressure test (Clause 6.8.1)	Permitted by agreement			
4.7	Initial service leak test (Clause 6.9)	Permitted in conjunction with other tests by agreement (Clause 6.8.3)	Permitted in conjunction with other tests (Clause 6.8.2 and 6.8.3)	Permitted	
4.8	Sensitive leak test (AS 4037)	Required where specified (Clause 6.8.3)	Required where specified (Clause 6.8.3)	Not required	
4.9	Material test certificate	Required	Normally required	Not required	
4.10	Marking (Clause 8.3.2)	Required	Normally required	Not required	
5 INSPECTION (Depends on hazard level) (Section 8)		Required	Normally required	Not normally required	
6 CONTROLS					
6.1	Pressure control tolerance	+10%		+15%	
6.2	Design temperature control tolerance (Note 4)	+ Half the appropriate temperature interval in Table D2 for the material		+ Double Class 1 and 2 entry, i.e. 100% of appropriate temperature interval	
7 COPPER PIPING (Item 2.4 and Note 7)					

LEGEND:

MDMT = material design minimum temperature (see Clause 1.7).

 R_e = (see Clause 1.7). R_m = (see Clause 1.7).**NOTES:**

- 1 This Table outlines the basic difference between the classes, and reference should be made to the text for full details.
- 2 Materials, design, welding, examination and testing and inspection are shown as 'permitted' on the basis that such items comply in all other respects 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 Applies generally except as provided by Clauses 3.4, 3.9.5 and 3.10.3 for the creep range. Examples of the Class 1 upper temperature control tolerance for API 5L B pipe for the listed maximum temperatures are given below:

Maximum temperature, °C	Class 1 tolerance °C
75	+25
405	+ 5
475	+ 5

- 5 See Appendix D design strength and Appendix I determination of design strength.
- 6 See Clause 2.6.2 for possible effect of joint in corrosion performance.
- 7 See Clause 3.12.3

1.5.2 Mixing classes

Designers should nominate the class of pipe early in the design process. Classes may be mixed. Welds and components at the interface between different classes shall comply with the higher class.

A total piping system may be divided arbitrarily and the divisions given a different class number in accordance with Table 1.4 of this Standard and at the designer's discretion.

1.6 ALTERNATIVE STANDARDS

Piping complying with the following alternative Standards is deemed to comply with this Standard, according to their particular scope, provided that any requirement of this Standard nominated by the owner is complied with:

- (a) Power piping ASME B31.1
- (b) Process piping ASME B31.3
- (c) Refrigeration piping..... ASME B31.5
- (d) Building services piping ASME B31.9
- (e) Industrial piping EN 13480
- (f) Petroleum and gas industries piping ISO 15649

Mixing the content of application Standards is not permitted except where agreed by the parties concerned. The materials, design, construction, testing and inspection of the alternative specification shall be used in full unless otherwise agreed.

1.7 DEFINITIONS

For the purpose of this Standard, the definitions in AS 4942 and those below apply.

1.7.1 Accessory

A component of a piping system, other than a pipe, valve, or fitting, but including a relief device, pressure-containing item, pipe support, and any other item necessary to make the piping operative whether or not these items are specified in the Standard.

1.7.2 Agreed and agreement

Agreed by or agreement between the parties concerned.

1.7.3 Assemblies

A collection of individual components joined together.

1.7.4 Cold spring

The forcing into position of a component that has been fabricated to a length shorter or longer than its nominal length, so that it is stressed in the installed condition, with the intention of compensating for the change in length produced by an increase or decrease in temperature. (Also called ‘cold pull’ or ‘cold push’).

1.7.5 Component

A part of a piping system, including a pipe, valve, fitting, and an accessory.

1.7.6 Corrosion

The wastage of a metal, because of a reaction with its environment, including oxidation, scaling, mechanical abrasion, erosion, and all other forms of wastage.

1.7.7 Design

Drawings, calculations, specifications, models, and all other information necessary for the complete description of the fabrication and installation of the piping.

1.7.8 Designer

The person or organization responsible to the owner for the assurance that the engineering design complies with this Standard and any additional requirements specified by the owner.

1.7.9 Design strength

The maximum allowable stress for use in the equations for the calculation of the minimum thickness or dimensions of pressure parts. (Quantity symbol: f .)

1.7.10 Elongation after rupture

Elongation (Quantity symbol: A_5) is the specified minimum percentage elongation measured on a gauge length = $5d$ where d is the diameter of the round specimen or $5.65 \sqrt{S_0}$, where S_0 = cross sectional area of the specimen.

1.7.11 Extruded outlet

An outlet in a pipe or piping component where a lip has been formed at the outlet so that the lip height above the surface of the main pipe is not less than the radius of curvature of the external contoured portion of the outlet, i.e. $h_o \geq r_o$ (see Figure 3.19.9.2).

1.7.12 Fabrication

The forming and joining of piping components which includes cutting, bending, threading, welding, and any other operation on these components which is not part of installation.

NOTE: Fabrication may be carried out in the workshop or on site.

1.7.13 Fabricator

The person or organization who welds pressure equipment.

NOTE: In AS/NZS 3992, ‘fabricator’ includes ‘contractor’, ‘assembler’, ‘installer’, and ‘erector’ and is used to embrace all or some of these terms. This is applicable to all locations, on or off site, where components are fabricated.

1.7.14 Fitting

A component, including a bend, a tee, a flange, a bolt, or a gasket, used to join pipes, to change the direction or diameter of a pipe, provide a branch, or terminate a pipe.

1.7.15 Fluid

Any vapour, liquid, gas, or mixture thereof or fluidized solid, e.g. slurry and powdered material. (See AS 4343 for fluid classification.)

1.7.16 Gas

A substance which is completely gaseous at 20°C and 101.3 kPa absolute or at 50°C has a vapour pressure greater than 300 kPa.

For this Standard, gas also includes:

- (a) Compressed gas which is entirely gaseous at 20°C and 101.3 kPa absolute.
- (b) Liquefied gas which is partially liquid at 20°C.
- (c) Refrigerated liquefied gas which is partially liquid because of its low temperature.
- (d) Gas in solution which is a compressed gas dissolved in a solvent.
- (e) Any liquid when it is above its atmospheric pressure boiling point, e.g. pressurized high-temperature water which flashes to steam on release of the pressure.
- (f) Fluidized solids in compressed air or other gas.

1.7.17 Hydrostatic test

A pressure test that exerts a pressure uniformly with a liquid for a specified period, and is used to prove the integrity and the leaktightness of the piping.

1.7.18 Inspection

The examination and verification, carried out by the owner or the inspection body, of materials, design, fabrication, installation, examinations, tests, certificates, documents and records to determine compliance with this Standard.

1.7.19 Inspection body

A body corporate or firm responsible for the inspection of pressure equipment and certification of inspection results.

1.7.20 Installation

The complete installation of a piping system in the locations and on the supports given by the engineering design including any field assembly, fabrication, examination, and testing of the system as specified in this Standard.

1.7.21 Liquid

Any substance below its atmospheric pressure boiling point, e.g. water <100°C. Liquid also includes solids fluidized in liquids, e.g. slurries.

1.7.22 Manufacturer

A body corporate, firm or person who manufactures pressure equipment.

NOTE: The manufacturer may include the designer.

1.7.23 May

Indicates the existence of an option.

1.7.24 Mitre bend

A bend consisting of one or more mitre joints.

1.7.25 Mitre joint

A joint formed by two straight sections of pipe that are matched and joined by welding on a plane bisecting the angle of junction so that the change in direction exceeds three degrees.

1.7.26 Nominal pressure

A numerical designation which is a convenient rounded number for reference purposes. All equipment of the same nominal size (DN) and designated by the same PN number should have compatible mating dimensions.

NOTES:

- 1 The maximum allowable pressure depends on material, design and temperature and should be selected from the tables of pressure/temperature ratings given in the appropriate Standard. Steel pipe Standards commonly do not have tables of nominal pressure.
- 2 Nominal pressure is designated 'PN' followed by an appropriate number and unit.

1.7.27 Nominal size

A numerical designation of size which is common to all components in a piping system other than components designated by outside diameters or by thread size. It is a convenient round number for reference purpose and is only loosely related to manufacturing dimensions (see Appendix B).

NOTES:

- 1 Nominal size is designated 'DN' followed by an appropriate number.
- 2 The nominal size cannot be subjected to measurement, tolerances or used for purposes of calculation and has no units.
- 3 Not all components are designated by nominal size, e.g. steel tubes are designated by outside diameter and thickness.

1.7.28 Owner

The person or organization having the overall responsibility for compliance with this Standard and the engineering design, and for the establishment of the requirements for design, construction, examination, inspection, testing, operation and maintenance which will govern the entire fluid handling or process system of which piping is a part.

NOTE: For the purpose of this Standard, the term 'owner' includes the purchaser or hirer.

1.7.29 Parties concerned

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

1.7.30 Pipe

A pressure-tight cylinder used to convey a fluid or to transmit a fluid pressure, ordinarily designated 'pipe' in the applicable material specification.

NOTE: For the purpose of this Standard, the term 'pipe' is synonymous with 'tube' except where otherwise noted.

1.7.31 Pipe support

An accessory consisting of fixtures and attachments as follows:

- (a) Fixtures which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include fixtures of the hanging type, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides and anchors, and fixtures of the bearing type, such as saddles, bases, rollers, brackets, and sliding supports.
- (b) Attachments which are welded, bolted, or clamped to the pipe. These include clips, lugs, rings, clamps, clevises, straps, skirts, and anchor attachments.

1.7.32 Pressure piping

An assembly of pipes, pipe fittings, valves and pipe 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.

1.7.32.1 Control piping

Piping used to convey pneumatic or hydraulic pressure to controlling apparatus and between instrument transmitters and receivers.

1.7.32.2 Instrument piping

Piping used to connect instruments to main piping, to other instruments and apparatus, or to measuring equipment.

1.7.32.3 Sampling piping

Piping used for the collection of samples from the contents of the main piping.

1.7.33 Pressure, design

The pressure used to determine the wall thickness of a pressure containing component, being that pressure at the most severe condition of temperature and coincident internal or external pressure expected during normal operating conditions. (Quantity symbol: p)

NOTE: Unless otherwise stated, pressure is expressed in kilopascals or megapascals above atmospheric pressure, i.e. gauge pressure.

1.7.34 Pressure, operating

Pressure that the piping may be subject to during normal operation. It is determined by the technical requirements of the process.

1.7.35 Proprietary components

Components made or marketed by a company having the right to manufacture and sell them. Technical data and experience may also be proprietary, i.e. not in the public domain.

1.7.36 Safeguarding

The provision of protective measures that, in the event of piping failure, prevent damage to persons and environment. See Section 7.

1.7.37 Service conditions

The range of pressure, temperature and other conditions to which the piping is subject during its design life.

1.7.38 Severe cyclic conditions

Conditions applying to piping and components where the computed stress range due to the service condition exceeds 80% of the allowable stress range (f_a) as defined in Clause 3.11.7 and the equivalent number of cycles exceeds 7000, or other conditions which the designer deems will produce an equivalent effect.

1.7.39 Shall

Indicates that a statement is mandatory.

1.7.40 Should

Indicates a recommendation.

1.7.41 Socket welded joint

That joint formed from the end of a pipe entering the socket end of a socket-welding fitting and the pipe and socket being joined by means of a fillet weld.

1.7.42 Strength

1.7.42.1 *Specified minimum tensile strength*

The minimum tensile strength at room temperature specified in the Standard to which the material or component is made. (Quantity symbol: R_m) It may be qualified by the test temperature.

1.7.42.2 *Specified minimum yield strength*

The minimum yield strength specified in the Standard to which the material or component is made. (Quantity symbol: R_e .) It is qualified by the test temperature.

1.7.43 Temperature

1.7.43.1 *Design temperature*

The material temperature at the coincident design pressure, used to select the design strength and to determine the dimensions of the part under consideration (see Clause 3.3).

1.7.43.2 *Material design minimum temperature (MDMT)*

A characteristic minimum temperature of a material. It is used in design to select material with sufficient notch toughness to avoid brittle fracture and to select the temperature at which the material can be used at full design strength (see Clause 2.11.2.2).

1.7.43.3 *Maximum operating temperature*

The highest material temperature to which the piping under consideration is subjected under normal operation. It is determined by the technical requirements of the process. (To avoid confusion with the following definition it is never reduced to an acronym.)

1.7.43.4 *Minimum operating temperature (MOT)*

The lowest mean material temperature through the thickness to which the piping under consideration is subjected under normal operation. It is determined by the technical requirements of the process, or lower temperature where specified by the purchaser.

1.7.44 Testing

The assessment of the properties of materials or components by the use of mechanical methods, pressure testing or other destructive or potentially destructive methods to ensure compliance with specified requirements.

1.7.45 Thickness

1.7.45.1 *Actual thickness*

The actual wall thickness of the material or a component used in the piping, which is the measured thickness or, when the material is not measured, the nominal thickness less the greatest negative tolerance specified in the Standard to which the material or component was made.

1.7.45.2 *Pressure design thickness*

The wall thickness calculated according to the equations to resist pressure, but which does not include an allowance for loss of thickness due to corrosion, forming, threading, grooving, and other action.

1.7.45.3 *Required thickness*

The sum of the pressure design thickness and the allowance for corrosion, forming, threading, grooving, and other actions.

1.7.45.4 Nominal thickness

The wall thickness nominated on the purchase order and to which the manufacturer's tolerances on wall thickness are applicable.

1.7.46 Verification

Confirmation by examination and provision of evidence that specified requirements have been met.

1.7.47 Weld joint factor

An arbitrary quality ratio of the allowable stress across a longitudinal, spiral welded or circumferential joint to that allowed in the adjacent parent material.

1.7.48 Weld joint types

'CW' (BW) = Furnace butt welded where the whole strip from which the pipe is made is formed into a pipe hot and the seam pressed together by the forming rolls. No filler metal is added.

'ERW' = Electric resistance welded where the strip is formed into a pipe hot and only the edge of the strip heated by electric induction and the seam pressed together by the forming rolls. No filler metal is added.

'SAW' = Submerged-arc welded. This is one of many arc welding processes where filler metal is added to the longitudinal or spiral welded joint.

1.8 NOTATION

Symbols used in equations in this Standard are defined in relation to the particular equations in which they occur.

1.9 NON-SI UNITS

Where units other than SI units are used in nominated Standards, the conversion to SI units shall be made in accordance with AS/NZS 1376.

1.10 REFERENCED DOCUMENTS

The documents referred to in this Standard are listed, with titles, in Appendix A.

1.11 REPORTS AND CERTIFICATES

1.11.1 Manufacturer's data report

After the piping has been completed, tested and inspected, the fabricator shall complete a manufacturer's data report for hazard level A and B of AS 4343 piping and where specified by the owner, the report shall briefly identify the piping, and certify that the piping has been designed, fabricated, installed and tested in partial or complete compliance with the requirements of this Standard.

Where the design of piping to hazard level A or B of AS 4343 piping has not been carried out by the fabricator, the designer shall provide a report certifying partial or complete compliance of the design with the Standard.

In most cases the above is adequate certification. When agreed and specified in the contract, one or more of the following additional documents shall be provided:

- (a) Materials test certificates.
- (b) Welding procedure and welder qualification test results.
- (c) Heat treatment reports.

- (d) Non-destructive examination reports.
- (e) Other reports as specified.

1.11.2 Copies

Reports complying with Clause 1.11.1 shall be given to —

- (a) the owner when required by the design (and hence at the owner's option);
- (b) the inspection body, if requested; and
- (c) 'to whom it may concern', if required by law or regulation.

1.12 NOT ALLOCATED

1.13 NOT ALLOCATED

1.14 NON-METALLIC PIPING

The following provisions apply to non-metallic piping and piping lined with a non-metallic material:

- (a) Piping shall comply with requirements of ISO 14692 (for GRP piping), ASME B31.3 or an equivalent National Standard.

Equivalent Australian Standards listed in Clause 2.2.1 may be applied in lieu of material Standards referred to in ASME B31.3.

- (b) Piping shall comply with the engineering design.
- (c) Other requirements may be agreed by the parties concerned.

1.15 INTERPRETATION OF STANDARDS

See AS/NZS 1200 for interpretation of Standards.

1.16 NEW DESIGNS, MATERIALS AND FABRICATION METHODS

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

1.17 DIMENSIONAL AND MASS TOLERANCES

Dimensional and mass tolerances for pipe, components and assemblies shall comply with the tolerances—

- (a) provided with the material component specification;
- (b) according to AS 1210 for assemblies;
- (c) specified in engineering drawings; or
- (d) as otherwise agreed by the parties concerned.

1.18 ALTERNATIVE DESIGN OF ACCESSORIES

Any accessory (see Clause 1.7.1) in a piping system may be made from standard pipe and standard fittings at the designer's option. Such an accessory is deemed to be piping and may be designed as either piping or as a pressure vessel.

SECTION 2 MATERIALS AND COMPONENTS

2.1 GENERAL

Materials and components which are to be used for piping shall be—

- (a) suitable and safe for fabrication and the service conditions under which they are used; and
- (b) qualified for the conditions of their use by compliance with the nominated Standards (Clause 2.2.1) and any additional requirements of this Standard.

2.2 QUALIFICATION OF MATERIALS AND COMPONENTS

2.2.1 Materials and components complying with nominated Standards

Materials and components which comply with the following Standards may be used for appropriate applications, as specified and limited by this Standard (for limits of materials see Appendix D), without further qualification. Items (a) to (m) cover metallic materials and Item (n) covers plastics and non-metallic materials.

For limitation on use of materials listed in this Clause 2.2.1, reference should be made to other relevant Clauses in this Standard, e.g. Clauses 2.2.4, 2.6, 2.7, 2.11 and 3.14.2 and Appendix D, and any other limitation of this Standard.

(a) Pipes

AS 1074	ASTM A 249	ASTM A 691	ASTM B 514
AS 1432	ASTM A 250	ASTM A 789	ASTM B 515
AS 1569	ASTM A 268	ASTM A 790	ASTM B 516
AS 1572	ASTM A 269		ASTM B 517
AS 1579	ASTM A 312	ASTM B 42	ASTM B 535
AS 1751	ASTM A 333	ASTM B 75	ASTM B 619
AS 4728	ASTM A 334	ASTM B 88	ASTM B 622
	ASTM A 335	ASTM B 111	ASTM B 626
AS/NZS 1866	ASTM A 358	ASTM B 161	
AS/NZS 1867	ASTM A 369	ASTM B 163	BS 1387
AS/NZS 1571	ASTM A 376	ASTM B 165	
AS/NZS 2280	ASTM A 381	ASTM B 167	EN 1057
	ASTM A 409	ASTM B 210	EN 10216
ASTM A 53	ASTM A 423	ASTM B 221	EN 10217
ASTM A 106	ASTM A 451	ASTM B 241	EN 12449
ASTM A 135	ASTM A 452	ASTM B 315	EN 12451
ASTM A 178	ASTM A 524	ASTM B 338	
ASTM A 179	ASTM A 587	ASTM B 395	API 5L
ASTM A 209	ASTM A 671	ASTM B 407	
ASTM A 210	ASTM A 672	ASTM B 423	ISO 9329
ASTM A 213	ASTM A 688	ASTM B 444	ISO 9330

Pipes fabricated in accordance with AS 1210 or equivalent Standard.

(b) *Plates*

AS 1548	ASTM A 203	ASTM B 96	ASTM B 435
AS 1566	ASTM A 204	ASTM B 127	ASTM B 443
	ASTM A 240	ASTM B 162	ASTM B 575
AS/NZS 1594	ASTM A 302	ASTM B 171	
AS/NZS 1734	ASTM A 353	ASTM B 333	EN 10028-7
AS/NZS 3678	ASTM A 387	ASTM B 409	
	ASTM A 516	ASTM B 424	
	ASTM A 517	ASTM B 434	

(c) *Rods, bars and sections*

AS/NZS 1567	ASTM A 479	ASTM B 211	ASTM B 446
AS/NZS 1865	ASTM B 160	ASTM B 335	EN 10272
AS/NZS 1866	ASTM B 164	ASTM B 408	EN 10273
AS/NZS 3679	ASTM B 166	ASTM B 425	

(d) *Castings*

AS 1565	AS 1833	ASTM A 217	BS 3071
AS 1830	AS 1874	ASTM A 276	
AS 1831	AS 2074	ASTM A 351	EN 1676
AS 1832	ASTM A 216	ASTM A 352	

(e) *Forgings*

AS 1448	ASTM A 181	ASTM A 350	EN 10222
	ASTM A 182	ASTM B 381	
ASTM A 105	ASTM A 336	ASTM B 564	

(f) *Fittings*

AS 3673	ASME B16.9	ASTM A 420	MSS SP-97
AS 3688			
	ASTM A 182	BS 143 and 1256	EN 10241
AS/NZS 2280	ASTM A 234	BS 1640	
AS/NZS 2544	ASTM A 403	BS 3799	

Fittings fabricated in accordance with AS 1210 or equivalent Standard.

(g) *Pressure gauges*

AS 1349

(h) *Valves*

AS 1271	API STD 606	BS 5159	EN 13709
AS 1628		BS 5353	EN 13789
	ASME B16.10		EN 13397
ASTM A 182	ASME B16.34	EN 593	EN 15761
		EN 1171	
API STD 600	BS 1868	EN 1984	ISO 10434
API STD 602	BS 1873	EN 4126-1	
API STD 603	BS 5158	EN 12334	

(i) *Flanges*

AS 2129	ASME B16.5	BS 1560.3.2	MSS SP-44
AS 4087	ASME B16.47	BS 3293	EN 1759
AS/NZS 4331			

(j) *Bolting and gaskets*

AS 1110	ASME B16.20	ASTM A 193	ASTM A 325
AS 1111	ASME B16.21	ASTM A 194	ASTM A 449
AS 1112		ASTM A 307	
AS 2465	ASTM A 108	ASTM A 320	EN 1515-1
AS 2528			

(k) *Welding consumables*

Any welding consumables complying with AS/NZS 3992.

(l) Any valve or fitting complying with Standards acceptable to ASME B31.1 and B31.3.

(m) *Refrigeration system components*

Valves, fittings and controls acceptable to ASME B31.5.

(n) *Plastics and non-metallic components*

AS 3571	AS/NZS 1477	AS/NZS 4129	AS 4441
	AS/NZS 3518	AS/NZS 4130	AS/NZS 4765

2.2.2 Materials and components complying with Standards not nominated in this Standard

Where a material conforming to one of the Standards in Clause 2.2.1 is not available, then, subject to acceptance by the parties concerned where specified on the order, alternative materials and components not complying with a Standard listed in Clause 2.2.1 may be used provided that they comply with the requirements of a relevant specification of ISO, the American Society of Mechanical Engineers (ASME), the European Committee for Standardization (CEN), or other specification for material of equivalent grade and quality.

2.2.3 Alternative product form

Where there is no Standard for a particular product form of a wrought material but there is a nominated Standard for other product forms, that product form may be used, provided that it is in compliance with the following:

- (a) The chemical, mechanical and physical properties, heat treatment requirements, and any requirements for deoxidation or grain size conform to those in the nominated Standard.
- (b) The manufacturing procedures, tolerances, tests, and marking are in accordance with a nominated Standard for the same product form of a similar material.
- (c) The nominated Standards in Item (a) and Item (b) are compatible in all respects, e.g. testing and welding requirements in the one form are appropriate for the material specified in the other form.
- (d) The thickness range is comparable with the nominated Standard.

Where a product form is used according to this Clause (2.2.3), the following shall apply:

- (i) The design strength values to be used shall be those for the nominated Standard in the appropriate thickness range.
- (ii) The manufacturer's test reports shall make reference to the Standards used to produce the material, and shall make reference to this Clause (2.2.3).

2.2.4 Use of structural steel

Pipe or steel, identified by specification or label as structural may be used for pressure containment in accordance with the applicable Clauses of this Standard for Class 3 only and as follows:

- (a) The actual tensile strength shall be lower than 560 MPa and tensile properties shall be measured transversely if pipe diameter is greater or equal to DN 250.
- (b) The actual analysis (or ladle analysis if available) shall be less than the following:

Element	Percentage
C	0.25
P.....	0.04
S.....	0.04
Carbon equivalent (Clause 2.4.6).....	0.45

- (c) Mechanical and chemical tests shall be recorded on test certificates identified with the product.
- (d) If pipe, it shall have been pressure tested at the shop prior to fabrication to 60% R_e .
- (e) The steel shall be free from lamination.
- (f) Plate used for flanges shall not be thicker than 40 mm.

Pipe or steel identified by specification or label as structural may be used for non-pressure containment in accordance with this Standard, provided that the carbon equivalent is less than 0.45%.

Compliance with pipe specification given in Clause 2.2.1 overrides any structural identification.

2.2.5 Components, other than pipe, for which there are no Standards

A component, other than pipe, for which there is no Standard shall be qualified.

NOTE: Components may be qualified by tests or investigations (or both) that demonstrate to the satisfaction of the parties concerned that the component is suitable and safe for the proposed service.

2.2.6 Reclaimed components complying with a nominated Standard

A reclaimed component may be re-used provided that the component—

- (a) was manufactured to a nominated Standard, and for Class 1 and 2 piping its material certificate is available; and
- (b) upon inspection, is found to—
 - (i) have adequate thickness and shape and be free of unacceptable imperfections; and
 - (ii) have all welds, other than the longitudinal or spiral weld in pipe, complying with this Standard; and
- (c) its use is accepted by the parties concerned.

Pipe shall be cleaned and inspected to determine its acceptability, freedom from deleterious corrosion, distortion, and mechanical or metallurgical damage.

A component, other than pipe, shall be cleaned and examined and, if necessary, reconditioned, and tested to ensure that it is sound, free of unacceptable imperfection, and suitable for the proposed service.

An assessment shall be made of the effects of any adverse operating conditions, e.g. creep or high stress reversals (both thermal and mechanical), under which the component has been previously used. Where this assessment shows that the component is not adversely affected, the component may be used, subject to a hydrostatic test (see Clause 2.2.9).

2.2.7 Material and components not fully identified

A material or component which cannot be fully identified with a nominated Standard may be used for pressure provided that it can be demonstrated that the material or component—

- (a) has the chemical composition and the mechanical properties specified in a nominated Standard;
- (b) has dimensions comparable with a nominated Standard;
- (c) has been inspected;
- (d) has been hydrostatically tested where practicable (see Clause 2.2.9);
- (e) is suitable for the proposed service, and for welding if appropriate; and
- (f) is acceptable to the parties concerned.

2.2.8 Unidentified materials and components

A material or component which cannot be identified with a nominated Standard or by a manufacturer's test certificate may be used for non-pressure parts (i.e. parts not subject to stress due to pressure, such as supporting lugs) provided that each item is otherwise suitable for the intended service.

Where an unidentified material or component is to be welded directly onto a pressure-containing component, it shall be capable of being welded satisfactorily without impairing the properties of the pressure-containing component. (See also Clause 2.11.1.)

NOTE: Where tests are required to demonstrate this, the type, method and criteria of acceptance shall be subject to agreement between the parties concerned.

2.2.9 Hydrostatic test

A hydrostatic test (or non-destructive examination) shall be carried out on components, the strength of which may have been reduced by corrosion or other deterioration, and on pipe or components manufactured to a Standard which does not specify the manufacturer's hydrostatic test. The test may be carried out either on the individual item in a test similar to a manufacturer's test or, when the item has been incorporated into the piping system after erection, to at least the test pressure required to establish the maximum design pressure for which the item will be used in service. Where appropriate, the hydrostatic test may be replaced either by 100 percent radiography or ultrasonic testing where agreed between the parties concerned.

2.2.10 Specially tested materials

Material which does not comply with this Clause (2.2) may be used provided that—

- (a) the material is shown by special tests to be equally suitable for the particular application as a similar material which complies with a nominated Standard;
- (b) the type, method, and criteria of acceptance of any special test is agreed between the parties concerned; and
- (c) the use of specially tested materials is agreed between the parties concerned.

NOTES:

- 1 These special tests may include chemical analysis, mechanical tests, and non-destructive examination.
- 2 See also Clause 2.2.2, Clause 2.2.3, Clause 2.7 and Clause 2.8.

2.3 NOT ALLOCATED

2.4 PROPERTIES OF MATERIALS

2.4.1 General

Physical, mechanical and other relevant properties of material used for the design and fabrication shall be as specified in this clause. Materials are allocated a base metal group number. This base metal group number facilitates specification of welding, heat treatment and non-destructive examination requirements. For details see AS/NZS 3992 and AS 4037.

2.4.2 Mechanical properties

Mechanical properties of materials nominated in this Standard shall be as shown in the material Standard (see also Appendix D) or, where a property is not shown or material is not included, reference shall be made to an appropriate Standard or an authoritative source or it shall be determined by test.

2.4.3 Thermal expansion

The change in length due to thermal effects shall be as shown in Appendix E or, for materials not included, shall be obtained by reference to an authoritative source.

2.4.4 Young's modulus

Young's modulus shall be as shown in Appendix F, or for materials not included, shall be obtained by reference to an authoritative source.

2.4.5 Poisson's ratio

Poisson's ratio shall be taken as 0.3 for all metals at all temperatures, but a more accurate figure may be used if this is available or required. For other materials, reference shall be made to an authoritative source.

2.4.6 Weldability

Material for Classes 1 and 2 piping, which is to be welded, shall be supplied with a certificate identifying the pipe batch and showing the chemical analysis and, for carbon and carbon manganese steels, the carbon equivalent. The carbon equivalent (CE , in %) shall be calculated using the following equation:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad \dots 2.4.6$$

where C , Mn , Cr , Mo , V , Ni and Cu represent the percentage by weight of the particular element.

2.5 IDENTIFICATION OF MATERIALS AND COMPONENTS

The identification of materials and components shall be in accordance with AS 4458.

2.6 LIMITATIONS ON APPLICATION

2.6.1 General

Materials and components specified for piping shall be suitable for the specified pressure, temperature, fluid, and other service conditions and for the method of fabrication.

Materials and components shall be used within the limitations shown in this Clause (2.6) and Appendix D.

NOTE: Materials may be used at temperatures higher or lower than those specified in this Standard only by agreement between the parties concerned and after appropriate examinations or tests, or both, have established that the material is safe for the service conditions and provides the same level of safety implied in this Standard.

2.6.2 Deterioration of materials and components

An assessment shall be made on the deterioration of materials or components during the design life. Materials and components shall be selected so that they are suitable for the service conditions. Attention shall be given to the adverse effects of creep, fatigue, stress corrosion, erosion, corrosion, products of corrosion, and other forms of deterioration resulting from the effect of service conditions. Consideration should be also given to internal weld bead or other shape changes and fluid velocity for possible effect on corrosion.

2.6.3 Materials for ambient and high temperature service

2.6.3.1 General

Materials shall be suitable for ambient and high-temperature service conditions. The temperature of application shall not exceed the highest value for which a design stress is given in Appendix D, except as provided for in Clauses 2.6.1 and 3.4.

NOTE: This Clause (2.6.3) notes, among other things, some of the difficulties that may be encountered when materials are used at high temperatures.

2.6.3.2 Carbon and low and medium alloy steels

Carbon, carbon-manganese and low and medium alloy steels shall be used only after suitable provision has been made in the design for the following:

- (a) During long-term exposure above 425°C, the possible conversion of carbides to graphite, in carbon steel, carbon-manganese steel, manganese-vanadium steel, carbon-silicon steel, and low alloy nickel steels.
- (b) During long-term exposure at temperatures above 470°C, the possible conversion of carbides to graphite in carbon-molybdenum steel, manganese-molybdenum-vanadium steel and chromium-vanadium steel.
- (c) Above 480°C, the advantages of silicon or aluminium killed carbon steel.
- (d) At high temperatures, the loss of thickness due to scaling.
- (e) The susceptibility to undesirable intercrystalline penetration of steel particularly under simultaneous presence of applied or residual tensile stress and molten metal contact such as zinc, lead, tin or copper and their compounds at similarly elevated temperatures. Refer to Clause 2.7 for components in corrosive service.
- (f) 100% radiographic examination of the weld in alloy longitudinal welded pipe to be operated in the creep range.
- (g) The need to consider the requirements of AS/NZS 3788 for in-service inspection of piping in the creep range.

2.6.3.3 High alloy steels

High alloy steels shall be used only after suitable provision has been made in the design for the following:

- (a) The susceptibility to intercrystalline corrosion of austenitic steels, following exposure at temperatures between 425°C and 870°C, unless stabilized or low carbon grades are used.
- (b) The susceptibility to brittleness of ferritic stainless steels at temperatures above 370°C.
- (c) The possibility of stress-corrosion cracking of austenitic stainless steels when exposed to chlorides and other halides either internally or externally in the presence of applied or residual tensile stress, e.g. salt contaminated water used for hydrostatic testing which is subsequently heated above approximately 70°C. Such corrosion can result from the incorrect selection or misapplication of thermal insulation.

- (d) The susceptibility of undesirable penetration of ferritic and austenitic steels on contact with zinc, lead or copper above their melting points or with many lead, zinc, and copper compounds at similarly elevated temperatures.

NOTE: For guidance, see WTIA TN 13.

2.6.3.4 Ductile iron and other iron castings

Pipe and pressure retaining components made from ductile iron, grey iron or malleable iron shall comply with the thickness limits of Clause 3.14.5 and ductile iron shall comply with Table 2.6.3.4.

Ductile iron pipe to AS/NZS 2280 is given a pressure rating in its material Standard. Its use is covered in Table 2.6.3.4 and is not listed in Appendix D.

TABLE 2.6.3.4
LIMITS OF APPLICATION OF DUCTILE IRON PIPE AND
COMPONENTS (NOTE 1)

Material	Application	Maximum design pressure MPa	Design temperature °C	
			Min. (Note 2)	Max.
Ductile iron (Nodular spheroidal) $A_5 \geq 15\%$	1 Lethal fluid (gas or liquid)	Not permitted (Note 4)		
	2 Very harmful fluid (gas or liquid) (Note 3) (e.g. flammable, toxic, harmful to human tissue)	7	−30	230
	3 Harmful fluid (gas or liquid)	7	−30	350
	4 Non-harmful gas	7	−30	350
	5 Non-harmful liquid	10	−30	90
Ductile iron (Nodular spheroidal) $A_5 < 15\%$	1 Lethal fluid (gas or liquid)	Not permitted		
	2 Very harmful fluid (gas or liquid) (e.g. flammable, toxic, harmful to human tissue)	1.1	−30	150
	3 Harmful fluid (gas or liquid)	1.8	−30	250
	4 Non-harmful gas	1.8	−30	250
	5 Non-harmful liquid	4	0	90
	6 Severe cyclic or shock service	Not permitted		

NOTES:

- 1 No welds are permitted for ductile iron components.
- 2 Refer to Table 2.11.2(C).
- 3 Use of ductile iron is not permitted for very harmful fluids in severe cyclic service.
- 4 Ductile iron with $A_5 \geq 15\%$ may be used for lethal fluids only if all of the following criteria are met:
 - (a) The design temperature and pressure shall be based on the coincident pressure-temperature conditions that require the greatest wall thickness or highest component rating. For example, the variations in operating conditions allowed under Clause 3.10.3 are not permitted.
 - (b) The design pressure is limited to 2.4 MPa, and the design temperature is in the range −30°C to +230°C.
 - (c) The casting quality factor is at least 90%.
 - (d) The requirements of Clause 2.11 are met (especially 2.11.4.2).
 - (e) Use of ductile iron for lethal services is permitted mainly to allow use of lined valves where the only available alternative is a non-metallic valve of inferior pressure-temperature rating. Use of ductile iron for entire piping systems for lethal services should be avoided where possible.

2.6.3.5 *Copper and copper alloys*

Copper and copper alloys shall be used only after suitable provision has been made in the design for the following:

- (a) The possibility of dezincification of brass alloys.
- (b) The susceptibility to stress-corrosion cracking of copper-based alloys in certain environments.
- (c) The possibility of unstable acetylide formation when alloys having more than 70% copper are exposed to acetylene.

2.6.3.6 *Aluminium and aluminium alloys*

Aluminium and aluminium alloys shall be used only after suitable provision has been made in the design for the following:

- (a) Above 65°C, the susceptibility of aluminium alloys 5083, 5086, 5154 and 5456 to exfoliation or intergranular attack.
- (b) Above 350°C, the susceptibility of some aluminium and aluminium alloys to embrittlement.
- (c) The possibility of corrosion from concrete, mortar, lime, plaster or other alkaline materials used in buildings or structures.
- (d) The compatibility of compounds used to prevent seizing and galling in aluminium threaded joints.
- (e) The low resistance to fire of unprotected aluminium and aluminium alloys.
- (f) The susceptibility to sustained load cracking of some aluminium alloys, e.g. 6351 and 6061 under some conditions.

Extruded aluminium pipe for Class 1 piping shall have been made by the mandrel method only.

2.6.3.7 *Nickel and nickel alloys*

Nickel and nickel alloys shall be used only after suitable provision has been made in the design for the following:

- (a) At temperatures above 315°C, the susceptibility to grain boundary attack of nickel and nickel-based alloys not containing chromium when exposed to even small quantities of sulfur during fabrication or service.
- (b) At temperatures above 595°C, under reducing conditions and above 760°C under oxidizing conditions, the susceptibility to grain boundary attack of nickel-based alloys containing chromium.
- (c) The possibility of stress-corrosion cracking of nickel-copper alloy (70Ni-30Cu) in hydrofluoric acid vapour if the alloy is highly stressed or contains residual stresses caused by or resulting from forming or welding.

2.6.3.8 *Titanium and titanium alloys*

Titanium and titanium alloys shall be used above 315°C only after suitable provision has been made in the design for the possibility of deterioration of these materials.

2.6.4 **Fittings**

A threaded, flanged, socket-welding or butt-welding fitting which complies with a nominated Standard may be used within the material, size, pressure and temperature limitations of that Standard.

2.6.5 Valves

2.6.5.1 General

A valve which complies with a nominated Standard shall be used within the material, pressure, and temperature limitations of that Standard except where otherwise permitted in this Standard (see Clause 2.6.3).

2.6.5.2 Valve bodies

For lethal and very harmful fluids, grey cast iron, malleable cast iron, and spheroidal or nodular graphite cast iron with an elongation of less than 15% on a gauge length $L = 5.65\sqrt{S_0}$ shall not be used in valve bodies.

Where the design pressure does not exceed 7 MPa, a valve having body components made of spheroidal or nodular graphite cast iron may be used at pressures up to 80% of design pressure for comparable steel valves at their listed temperatures.

Any spheroidal or nodular graphite or grey cast iron part of a valve shall not be subjected to welding.

2.6.5.3 Drain valves

Valves for drain piping should be of the straight-through type or be specifically designed for the purpose.

2.6.5.4 Valve trim

Valve trim shall be suitable for the temperature range and the fluid.

2.6.5.5 Valve spindles

Valves with inside screw spindles should not be used in corrosive service or where deposits may develop.

2.6.5.6 Bypasses

A bypass (where required) may be integral with the valve or connected to the piping adjacent to the valve. The materials and components of the bypass shall be suitable for the same design conditions as the valve.

2.6.6 Flanges

For limitations and requirements of flanges. See Clause 3.24.4.

2.6.7 Bolting for flanges

For limitations and requirements of bolting for flanges. See Clause 3.24.4.5.

2.6.8 Gaskets

See Clause 3.24.4.4.

2.6.9 Material for forming and bending

Material that may be subjected to forming and bending shall be suitable for these processes, and shall comply with the relevant requirements of AS 4458.

2.6.10 Limit of application of pipe made by the CW (BW) process

Pipe made by the CW(BW) process, (see Table 1.5) is limited by this code to Classes 2A and 3 and if the pipe is produced to AS 1074, only Medium and Heavy pipes are permitted. The minimum thickness shall be calculated using the appropriate stress value from Table D2, a weld joint factor from Table D12 and a class design factor selected from Table 3.12.3. Additionally, the maximum design condition that medium and heavy pipe can be used for is 2.0 MPa and 250°C.

2.6.11 Limit of application of ERW AS 1074 pipe

Pipe to AS 1074 is limited by this Standard to Classes 2 and 3. The minimum thickness shall be calculated using the appropriate stress value from Table D2, and a weld joint factor from Table D12 and a class design factor selected from Table 3.12.3.

Additionally, the maximum temperature used shall be 250°C.

2.7 MATERIALS AND COMPONENTS FOR CORROSIVE SERVICE

In the selection of material and components for corrosive service, consideration shall be given to the possibility of general or local wastage, corrosion, stress corrosion and corrosion fatigue. Suitable provisions shall be made in the design for the following:

- (a) At temperatures above approximately 50°C, the susceptibility to stress-corrosion cracking of steels in contact with ammonia, chlorides, amines, hydrogen sulfide or other solutions. Refer to NACE Standard MR 0175 for H₂S cracking.

NOTE: Consideration should be given to the benefit of postweld heat treatment to reduce the possibility of stress corrosion cracking when welded steel is used.

- (b) The possibility of hydrogen damage when piping is exposed to hydrogen or to aqueous acid solutions under certain temperature and pressure conditions.
- (c) Where the fluid is alkaline or caustic, the possibility of embrittlement, particularly in conditions where concentration by evaporation can occur.
- (d) Where the fluid is diesel oil, the possibility of deterioration of galvanized pipe or components.
- (e) Anhydrous ammonia may cause stress corrosion cracking of steel in the presence of specific quantities of oxygen and other gases.

Anhydrous ammonia may be carried in all steel pipes listed in Appendix D except the high tensile pipe quenched and tempered to ASTM A 517. However, this grade may be used satisfactorily if the ammonia has 200 ppm of water minimum added.

It is good practice to stress relieve all welds in ammonia piping irrespective of the steel strength.

2.8 DISSIMILAR MATERIALS

Mitigation of corrosion due to electrolytic reaction and stress due to the different thermal expansions shall be considered when adjacent piping of dissimilar materials are being specified.

2.9 BACKING RINGS AND FUSIBLE INSERTS

2.9.1 Permanent backing rings

Permanent backing rings (i.e. those that are not removed after welding) made from bar, strip or pipe shall be compatible with the parent material.

For high alloy steels with special metallurgy this means using the parent material e.g. 9% Cr, 12% Cr, stainless steels, 3% Ni and 9% Ni. For high temperature steam pipe of 2¼ Cr and lower grades, a backing ring one grade lower than the parent material is acceptable.

2.9.2 Temporary backing rings

Temporary backing rings (i.e. those that are removed after welding) shall be made from pipe, bar or strip, and the material shall have a similar chemical composition to that of the parent material; or for carbon and alloy steel with alloys less than 3 percent, shall be made from carbon steel with a carbon content not greater than 0.26 percent and a sulfur content not greater than 0.04 percent.

However, backing rings made from dissimilar non-ferrous or non-metallic materials may be used provided that the welding procedure is qualified.

2.9.3 Fusible inserts

Fusible inserts should be made from materials having chemical compositions such that, when fused with the material, they will produce weld metal that is of similar chemical composition to that of the parent material.

2.10 BRAZING MATERIALS

See Clause 3.24.8.

2.11 MATERIALS FOR LOW TEMPERATURE SERVICE

2.11.1 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, or where the fluid is lethal, shall comply with the appropriate requirements of this Clause (2.11).

If the operating temperature in normal service or due to malfunction is lower than 0°C, the design shall comply with this Clause (2.11).

These requirements need not apply to non-pressure parts such as supports if they are not attached to a pressure part by welding nor otherwise an integral part of a pressure-containing component.

In this Clause (2.11), 'all forms' means plates, strip, seamless and welded pipe, bars, castings and forgings; but bolting and weld metal are excluded.

Untested steel permitted by this Clause (2.11) shall have a carbon content of less than 0.30 percent. For impact tested steel, the impact test result supersedes the need for special carbon limit.

This Clause also requires steel when tested to possess minimum of 27 J, 31 J, or 40 J or 0.38 mm lateral expansion according to the tensile strength (see Table 2.11.2). For pipe to ASTM A 333 and A 334 (pipe for low temperature service), higher Charpy energy requirements than specified in those Standards apply.

Piping to Class 3 shall be designed as if for use at 20°C below the design minimum temperature (see Clause 2.11.4) by adjustment to the MDMT.

NOTE: AS/NZS 3992 specifies requirements for impact testing for the heat-affected zone and weld metal as part of welding procedure qualification tests for welds between parts for which this Standard requires impact testing.

2.11.2 Selection of suitable material for low temperature service

2.11.2.1 General

Suitable material may be selected for each component in the piping system by the provisions given in the following:

- (a) Carbon, carbon-manganese steel in all forms except bolting and weld metal (material Groups A1, A2 and A3) which are treated as one group (see Clause 2.11.2.2).
- (b) Alloy steels and non-ferrous metals (see Clause 2.11.2.3).
- (c) Small diameter heat exchanger tubing and very thin steel pipes and tubes (see Clause 2.11.2.4).
- (d) Cast iron and ductile iron (see Clause 2.11.2.5).

- (e) Steel bolting (see Clause 2.11.2.6).
- (f) Non-metallic pipe and components (see Clause 2.11.2.7).

2.11.2.2 Material Groups A1, A2 and A3

Figure 2.11.2(A) relates MDMT to material reference thickness and testing temperature for these steels in the as-welded condition.

Similarly, Figure 2.11.2(B) relates MDMT to material reference thickness and testing temperature for these steels in the postweld heat treated condition.

To qualify for application to one of the curves, the steel must comply with Table 2.11.2(A) and its foot notes, and, Table 2.11.2(B).

Curve +20°C materials are exempt from impact tests. Additionally, API 5L X42 and X52 steel pipe may be exempt from tests for curves 0°C and minus 10°C, respectively, within the limits imposed by Table 2.11.2(A).

In the case of a steel ($R_m > 470$) which does not have the required 40 J but has a measured value greater than 27 J, a curve 10°C higher may be used or the steel rejected.

For pipe and component specifications with Charpy requirements other than 27 J, 31 J or 40 J, if the achieved value is between 18 J and 50 J, an equivalent test temperature may be assigned by adjustment on the basis of 1.5 J per kelvin.

Example 1:

Pipe tested to 21 J on R_m 400 MPa steel at –20°C. This may be regarded as equivalent to 27 J at –16°C.

Example 2:

ASTM A 333, Grade 6 (R_m 415) which calls for 18 J and achieves 19 J at –45°C. This may be regarded as equivalent to 27 J at –39°C.

Suitable material may be selected by the following procedure:

- (a) Determine the required MDMT by reference to Clause 2.11.4.
- (b) Determine the material reference thickness (T_m) by reference to Clause 2.11.5.
- (c) Enter the values obtained in Steps (a) and (b) above, in Figure 2.11.2(A) or Figure 2.11.2(B) as appropriate. The curves at, or below, the intersection of these values gives the permitted steels (and any necessary impact tests).
- (d) From Table 2.11.2(A) and Table 2.11.2(B) select the steel type or pipe specification for the curve noted in Step (c).

When Table 2.11.2 exempts steel from impact tests, the material reference thickness (Clause 2.11.5) and the assigned curve give the lowest MDMT permitted which must not be warmer than that required in Clause 2.11.4.

2.11.2.3 Alloy steels and non-ferrous metals (all forms excluding bolting and weld metal)

The MDMT for alloy steels and non-ferrous metals (all forms excluding bolting and weld metal) is given in Table 2.11.2(C).

Suitable material for this subgroup may be selected as follows:

- (a) *With test*
 - (i) Determine the minimum operating temperature (MOT) for the component by reference to Clause 2.11.3; and
 - (ii) select permitted material (and any necessary impact tests) having a MDMT not warmer than MOT, by reference to Table 2.11.2(C).

(b) *Exempt from tests*

- (i) Where Table 2.11.2(C) specifies a curve, refer to the curve in Figure 2.11.2(A) or (B), enter the appropriate graph at the material reference, thickness (Clause 2.11.5) to determine the warmest MDMT permitted and compare it to that determined from Table 2.11.2(C).
- (ii) Where Table 2.11.2(C) specifies an MDMT numeral, this is compared directly with the required MDMT from Clause 2.11.4 and Figures 2.11.2(A) or (B) do not apply.

TABLE 2.11.2(A)
QUALIFYING CONDITIONS FOR LOW TEMPERATURE APPLICATION
—STEEL ALL FORMS (EXCEPT BOLTING AND WELD METAL)

1	2	3	4	5	6	7	8
Curve (See Figure 2.11.2) °C	Standard impact temperature °C	Standard impact test value (Note 1), J			Limits of steel (Note 5)	Maximum thickness mm	Carbon equivalent max. (cast or product) % (Note 6)
		Tensile strength, MPa					
		Specified min. $R_m \leq 450$ (Note 2)	Specified min. $R_m > 450 \leq 470$ (Note 3)	Specified min. $R_m > 470$ (Note 4)			
+20	No test	No test	No test	No test	None	None	—
0	No test	No test	No test	Not applicable	X42 Fine grained	75	0.36
0	0	27	31	40	None	None	—
−10	No test	Not applicable	No test	Not applicable	X52 Fine grained and micro alloyed	13	0.27
−10	−10	27	31	40	None	None	—
−20	−20	27	31	40	None	None	—
−30	−30	27	31	40	None	None	—
−40	−40	27	31	40	None	None	—
−50	−50	27	31	40	None	None	—

NOTES:

- 1 Impact test values are minimum average values.
- 2 Additionally an actual maximum R_m limit of the lesser of 560 MPa and any maximum R_m in the product specification applies.
- 3 Additionally an actual maximum R_m limit of the lesser of 600 MPa and any maximum R_m in the product specification applies.
- 4 Additionally an actual maximum R_m limit of the lesser of 650 MPa and any maximum R_m in the product specification applies.
- 5 Fine grained steels produced to fine grained practice (AS 1733 grain size 7 or finer) include the following:
 - (a) Fully killed (Si-Al or Al) steels.
 - (b) Controlled rolled steels.
 - (c) Steels with grain refining elements added, e.g. API 5L X52.
- 6 See Clause 2.4.6 for carbon equivalent equation.

TABLE 2.11.2(B)
MATERIAL DESIGN MINIMUM TEMPERATURES (ALL FORMS EXCEPT
BOLTING AND WELD METAL) FOR CARBON AND CARBON MANGANESE
STEEL PIPE

1	2	3	4	5	6	7	8	9
ASME IX P No.	Steel group	General type	Specific- ation	Grade	R_m min. MPa	Material design minimum temperature (MDMT)		
						If not impact tested		If impact tested on 10 × 10 mm specimen
						Curve	Steel restrictions	
1	A1, A2 & A3	All	Any	Any	—	+ 20°	C = 0.30% max.	Not applicable
1	A1	C, C-Mn	API 5L	X42	413	0°C	Fine grained $t \leq 75$ mm	Not applicable
1	A1	C, C-Mn	API 5L	X42	413	Not applicable	Not applicable	Curve test temperature for 27 J
1	A2	C, C-Mn	ASTM A 106	C	485	Not applicable	Not applicable	Curve test temperature for 40 J
—	A3	C, C-Mn	API 5L	X52	455	−10°C	Fine grained, micro alloyed $t \leq 13$ mm $CE \leq 0.27\%$	Not applicable
—	A3	C, C-Mn	API 5L	X52	455	Not applicable	Not applicable	Curve −10°C and 31 J
—	A1	C, C-Mn	BS 3603	410	410	Not applicable	Not applicable	Curve −50°C and 27 J
—	A1	C, C-Mn	ASTM A 333 and A 334	1	380	Not applicable	Not applicable	Curve test temperature for 27 J
—	A1	C, C-Mn	ASTM A 333 and A 334	6	415	Not applicable	Not applicable	Curve test temperature for 27 J

LEGEND:

C = Percentage Carbon by weight
 CE = Carbon equivalent, in % (see Clause 2.4.6).
 t = thickness

TABLE 2.11.2(C)
MATERIAL DESIGN MINIMUM TEMPERATURE (MDMT) FOR ALLOY STEELS, NON-FERROUS METALS AND CAST IRONS
(ALL FORMS) EXCEPT BOLTING AND WELD METAL

1	2	3	4	5	6	7	8	
P No.	Steel group	General type	Specification	Grade	R_m min.	MDMT		
						If not impact tested	If impact tested (10 mm × 10 mm specimen)	
Low alloy steels with obligatory Charpy testing (pipe specifications listed)								
9B	E	¼ Ni	ASTM A 333	10	550	Not applicable	Test at −45°C for 40 J	
		2½ Ni	ASTM A 333 and A 334	7	450	Not applicable	Test at −70°C for 27 J	
			ASTM A 333 and A 334	9	435	Not applicable	Test at −70°C for 27 J	
11A	F	3 Ni	ASTM A 333 and A 334	3	450	Not applicable	Test at −100°C for 27 J	
		1 Ni-1 Cr	ASTM A 333	4	415	Not applicable	Test at −90°C for 27 J	
		9 Ni	ASTM A 333 and A 334	8	690	Not applicable	Test at −195°C for 0.38 mm lateral expansion	
		E	3½ Ni	BS 3603	503	440	Not applicable	Test at −100°C for 27 J
		F	9 Ni	BS 3603	509	490	Not applicable	Test at −196°C for 40 J
Low alloy steels (unlisted product specifications)								
	E	3 Ni	Any	Any	—	Curve, −30°C	Test temperature giving 27, 31, 40 J depending on R_m	
	B, C, D ₁ , D ₂	Various	Any	Any	—	Curve +20°C but MDMT ≥0°C	Test temperature giving 27, 31, 40 J or 0.38 mm lateral expansion	
High alloy steels (product specification listed)								
11B	G	Quenched and tempered	ASTM A 517	All	795	Not applicable	Test temperature giving 0.38 mm lateral expansion	
6	H	Martensitic	ASTM A 268	409 410	380 415	Curve +20°C but MDMT ≥ −30°C	Test temperature giving 27 J on 10 × 10	

(continued)

TABLE 2.11.2(C) (continued)

1	2	3	4	5	6	7	8
P No.	Steel group	General type	Specification	Grade	R_m min.	MDMT	
						If not impact tested	If impact tested (10 mm × 10 mm specimen)
High alloy steels (product specification listed) (continued)							
7	J	Ferritic	ASTM A 268	405 430	415 415	Curve +20°C but MDMT ≥ −30°C	Test temperature giving 27 J on 10 × 10
8	K	Austenitic (seamless) or welded pipe (solution heat treated)	ASTM A 312	304	515	−255°C	Test temperature giving 40 J or 0.38 mm lateral expansion
			ASTM A 312	304L	485	−255°C	
			ASTM A 312	347	515	−255°C	
			ASTM A 312	321	515	−200°C	
			ASTM A 312	316	515	−200°C	
			ASTM A 312	316L	485	−200°C	
			ASTM A 312	317	515	−200°C	
			ASTM A 312	310S	515	−200°C	
		ASTM A 312	309S	515	−200°C		
There is no temperature limit for these austenitic steels if the operating stress is less than 50 MPa							
	L	High chromium	ASTM A 268	446	485	Not applicable	Test temperature giving 40J
	M	Ferritic austenitic	ASTM A 789	S31803	620	Not applicable	Test temperature giving 40J
High alloy steels (unlisted product identification)							
—	H	Martensitic	Any	405, 410, 429	—	Curve + 20°C but MDMT ≥ −30°C	Test temperature giving 27, 31, 40 J or 0.38 mm lateral expansion depending of R_m
	J	Ferritic	Any	410S	—		
	M	Ferritic austenitic	Any	31803	—		
	K	Austenitic stainless steel C > 0.1%	Any	Any	—	−30°C	Test temperature giving 40 J

(continued)

TABLE 2.11.2(C) (continued)

1	2	3	4	5	6	7	8
P No.	Steel group	General type	Specification	Grade	R_m min.	MDMT	
						If not impact tested	If impact tested (10 mm × 10 mm specimen)
	K	Austenitic stainless Heat treated below 900°C	Any	Any	—	Not applicable	Test temperature giving 40 J
Non-ferrous metals							
—	—	Aluminium alloys—wrought	—	—	—	–270°C	Not applicable
		Aluminium alloys—cast	—	—	—	–198°C	Not applicable
		Copper, copper alloys	—	—	—	–198°C	Not applicable
		Nickel, nickel alloys	—	—	—	–198°C	Not applicable
		Titanium, zirconium	ASTM B 265	—	—	–60°C	Test temperature for 20 J on 10 × 10
Cast irons							
—	—	Ductile iron	AS 1831	Any	—	–30°C	Not applicable
Note 3		Austenitic ductile	AS 1833	Any	—	–30°C	Test temperature giving 20 J
Note 3		Austenitic ductile	ASTM A 571	Any	—	–30°C	Test temperature giving 20 J
		Grey iron	AS 1830	Any	—	–30°C	Test temperature giving 20 J
		Malleable iron	AS 1830	Any	—	–30°C	Test temperature giving 20 J
		Cast irons—galvanized—all cast irons	—	—	—	–10°C	Test temperature giving 20 J

NOTES:

- In addition to Charpy V impact test, dropweight tests are required for—
 - Group F steels ≥ 16 mm thick for use at MOT below –170°C; and
 - Group G steels ≥ 16 mm thick for use at MOT below –130°C.
- For Group F and Group G steels, the maximum test temperature is to be 0°C.
- Austenitic ductile iron conforming to AS 1833 or ASTM A 571. The test temperature to be not less than –196°C.

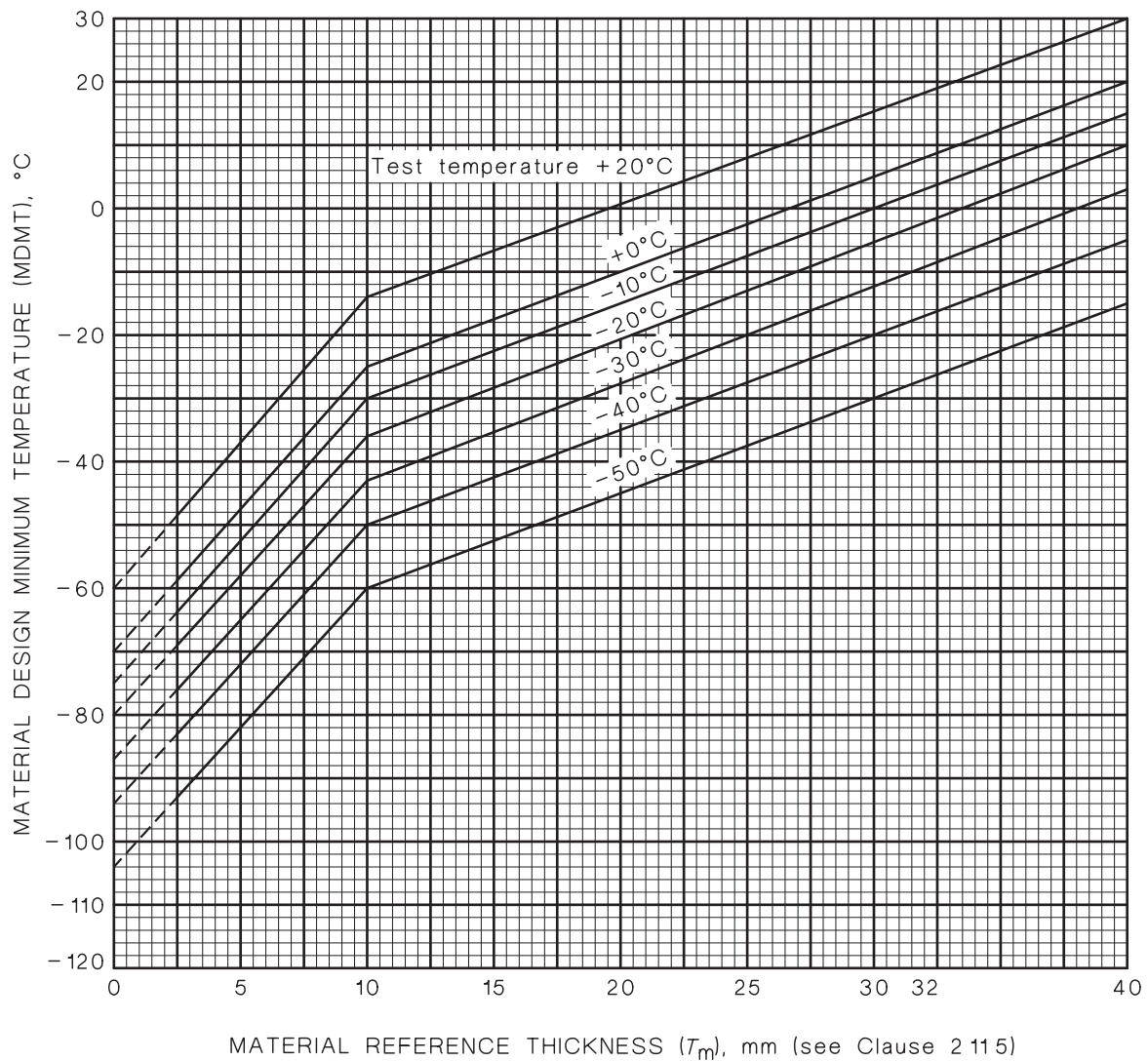


FIGURE 2.11.2(A) CARBON AND CARBON-MANGANESE STEELS FOR LOW TEMPERATURE SERVICE—AS-WELDED
(See also Tables 2.11.2(A) and (B))

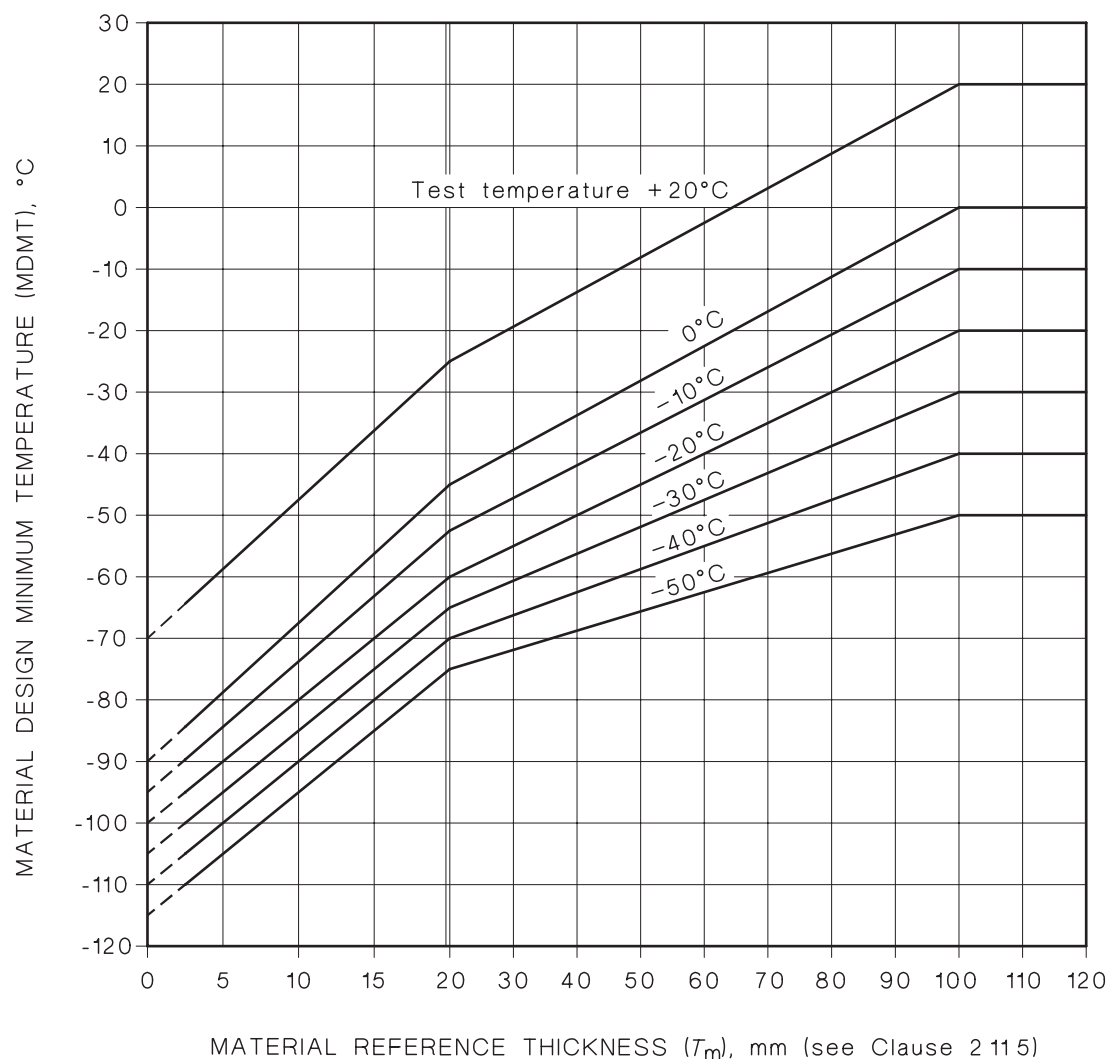


FIGURE 2.11.2(B) CARBON AND CARBON-MANGANESE STEELS FOR LOW TEMPERATURE SERVICE—POSTWELD HEAT TREATED
(See also Tables 2.11.2(A) and (B))

2.11.2.4 Very thin steel pipes and tubes (including small heat-exchanger tubes)

Where there is insufficient thickness to obtain a 2.5 mm Charpy V notch specimen, that material may be used at a temperature either—

- (a) greater than or equal to that permitted for an non-impact tested material of the equivalent type; or
- (b) qualified by test on an equivalent but thicker material.

NOTE: The material may be qualified by an agreed non-standard test.

Alternatively, impact testing is not required for C and C-Mn steels 10 mm and thinner provided that the required MDMT is not lower than the corresponding values in Table 2.11.2.4. Welding in this Table applies to both welding in fabrication and welding in pipe manufacture.

TABLE 2.11.2.4
MATERIAL DESIGN MINIMUM
TEMPERATURE—THIN MATERIALS*

Thickness	As welded	Postweld heat treated	Unwelded
mm	°C	°C	°C
10	−15	−30	−70
8	−20	−35	−75
6	−25	−40	−80
4	−40	−55	−95
≤2	−55	−70	−110

* Taken from PD 5500.

2.11.2.5 Cast iron

The MDMT for cast iron is given in Table 2.11.2(C).

Ductile iron pipe to AS/NZS 2280 is not recommended for temperatures below 0°C. Victaulic jointing systems and similar systems using cast iron couplings should be used only in the temperature range recommended by the manufacturers of the total system.

2.11.2.6 Bolting materials

For bolting materials—

- (a) determine the MOT by reference to Clause 2.11.3; and
- (b) select material permitted for bolting having a listed minimum operating temperature not higher than MOT by reference to Table G1 in Appendix G.

For bolting to operate at temperatures lower than the listed MOT, the testing requirements shall include impact testing, which shall comply with the requirements given in Table 2.11.2(B) and Table 2.11.2(C) for the equivalent material type strength and thickness at the minimum operating temperature.

2.11.2.7 Non-metallic materials

Non-metallic pipe and materials that include bolting, parts of valves, gaskets, packing and similar parts used for low temperature service shall be suitable for service at the MOT. Allowance shall be made for any handling, ageing or embrittlement.

2.11.3 Minimum operating temperature

For non-ferrous metals, alloy steels and bolting, the MOT shall be the lowest mean metal temperature through the thickness of the part under consideration during normal operation, including fluctuations that may occur during normal process operations and during start-up and shutdown and malfunction.

The MOT shall be the lowest of the following:

- (a) For piping that is thermally insulated externally . . . the minimum temperature of the fluid within the pipe.
- (b) For piping that is not thermally insulated . . . the lower of—
 - (i) the minimum temperature of the fluid within the pipe; and

- (ii) 10°C above the lowest one day mean ambient temperature (LODMAT) where the metal may be subjected to this temperature while the piping is under pressure. Appendix H provides LODMAT data.

Where there is evidence to show that, because of radiation, adiabatic expansion or other effects, Items (a) and (b) will not provide a reliable estimate of minimum operating temperature, the method to be used in assessing that temperature is the subject of agreement between the parties concerned and allowance shall be made for any sub-cooling during pressure reduction.

2.11.4 Required material design minimum temperature

2.11.4.1 *Lethal fluids*

Where the contents of piping is lethal, the required MDMT determined under this rule shall not exceed 0°C.

2.11.4.2 *Class 3 piping*

The class design factor of 0.60 for Class 3 increases the wall thickness considerably, and the concessions for non-destructive examination require Class 3 piping to have an additional margin of –20°C when determining MDMT for Class 3 pipe.

2.11.4.3 *MDMT for steel groups A1, A2 and A3*

The required MDMT for these steels shall be determined as follows:

- (a) *General* The MDMT for use in Figures 2.11.2(A) and 2.11.2(B) shall be the lowest value of the following, adjusted where necessary by reference to Items (b), and (c) below:

- (i) The lowest temperature occurring coincidentally with process condition which results in the calculated membrane stress

$$\geq \frac{2f}{3} \times \text{Classification factor}$$

where

f = design tensile strength at ambient temperature (see Appendix D);
design factor is given in Table 1.3, Item 2.3.

- (ii) A temperature 10°C warmer than the lowest temperature occurring coincidentally with process conditions which result in the calculated membrane stress being

$$\geq 50 \text{ MPa but } < \frac{2f}{3} \times \text{class design factor}$$

- (iii) A temperature 50°C warmer than the lowest temperature occurring coincidentally with process conditions which result in the calculated membrane stress being <50 MPa.

The stresses calculated in Clause 2.11.4.3(a) shall take into account pressure, contents and piping dead weight, thermal stress and external loadings.

Stresses shall be calculated based on minimum wall thickness less allowances at the design minimum metal temperature.

The combined longitudinal stresses due to pressure, contents and piping dead weight and displacement strain shall be determined by—

- (A) calculating the forces and moments based on nominal pipe dimensions; and

- (B) calculating the stresses based on nominal thickness less allowances. The stress intensification factors are not included in this calculation.

For piping components with pressure ratings, the stress can be calculated based on the ratio of the pressure under consideration divided by the component's rated pressure multiplied by the design strength of the component at the design minimum metal temperature.

Where the piping is likely to be subject to a higher pressure at higher temperatures, e.g. in refrigeration systems with liquefied gases, the material and design shall be suitable for all expected combinations of operating temperatures and pressures.

- (b) *Adjustment for partial postweld heat treatment* For Class 1 piping, where the pipe lengths contain branches, welded supports, or other welded attachments and the pipe circumferential welds are not postweld heat treated, the MDMT obtained from Item (a), applied to as-welded parts, may be raised a further 15°C, subject to both of the following:
- (i) The welded attachment as a subassembly is postweld heat treated prior to circumferential butt-welding to the pipe.
 - (ii) Circumferential butt joints are more than 150 mm from attachment welds.
- (c) *Material for piping subject to shock* For ferritic steels used for piping on transportable vessels or in other applications which may be subjected to severe shock, impact or plastic deformation, an additional margin of –15°C shall be added in the determination of MDMT.

2.11.4.4 MDMT for all other materials

For all other materials, the required MDMT is equal to or less than the MOT (adjusted if appropriate for lethal fluids and Class 3 margin).

2.11.5 Material reference thickness

Except for castings the reference thickness (T_m) used in applying Figure 2.11.2(A) and Figure 2.11.2(B) shall be that thickness designated in Figure 2.11.5, based on the nominal thickness, including any integral cladding or weld overlay. For castings, the reference thickness shall be the largest actual thickness.

The reference thickness listed in Figure 2.11.5(a), (b), (e), (i) and (j) for the thinner part, branch, or attachment shall extend along the branch or attachment for at least the distance shown in the figures.

The reference thickness for weld neck flanges, plate and slip-on (or hubbed) flanges, and flat ends shall be the greater of one-quarter the thickness of the flange or the flat end, or the thickness of the branch or shell attached thereto (see Figure 2.11.5).

If the distance from the flange, 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.

2.11.6 Impact tests

2.11.6.1 Where required

Impact testing of parent metal of pressure parts, and non-pressure parts welded directly to pressure parts, shall apply as follows:

- (a) Where the MDMT thickness in Figures 2.11.2(A) and 2.11.2(B) require impact testing.
- (b) Where specified in Tables 2.11.2(B) and 2.11.2(C).

See AS/NZS 3992 for impact testing requirements of weld procedure tests.

The longitudinal weld of pipes complying with an appropriate pipe specification for the minimum operating temperature is exempt from impact testing of the weld metal.

Where the pipe is not supplied to such a pipe specification, the weld in welded pipe shall also be qualified when Charpy testing of the pipe body is required. The test pieces for SAW pipe shall be transverse to the weld with the base of the notch at the weld centre line with a second test piece, with the base of the notch in the HAZ (see Figure 2.11.6(A)). The test pieces for ERW pipe may either be transverse as for SAW or longitudinal with the base of the notch at the weld centreline (see Figure 2.11.6(B)). In all cases, the base of the notch is to be perpendicular to the pipe surface.