

Australian/New Zealand Standard™

Pipelines—Gas and liquid petroleum

Part 1: Design and construction



AS/NZS 2885.1:2018

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee ME-038, Petroleum Pipelines. It was approved on behalf of the Council of Standards Australia on 31 October 2018 and by the New Zealand Standards Approval Board on 6 November 2018.

This Standard was published on 3 December 2018.

The following are represented on Committee ME-038:

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Australasian Corrosion Association
Australian Industry Group
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Australian Petroleum Production and Exploration Association
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This Standard was issued in draft form for comment as DR AS/NZS 2885.1:2017.

Australian/New Zealand Standard™

Pipelines—Gas and liquid petroleum

Part 1: Design and construction

First published in part as part of AS CB28—1972.
Revised and redesignated AS 1697—1975.
AS 1958 first published 1976.
AS 2018 first published 1977.
Second edition AS 1697—1979.
Third edition 1981.
Second edition AS 1958—1981.
Second edition AS 2018—1981.
AS 1958—1981 and parts of AS 1697—1981 and AS 2018—1981 revised, amalgamated and redesignated AS 2885—1987.
Parts of AS 1697—1981, AS 2018—1981 and AS 2885—1987 revised, amalgamated and redesignated in part as AS 2885.1—1997.
Second edition AS 2885.1—2007.
Third edition AS 2885.1—2012.
Jointly revised and redesignated AS/NZS 2885.1:2018.

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Jointly published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001 and by Standards New Zealand, PO Box 1473, Wellington 6140.

ISBN 978 1 76072 257 9

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME-038, Petroleum Pipelines, to supersede AS 2885.1—2012, *Pipeline—Gas and liquid petroleum*, Part 1: *Design and construction*.

The inclusion of roles and responsibilities in AS/NZS 2885.1:2018, was approved by the Standards Development Committee on 1 May 2015, as a one-off exemption to the directives of *Standardisation Guide 009: Preparation of Standards for Legislative Adoption*.

The objective of this Standard is to specify requirements for the design and construction of steel pipelines and associated PIPING and components that are used to transmit single-phase and multi-phase hydrocarbon fluids.

This Standard also provides guidelines for use of pipe manufactured from certain non-steel or corrosion-resistant materials, and guidelines for the transport of supercritical carbon dioxide.

The AS(/NZS) 2885 series comprises the following:

AS 2885.0, *Pipelines—Gas and liquid petroleum*, Part 0: *General requirements*

AS/NZS 2885.1, *Pipelines—Gas and liquid petroleum*, Part 1: *Design and construction* (this Standard)

AS/NZS 2885.2, *Pipelines—Gas and liquid petroleum*, Part 2: *Welding*

AS 2885.3, *Pipelines—Gas and liquid petroleum*, Part 3: *Operation and maintenance*

AS 2885.4, *Pipelines—Gas and liquid petroleum*, Part 4: *Submarine pipeline systems*

AS/NZS 2885.5, *Pipelines—Gas and liquid petroleum*, Part 5: *Field pressure testing*

AS/NZS 2885.6, *Pipelines—Gas and liquid petroleum*, Part 6: *Pipeline safety management*

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.

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

Small caps have been used in this document to indicate terms which have been defined in AS 2885.0 (for example, PIPELINE SYSTEM).

The terms ‘may’, ‘should’ and ‘shall’ are not in small caps but are defined terms that are used in this Standard to indicate an option (may, should) or that a requirement is mandatory (shall).

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FOREWORD

AS 2885 was first published in 1987, superseding AS 1697—1981 (gas transmission and distribution) and AS 2018—1981 (liquid petroleum pipelines). A revision in 1997 split the Standard into separate parts (design and construction, welding, and operation and maintenance) and introduced the concept of RISK ASSESSMENT. The 2007 revision of Part 1 included numerous major changes, of which the most significant were provision for upgrading MAOP and substantially expanded requirements for RISK ASSESSMENT which was also relabelled as safety management. A revision in 2012 was primarily to harmonize with other parts of AS 2885 but also added appendices on fiberglass pipe and carbon dioxide pipelines.

This revision is a result of a thorough review of all sections of the Standard.

The greatest change has been the relocation of all details of safety management to a new standard, AS/NZS 2885.6, Pipeline safety management.

Other changes include:

- (a) Clarification that AS/(NZS) 2885 series are the standards for complete PIPELINE SYSTEMS, and improving the distinction between MAINLINE PIPE, other PIPING, and non-pipe elements of a PIPELINE SYSTEM. Related is clarification of the distinction between, and the requirements for, PIPING designed to this Standard and PIPING designed to other standards for STATION PIPING. Particular care has been taken with the definition and use of defined terms such as MAINLINE PIPE, PIPELINE ASSEMBLY and COMPONENT, so that the application of requirements for such items is unambiguous. Figure 4.1 (Pipeline system schematic) has been redrawn and expanded to show these distinctions and definitions.
- (b) Requirements for environmental management have been minimized in recognition that there are other more appropriate sets of rules such as the APGA *Code of Environmental Practice*.
- (c) Removal of all requirements that apply to existing pipelines; such requirements are being transferred to Part 3. Nevertheless, some informative information relevant to existing pipelines remains in Appendix E.
- (d) Sections 4 (Pipeline system design) and 5 (Pipeline design) have been restructured so that the content is appropriate to the section heading, although the technical requirements have generally undergone only minor change except for topics specifically mentioned here.
- (e) A new clause (see Clause 4.4) on design temperatures has been added in Section 4, and a corresponding clause on temperature control in Section 7 (see Clause 7.2.3).
- (f) Requirements for classification of locations have been moved to AS/NZS 2885.6. The former clause dealing with change of LOCATION CLASS creating a HIGH CONSEQUENCE AREA where none existed previously has been moved to Part 3.
- (g) The fracture control requirements have been re-written to improve clarity and a new flowchart has been prepared, although the technical details have changed relatively little. Fracture initiation control is required for all PIPING but propagation control is required only for MAINLINE PIPE. Emphasis is given to use of recommended software.
- (h) The stress and strain requirements have been re-written to expand coverage and align requirements with overseas standards and software.
- (i) Requirements for trenchless crossings have been made more specific, and recognize the distinction between requirements for the design phase (see Section 5) and the construction phase (see Section 10).

- (j) The requirements for design for pressure testing has been extensively revised in parallel with revision of AS 2885.5.
- (k) The potential for acoustically- and flow-induced vibration is recognized as a design condition.
- (l) The corrosion section has been generally revised, with removal of detail that is better covered by reference standards.
- (m) The section on upgrade of MAOP has been revised in light of an Energy Pipelines Cooperative Research Centre project to review experience in its application since it was introduced in 2007.
- (n) The sections on construction and inspection and testing have undergone editorial changes and restructuring to achieve a more logical and consistent approach.

The appendices have been substantially reorganized. All appendices dealing with safety management have been removed because they are covered by AS/NZS 2885.6.

Three new appendices have been added:

- (i) Appendix B (informative), Guidance for use of a design factor above 0.72.
- (ii) Appendix K (informative), Land stability and seismic design.
- (iii) Appendix M (informative), Test section analysis using engineering software (or FEA methods) (formerly Appendix N of AS/NZS 2885.5).

The former appendix on radiation contours has been moved to Part 6.

The former appendix on bolt tensioning has been removed. Assembly requirements for flanged joints are now addressed through references to ASME and other documents. The remaining appendices have been re-ordered largely into the sequence in which they are cited in the body of the Standard.

All appendices have been reviewed and revised to some extent, with major changes including:

- (A) Appendix E, Resistance to penetration—extensive revision, additional guidance and worked examples.
- (B) Appendices F, H and I, Stress analysis—substantially or completely re-written.
- (C) Appendix J, Fatigue—addition of an important qualification on the validity limits for the simplified screening criterion and recognition of acoustically- and flow-induced vibration.
- (D) Appendix S, Fibreglass pipe—Manufacture, design and construction considerations—updated to reflect experience.
- (E) Appendix T, Guidelines for pipelines for the transport of CO₂ Carbon dioxide pipelines—updated to reflect research and new knowledge.

STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

**Australian/New Zealand Standard
Pipelines—Gas and liquid petroleum****Part 1: Design and construction**

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for design and construction of onshore carbon and carbon-manganese steel PIPELINE SYSTEMS that are used to transport single-phase and multi-phase hydrocarbon fluids, such as natural and manufactured gas, liquefied petroleum gas, natural gasoline, crude oil, natural gas liquids and liquid petroleum products.

The principles are expressed in practical rules and guidelines for use by COMPETENT PERSONS.

AS 2885.0 sets out the fundamental principles on which the AS(/NZS) 2885 series is based. These fundamental principles and the practical rules and guidelines set out in AS/NZS 2885.1, AS/NZS 2885.2, AS 2885.3, AS/NZS 2885.5 and AS/NZS 2885.6 are the basis on which an engineering assessment is to be made where these Standards do not provide detailed requirements appropriate to a specific item.

NOTE: AS/NZS 2885.4 for offshore submarine PIPELINE SYSTEMS is a standalone document. AS/NZS 2885.1 applies up to the shoreward limit of AS/NZS 2885.4. Pipelines that start and end onshore but include crossings of large waterways such as rivers, lakes and estuaries fall within the scope of AS/NZS 2885.1.

This Standard does not apply to design and fabrication of the following:

- (a) Equipment for instrumentation, telemetering and remote control.
- (b) Compressors, pumps and their prime movers and integral PIPING.
- (c) Heat exchangers and pressure vessels (refer to AS 1210).
- (d) PROPRIETARY items.
- (e) Wellhead assemblies and associated metering, valves and PIPING.
- (f) Casing, tubing or PIPING used in petroleum wells.

1.2 APPROVAL

Each document prepared for a pipeline in accordance with this Standard shall be APPROVED as required by AS 2885.0.

1.3 APPLICATION

Where this Standard imposes requirements, which add to or override the requirements of a NOMINATED STANDARD or Code, the additional requirements, that are explicitly stated in this Standard shall be met.

Where APPROVED, this Standard may also be used for design and construction of pipelines made with corrosion-resistant alloy steels, fibreglass and other composite materials. Where this Standard is used for pipelines fabricated from these materials, relevant requirements

shall be established to replace the provisions of this Standard in relation to NOMINATED STANDARDS for materials (see Section 3), fracture control (see Clause 5.3), stress and strain (see Clause 5.7) and corrosion (see Section 8) and the provisions of AS/NZS 2885.2 in relation to welding and NON-DESTRUCTIVE TESTING. For composite material, appropriate requirements shall be established to replace the STRENGTH TEST endpoint provisions of AS/NZS 2885.5.

As provided in AS 2885.0, where APPROVED, this Standard may be used for the design and construction of pipelines to transport fluids that are predominantly CO₂ and for other fluids including slurries. Where this Standard is applied to fluids other than gas and liquid petroleum, a gap analysis shall be conducted to identify the differences between the proposed fluid and those of gas and liquid petroleum, and appropriate requirements shall be established to address those differences.

NOTE: Appendix T provides guidance for the design of CO₂ pipelines using this Standard.

1.4 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

AS

1100	Technical drawing
1100.401	Part 401: Engineering survey and engineering survey design drawing
1210	Pressure vessel
1319	Safety signs for the occupational environment
1330	Metallic materials—Drop weight tear test for ferritic steels
1345	Identification of the contents of pipes, conduits and ducts
1349	Bourdon tube pressure and vacuum gauges
1530	Methods for fire tests on building materials, components and structures
1530.1	Part 1: Combustibility test for materials
1544	Method for impact tests on metals
1544.2	Part 2: Charpy V-notch
1680	Interior lighting
1680.2.1	Part 2.1: Circulation spaces and other general areas
1855	Method for the determination of transverse tensile properties of round steel pipes
1929	Non-destructive testing—Glossary of terms
2187	Explosives—Storage and use
2187.2	Part 2: Use of explosives
2528	Bolts, studbolts and nuts for flanges and other high and low temperature applications
2812	Welding, brazing and cutting of metals—Glossary of terms
2832	Cathodic protection of metals
2832.1	Part 1: Pipes and cables
2885	Pipelines—Gas and liquid petroleum
2885.0	Part 0: General requirements
2885.3	Part 3: Operation and maintenance
3862	External fusion-bonded epoxy coating for steel pipes

AS	
3894	Site testing of protective coatings
3894.1	Method 1: Non-conductive coatings—Continuity testing—High voltage (brush) method
3920	Pressure equipment—Conformity assessment
4041	Pressure piping
4799	Installation of underground utility services and pipelines within railway boundaries
4822	External field joint coatings for steel pipelines
4827	Coating defect surveys for buried pipelines
4827.1	Part 1: Direct current voltage gradient (DCVG)
5100	Bridge design
5100.2	Part 2: Design loads
5488	Classification of subsurface utility information (SUI)
AS/NZS	
1158	Lighting for roads and public spaces (series)
1170	Structural design actions
1170.2	Part 2: Wind actions
1170.4	Part 4: Earthquake actions in Australia
1200	Pressure equipment
1518	External extruded high density polyethylene coating system for pipes
1768	Lighting protection
2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
2312.1	Part 1: Paint coatings
2312.2	Part 2: Hot dip galvanizing
2566	Buried flexible pipelines
2566.1	Part 1: Structural design
2566.1 Supp 1	Part 1: Structural design—Commentary (Supplement to AS/NZS 2566.1:1998)
2885	Pipelines—Gas and liquid petroleum
2885.2	Part 2: Welding
2885.4	Part 4: Submarine pipeline systems
2885.5	Part 5: Field pressure testing
2885.6	Part 6: Pipeline safety management
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)
3788	Pressure equipment—In-service inspection
4761	Competencies for working with electrical equipment for hazardous areas (EEHA)
4761.1	Part 1: Competency Standards
4853	Electrical hazards on metallic pipelines

AS/NZS	
60079	Explosive atmospheres
60079.10.1	Part 10.1: Classification of areas—Explosive gas atmospheres (IEC 60079-10-1, Ed.1.0 (2008) MOD)
60079.17	Part 17: Electrical installations inspection and maintenance (IEC 60079-17:2013 (ED.5.0) MOD)
ANSI/ASME	
B16.5	Pipe Flanges And Flanged Fittings: Nps 1/2 Through Nps 24 Metric/Inch Standard
B16.9	Factory-Made Wrought Buttwelding Fittings
B16.11	Forged Fittings, Socket-Welding And Threaded
B16.21	Nonmetallic Flat Gaskets For Pipe Flanges
B16.25	Buttwelding Ends
B16.34	Valves—Flanged, Threaded, And Welding End
ASME	
B31.1	Power Piping
B31.3	Process Piping
B31.4	Pipeline Transportation Systems For Liquids And Slurries
B16.47	Large Diameter Steel Flanges: Nps 26 Through Nps 60 Metric/Inch
B16.49	Factory-Made Wrought Steel, Buttwelding Induction Bends For Transportation And Distribution Systems
B18.2.1	Square, Hex, Heavy Hex, And Askew Head Bolts And Hex, Heavy Hex, Hex Flange, Lobed Head, And lag Screws (Inch Series)
BPVC	Boiler And Pressure Vessel Code (Section 8)
API	
RP 14E	Design And Installation Of Offshore Production Platform Piping Systems
RP 5L2	Internal Coating Of Line Pipe For Non Corrosive Gas Transmission Services
RP 521	Pressure-Relieving And Depressuring Systems
RP 579	Fitness For Service
RP 1102	Steel Pipelines Crossing Railroads And Highways
Spec 5LC	Specification For Line Pipe, Specification For CRA Line Pipe
Spec 5LD	Specification For Line Pipe, Specification For CRA Clad Or Lined Steel Pipe
Spec 6D	Specification For Pipeline Valves (Gate, Plug, Ball And Check Valves)
Spec 15HR	Specification For High Pressure Fibreglass Line Pipe
Spec 15LR	Specification For Low Pressure Fibreglass Line Pipe
STD 600	Steel Gate Valves—Flanged And Butt-welding Ends, Bolted Bonnets
STD 602	Gate, Globe, And Check Valves For Sizes Dn 100 (Nps 4) And Smaller For The Petroleum And Natural Gas Industries
STD 603	Corrosion-Resistant, Bolted Bonnet Gate Valves—Flanged And Butt-welding Ends

ASTM	
A105	Standard Specification for Carbon Steel Forgings for Piping Applications
A106	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A193	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
A194	Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure and High Temperature Service, or Both
A234	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperatures Service
A307	Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
A320	Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
A333	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
A350	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
A354	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
A420	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
A449	Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
A671	Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
A694	Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High Pressure Transmission Service
A860	Standard Specification for Wrought High-Strength Ferritic Steel Butt-Welding Fittings
D696	Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer
D1599	Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D2105	Standard Test Method for Longitudinal Tensile Properties of 'Fiberglass' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
D2412	Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

ASTM	
D2992	Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for ‘Fibreglass’) Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
E1049	Standard Practices for Cycle Counting in Fatigue Analysis
BS	
3183	Method for the determination of wool fibre diameter by the airflow method
3381	Specification for spiral wound gaskets for steel flanges to BS 1560
3799	Specification for steel pipe fittings, screwed and socket-welding for the petroleum industry
5500	Specification For Unfired Fusion Welded Pressure Vessels
7910	Guide To Methods For Assessing The Acceptability Of Flaws in Metallic Structures
ISO	
3183	Petroleum and natural gas industries—Steel pipe for pipeline transportation systems
14692	Petroleum and natural gas industries—Glass-reinforced plastics (GRP) piping
14692-1	Part 1: Vocabulary, symbols, applications and materials
14692-2	Part 2: Qualification and manufacture
14692-3	Part 3: System design
15590	Petroleum and natural gas industries—Induction bends, fittings and flanges for pipeline transportation systems
15590-1	Induction bends
17292	Metal ball valves for petroleum, petrochemical and allied industries
MSS	
SP 6	Standard Finishes For Contact Faces Of Pipe Flanges And Connecting-End Flanges Of Valves and Fittings
SP 25	Standard Marking System For Valves, Fittings, Flanges And Unions
SP 44	Steel Pipeline Flanges
SP 67	Butterfly Valves
SP 75	High-Strength, Wrought, Butt-Welding Fittings
SP 97	Integrally Reinforced Forged Branch Outlet Fittings—Socket Welding, Threaded, And Buttwelding Ends
ANSI/NACE	
MR0175/ ISO 15156	Petroleum and Natural Gas Industries—Material for use in H ₂ S-containing environments in oil and gas production
TM0284	Evaluation of Pipeline and Pressure Vessels Steels for Resistance to Hydrogen-Induced Cracking
CSA	
Z245.21	External Polyethylene Coating for Pipe
MGA94	The Map Grid of Australia 1994: A Simplified Computational Manual, Department of Sustainability and Environment

1.5 RETROSPECTIVE APPLICATION

Retrospectivity is governed by AS 2885.0.

This revision does not introduce additional changes that are intended to apply retrospectively.

1.6 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 2885.0 and AS 1929, AS 2812, AS 2832.1 apply.

1.7 SYMBOLS AND UNITS

Unless otherwise noted in this Standard, pressure and calculations involving pressure are based on gauge pressures.

NOTE: Symbols defined and used in appendices are not listed in this table.

Symbol	Description	Unit
A_C	Fracture area of the Charpy V-notch specimen	mm ²
$A_{YS_{min}}$	Lowest yield strength of any pipe in a test section, estimated statistically from the population of pipes with the highest design factor in that test section	MPa
CDL	CRITICAL DEFECT LENGTH	mm
CVN	Upper shelf Charpy V-notch energy (full size equivalent)	J
c	Half of the length of an axial through wall flaw	mm
D	Nominal outside diameter = Pipe diameter = Pipeline diameter	mm
D_m	Average diameter	mm
D_{max}	Largest diameter	mm
D_{min}	Smallest diameter	mm
d	Branch diameter	mm
d_w	Depth of part through wall flaw	mm
E	Young's modulus	MPa
F_D	Design factor for pressure containment	
F_{Bucket}	Force exerted at a bucket, correlated against excavator mass	kN
F_{MAX}	Maximum force exerted at bucket (most severe geometry)	kN
F_P	Pressure factor for bends	
F_{TP}	Test pressure factor	
F_{TPE}	Equivalent test pressure factor	
f	Stress cycling factor	
f_o	Ovality factor	
G	Sum of allowances	mm
H	Manufacturing tolerance	mm
L	Length of tooth at tip	mm
K_C	Critical stress intensity factor	MPa·mm ^{1/2}

Symbol	Description	Unit
M_T	Folias factor	
P_D	DESIGN PRESSURE	MPa
P_{EXT}	External pressure	MPa
P_L	Pressure limit	MPa
P_M	Measured pressure from pressure test	MPa
P_{TMAX}	Maximum STRENGTH TEST pressure	MPa
P_{TMIN}	Minimum STRENGTH TEST pressure	MPa
R	Bend radius to the centreline of the pipe	mm
r_M	Mean pipe radius	mm
R_p	Puncture resistance	kN
R_{Li}	Number of runs of n_p pipe, each run having a length i	
S_{EFF}	Effective stress (in accordance with API RP 1102)	MPa
S_F	Statistical factor	
S_{FG}	Stress limit for girth weld fatigue (in accordance with API RP 1102)	MPa
S_{FL}	Stress limit for longitudinal weld fatigue (in accordance with API RP 1102)	MPa
t	Wall thickness	mm
t_N	WALL THICKNESS—NOMINAL	mm
t_P	WALL THICKNESS—INTERNAL PRESSURE DESIGN	mm
t_W	WALL THICKNESS—REQUIRED	mm
W	Width of tooth at tip	mm
W_{OP}	Operating weight	tonne
ΔS_H	Stress for longitudinal welds (in accordance with API RP 1102)	MPa
ΔS_L	Stress for girth welds (in accordance with API RP 1102)	MPa
σ	Stress	MPa
σ_C	Combined equivalent stress	MPa
σ_E	Expansion stress	MPa
σ_{flow}	FLOW STRESS	MPa
σ_H	HOOP STRESS	MPa
σ_L	Longitudinal stress	MPa
$\sigma_{L,S}$	Longitudinal stress from sustained load	MPa
σ_U	Ultimate tensile strength	MPa
σ_Y	Specified minimum yield strength (SMYS)	MPa
ν	Poisson's ratio (stress and strain)	

1.8 ABBREVIATIONS

Abbreviations	Meaning	Unit
AFV	Allowable fluid variation	L/24 h
ALARP	AS LOW AS REASONABLY PRACTICABLE	
ANSI	American National Standards Institute	
APGA	Australian Pipelines and Gas Association	
API	American Pipeline Institute	
AS	Australian Standard	
AS/NZS	Standards Australian/Standards New Zealand	
ASME	American Society of Mechanical Engineers	
ASTM	American Society of Testing and Materials	
BS	British Standards Institution	
CDL	CRITICAL DEFECT LENGTH	
HAZOP	Control hazard and operability study	
CRA	Corrosion-resistant alloy	
DN	Nominal diameter	
DWTT	Drop weight tear test	
EIP	External interference protection	
EPCRC	Energy Pipelines Cooperative Research Centre	
FATT	Fracture appearance transition temperature	°C
GIS	Geographic information system	
HAZ	HEAT-AFFECTED ZONE	
HAZOP	Hazard and operability study	
HFV	High frequency welded	
HVPL	HIGH VAPOUR PRESSURE LIQUID	
ISO	International Organization for Standardization	
JSA	Job safety analysis	
LPG	Liquefied petroleum gas	
MAOP	MAXIMUM ALLOWABLE OPERATING PRESSURE	MPa
MLV	Main line valve	
MSS	Manufacturers Standardization Society of the Valve and Fitting Industry, USA	
NACE	NACE International, USA	
NZS	New Zealand Standard	
PRCI	Pipeline research council international	
SAW	Submerged arc welded	
SCADA	Supervisory control and data acquisition	
SCC	STRESS CORROSION CRACKING	

Abbreviations	Meaning	Unit
SIL	Safety integrity level	
SMS	SAFETY MANAGEMENT STUDY	
SMYS	SPECIFIED MINIMUM YIELD STRENGTH	MPa
TBFC	Temperature for brittle fracture control	°C
XS	Extra strong	

SECTION 2 SAFETY AND ENVIRONMENT

2.1 BASIS OF SECTION

AS/NZS 2885.6 defines the pipeline SAFETY MANAGEMENT PROCESS and provides requirements and guidance for each phase of design and construction.

Electrical safety, construction safety, and environmental management are addressed during design and construction in accordance with the requirements of this Section.

NOTE: Prior to this revision of AS/NZS 2885.1 the SAFETY MANAGEMENT PROCESS was defined in this Section. Where another Part of the AS/(NZS) 2885 series refers to a SAFETY MANAGEMENT STUDY in accordance with AS/NZS 2885.1, users should now refer to AS/NZS 2885.6.

2.2 PIPELINE SYSTEM SAFETY

The SAFETY MANAGEMENT PROCESS specified in AS/NZS 2885.6 shall be applied to PIPELINE SYSTEM design and construction.

A SAFETY MANAGEMENT STUDY plan in accordance with AS/NZS 2885.6 shall be prepared at the commencement of each pipeline project.

AS/NZS 2885.6 Section 1 also nominates requirements for the safety assessments of pipeline STATIONS, PIPELINE ASSEMBLIES, and control systems.

2.3 ELECTRICAL

A pipeline can be subject to voltages that can be hazardous to the pipeline itself, or to personnel who may come in contact with it.

Hazardous voltages can arise due to a variety of causes, such as earth potential rise in the vicinity of electrical earthing under fault conditions or due to voltages induced on the pipeline when faults occur on nearby parallel powerlines.

A pipeline in the vicinity of electricity supply powerlines or facilities shall be analysed to determine if controls are required to provide for electrical safety. Induced voltage, lightning and fault current protection for sections of the PIPELINE SYSTEM affected by these conditions shall be designed in accordance with AS/NZS 4853.

NOTE: General guidance on electrical hazards is given in Appendix Q.

2.4 CONSTRUCTION AND COMMISSIONING

2.4.1 Construction safety

Construction of PIPELINE SYSTEMS shall be carried out in a safe manner.

The safety of the public, construction personnel, adjacent property, equipment and the pipeline shall be maintained and not compromised.

A construction safety plan shall be prepared, reviewed by appropriate personnel, and APPROVED. The review shall take the form of a construction safety plan workshop.

NOTES:

- 1 The review by appropriate personnel should include designers, construction personnel, and health and safety personnel.
- 2 The construction safety plan detail should be consistent with the nature of the work being undertaken. It may be a part of an integrated construction safety system, a construction safety case (where the regulatory jurisdiction requires this), or a project or activity specific safety plan.

At a minimum, the following shall be addressed in the construction safety plan:

- (a) Fire protection shall be provided and local bushfire and other fire regulations shall be observed.
- (b) Where the public could be exposed to danger or where construction operations are such that there is the possibility that the pipeline could be damaged by vehicles or other mobile equipment, suitable PHYSICAL and/or PROCEDURAL MEASURES shall be implemented.
- (c) Where a power line is in close proximity to the route safe working practice shall be established.
- (d) Where a pipeline is in close proximity to a high voltage power line, potential threats from induced voltage and earth potential rise shall be assessed and appropriate measures taken to mitigate dangers to personnel and equipment.

NOTE: For guidance on measures that may be implemented, see Appendix Q.

- (e) Where excavation is to be undertaken, the identification and location of existing underground infrastructure including adequate protections to avoid asset strikes.
- (f) Adequate danger and warning signs shall be installed in the vicinity of construction operations, to warn persons of dangers (including those from mobile equipment, radiographic process and the presence of excavations, overhead powerlines and overhead telephone lines).
- (g) Unattended excavations in locations accessible to the public shall be suitably barricaded or fenced off and, where necessary, traffic hazard warning lamps shall be operated during the hours of darkness.
- (h) During the construction of submerged pipelines, suitable warnings shall be given. Signs and buoys shall be appropriately located to advise the public of any danger and to minimize any risk of damage to shipping. Where warnings to shipping are required by an authority controlling the waterway, the authority's requirements for warnings should be ascertained and the authority advised of all movements of construction equipment.
- (i) Provision of adequate measures to protect the public from hazards caused by welding.
- (j) Procedure to be followed for lifting pipes both from stockpile and into trench after welding.
- (k) Procedure for safe use and handling of chemicals and solvents.
- (l) Frequency and provision of safety talks (tool box meetings).
- (m) Accident reporting and investigation procedure.
- (n) Appointment of safety supervisor and specification of duties.
- (o) Travel associated with attending the worksite.
- (p) Statutory obligations.
- (q) Traffic management plan.

NOTE: APGA, *Onshore Pipeline Projects, Construction Safety Guidelines* provides guidance on construction safety for the Australian Pipeline Industry.

2.4.2 Testing safety

The construction safety plan shall address safety through all phases of testing of the pipeline during construction.

2.4.3 Commissioning safety

Preparation for COMMISSIONING shall include a documented review of the safety of the activities undertaken through all phases of COMMISSIONING and, where required, development of specific procedures to manage the safety during COMMISSIONING of the pipeline.

2.5 ENVIRONMENTAL MANAGEMENT

Environmental planning is necessary to ensure that the pipeline route, locations of facilities, and all construction practices and procedures minimize impact on the environment.

The LICENSEE shall review environmental aspects of its PIPELINE SYSTEM location and construction, and shall document them in an environmental management plan or equivalent. Any threats to the environment shall be assessed and controls implemented as part of the design and construction documentation.

NOTES:

- 1 It is not intended that a separate environmental management plan or equivalent be prepared for conformity with the AS(/NZS) 2885 series provided that an environmental management plan developed for other purposes also meets the requirements of this Standard.
- 2 The APGA *Code of Environmental Practice* provides industry accepted guidance on environmental management through the planning and acquisition, construction, operational and decommissioning phases of a pipeline lifecycle.

SECTION 3 PIPELINE MATERIALS

3.1 BASIS OF SECTION

Pipeline materials are comprised of MAINLINE PIPE, connecting PIPING, COMPONENTS and coatings.

STATION materials are chosen in accordance with the STATION PIPING design standard and are not necessarily required to conform with this Section.

Pipeline materials shall be suitable for the conditions under which they are used, including construction. They shall have the integrity strength, ductility, fracture toughness, weldability, temperature rating, and design life specified by the engineering design.

The engineering design shall take into account the effect of all manufacturing and construction processes and service conditions on the properties of the materials.

Each material shall meet the relevant clauses of this Section.

3.2 QUALIFICATION OF MATERIALS

3.2.1 General

Pipeline materials shall conform with one or more of the requirements of this Clause 3.2.

Documentary evidence demonstrating the means of qualification shall be provided in the construction records.

Materials conforming with Standards other than those listed in Clause 3.2.2, materials for which no Standard exists and reclaimed materials shall not be used unless APPROVED.

3.2.2 Materials conforming with nominated Standards

Where allowed by the engineering design, materials conforming with one of the following NOMINATED STANDARDS are qualified for use as specified and as limited by this Standard, but subject to the requirements of subsequent clauses of this Section.

Except as provided in Clause 3.5.3, materials shall be used in accordance with the pressure/temperature rating contained in the NOMINATED STANDARDS.

Materials conforming with NOMINATED STANDARDS shall be supplied with test certificates containing sufficient data to demonstrate conformity with this Standard, the engineering design, the relevant NOMINATED STANDARD(S), and any supplementary specifications:

NOTES:

- 1 NOMINATED STANDARDS for materials, especially line pipe specifications API Spec 5L and ISO 3183, contain multiple options that need to be specified by the purchaser, and for this reason, as well as the very common specification of supplementary requirements by pipeline designers, conformity with a NOMINATED STANDARD is necessary but insufficient.
- 2 Multiple examples have occurred where materials certified as conforming with NOMINATED STANDARDS were found on audit and/or pressure testing not to conform. Care should be exercised by line pipe purchasers to ensure that appropriate levels of inspection and quality assurance are implemented, e.g. refer to USA DOT PHMSA Advisory Bulletin ADB-09-01.

The NOMINATED STANDARDS are as follows:

- (a) *Carbon/carbon manganese steel pipe*—API Spec 5L, ISO 3183, DNVGL-ST-F101, ASTM A106/A106M-15, ASTM A333/A333M-16, ASTM A671/A671M16a.

NOTES:

- 1 Depending on the application, pipe may need to meet some additional requirements other than those listed in this Clause, in subsequent clauses of this Section, in Clause 5.12, and in AS/NZS 2885.2. The following are examples:
 - (a) Specific test methods, test data, minimum strength, maximum strength, maximum IIW CEq, or fracture toughness may be required.
 - (b) API Spec 5L and ISO 3183 do not require drop weight tear testing below DN 500, whereas AS/NZS 2885.1 requires control of brittle fracture for smaller diameters.
- 2 ASTM A106/A106M-15 specifies pipe for high temperature service and has no specific requirements for Charpy toughness. It is usually unsuitable for use as MAINLINE PIPE or in PIPELINE ASSEMBLIES unless toughness properties are specified, and specific tests are made to confirm conformity, or it is used in a service which has no fracture control requirements.
- 3 The listed permissible ASTM pipe grades are primarily intended for PIPELINE ASSEMBLY applications. They are available in multiple grades and conditions. Care has to be taken to ensure the selected grade and condition are fit for the intended pipeline service conditions.
- 4 Specification of linepipe strength has implications for girth weld strength. See the Note to Clause 5.10.2.

Minimum additional requirements for pipes conforming with any of these Standards are as follows:

- (i) Pipe for use in accordance with this Standard shall not have an SMYS greater than 555 MPa (X80).
- (ii) The integrity of each pipe length shall be demonstrated by both longitudinal seam NON-DESTRUCTIVE TESTING and pressure testing as part of the manufacturing process.
- (iii) Wall thickness tolerance—where the design factor exceeds 0.72—
 - (A) the minimum weight tolerance in API Spec 5L shall be adhered to, irrespective of the Standard to which the pipe is purchased;
 - (B) the level of eccentricity permitted in seamless pipe shall be established, and the resulting minimum allowable wall thickness shall be adopted in design calculations (see Clause 5.2.7); and
 - (C) the minimum permissible wall thickness after grind repair or internal trim for pipe manufactured by HFW or laser methods, shall be 90% of required wall thickness for material with an SMYS up to 485 MPa (X70) and 92% for material with an SMYS up to 550 MPa (X80).
- (b) *Corrosion resistant alloys*—API Spec 5LC and API Spec 5LD.
- (c) *Fibreglass pipe*—API Spec 15LR, API Spec 15HR or ISO 14692-1 and ISO 14692-2.
NOTE: Where this Standard is used for pipelines constructed with corrosion resistant alloy or fibreglass pipe, attention is drawn to the requirements of Clause 1.3.
- (d) *Fittings and components*—ASME B16.9, ASME BPVC Section VIII, BS 5500, AS/NZS 1200, ASME B16.11, ASME B16.25, ASTM A105/A105M-14, ASTM A234/A234M-16, ASTM A350/A350M-15, ASTM A420/A420M-16, ASTM A694, ASTM A860, BS 1965, BS 3799, MSS SP 75, MSS SP 97.

NOTE: Depending on the welding method chosen, additional limits to IIW CEq may be required.

- (e) *Induction bends*—ISO 15590-1, ASME B16.49.
- (f) *Valves*—ASME B16.34, API Spec 6D, API Std 600, API Std 602, API Std 603, ASTM A350/A350M-15, BS EN ISO 17292, MSS SP 25, MSS SP 67.
- (g) *Flanges*—ASME B16.5, ASME B16.21, ASME B16.47, MSS SP 6, MSS SP 44.
- (h) *Gaskets*—ASME B16.21, BS 3381.
- (i) *Bolting*—AS 2528, ANSI B18.2.1, ASME B16.5, ASTM A193/A193M-16, ASTM A194/A194M-17, ASTM A307-14e1, ASTM A320/A320M-17a, ASTM A354-11, ASTM A449-14.
- (j) *Pressure gauges*—AS 1349.
- (k) *Welding consumables*—AS/NZS 2885.2.
- (l) *Anti-corrosion coatings*—AS/NZS 2312 series, AS 3862, AS/NZS 1518, CSA Z245.21 system B tri-laminate.
- (m) *Galvanic anodes*—AS 2239.

3.2.3 Materials conforming with Standards not nominated in this Standard

Materials conforming with Standards that are not nominated in Clause 3.2.2 may be used subject to qualification and shall also meet the requirements of subsequent clauses of this Section.

Qualification shall be achieved by one of the following means:

- (a) Conformity with an APPROVED Standard that does not vary materially from a Standard listed in this Section with respect to quality of materials and workmanship. This Clause shall not be construed as permitting deviations that would tend to adversely affect the properties of the material. The design shall take into account any deviations that can reduce strength or wall thickness.
- (b) Tests and investigations to demonstrate their safety, provided that this Standard does not specifically prohibit their use. COMPONENTS that are not covered by NOMINATED STANDARDS or not covered by design equations or procedures in this Standard may be used, provided the design of similarly shaped, proportioned and sized COMPONENTS has been proved satisfactory by successful performance under comparable service conditions. Interpolation may be made between similarly shaped proven COMPONENTS with small differences in size or proportion. In the absence of such service experience, the design shall be based on an analysis consistent with the general philosophy embodied in this Standard and substantiated by one of the following:
 - (i) Proof tests as described in AS 1210, or an equivalent international Standard.
 - (ii) Experimental stress analysis.
 - (iii) Theoretical calculations.

The results of tests and findings of investigations shall be recorded in construction records.

3.2.4 Components for which no standard exists

Where a COMPONENT is not included in a NOMINATED STANDARD or is not used within the manufacturer's pressure/temperature rating, and for which design equations or procedures are not given in this Standard, the suitability for service shall be evaluated in terms of the PRESSURE STRENGTH of the COMPONENT at the design temperatures.

Satisfactory service experience of such COMPONENTS may be used to demonstrate their suitability where the design of similarly shaped, proportioned, and sized COMPONENTS has been proven to be satisfactory under comparable service conditions. Interpolation may be made between similarly shaped, proven COMPONENTS with small differences in size or proportion.

In the absence of such service experience, the design shall be based on an analysis consistent with the general philosophy of this Standard, and substantiated by one or more of the following:

- (a) Proof tests in accordance with AS 1210.
- (b) Experimental stress analysis.
- (c) Theoretical calculations.

3.2.5 Reclaimed pipe

Provided that any degradation of the pipe since its manufacture will not affect its performance under the operating conditions that are to be expected in the pipeline, reclaimed pipe may be treated as new pipe to the same Standard only where—

- (a) it has passed a pressure test (see Clauses 3.2.7 and 11.7);
- (b) the pipe was manufactured to a NOMINATED STANDARD;
- (c) the history of the pipe is known;
- (d) the pipe is suitable for the proposed service in light of its history;
- (e) an inspection is carried out to reveal any DEFECTS that could impair strength or pressure tightness;
- (f) a review and, where necessary, an inspection is carried out to determine that all welds conform with the requirements of this Standard; and
- (g) DEFECTS are repaired or removed in accordance with this Standard.

3.2.6 Reclaimed components

Provided any adverse conditions under which the COMPONENT had been used will not affect the performance under the operating conditions that are to be expected in the pipeline, it may be treated as new and may be used provided that—

- (a) it has passed a pressure test (see Clause 3.2.7);
- (b) the COMPONENT was manufactured to a NOMINATED STANDARD;
- (c) the history of the COMPONENT is known;
- (d) the COMPONENT is suitable for the proposed service in light of its history;
- (e) an inspection is carried out to reveal any DEFECTS that could impair its use; and
- (f) where necessary, an inspection is carried out to determine that the welds conform with the requirements of this Standard.

COMPONENTS shall be cleaned, examined and where required reconditioned and tested, to ensure that they conform with this Standard.

3.2.7 Pressure test

Reclaimed pipe and COMPONENTS, the strength of which may have been reduced by corrosion or other form of deterioration, or pipe or COMPONENTS manufactured to a Standard which does not specify pressure test during manufacture, shall be pressure tested either individually in a test conforming with an appropriate NOMINATED STANDARD or as part of the pipeline to the test pressure specified for the pipeline (see Clause 11.7).

3.3 IDENTIFICATION OF MATERIALS

All materials shall be identified such that their source can be established.

Materials that cannot be identified with a NOMINATED STANDARD or a manufacturer's test certificate shall not be used for pressure containment and may only be used for parts not subject to stress due to pressure (e.g. supporting lugs).

3.4 ADDITIONAL REQUIREMENTS FOR COMPONENTS TO BE WELDED

Except where otherwise indicated, where welding is specified by Standards nominated in this Section, that welding shall be acceptable without further qualification.

AS/NZS 2885.2 provides information on factors that affect weldability and those factors shall be reviewed and documented when specifying pipe and COMPONENTS.

NOTES:

- 1 Limits on pipe and COMPONENT strength range and composition (including IIW CEq) are commonly specified.
- 2 AS/NZS 2885.2 states that that Standard is not intended to be applied to welds made during the manufacture of a pipe or a COMPONENT.

3.5 ADDITIONAL MECHANICAL PROPERTY REQUIREMENTS

3.5.1 Yield strength

The yield strength (σ_Y) used in equations in this Standard shall be the SMYS specified in the Standard with which the pipe or COMPONENT conforms.

NOTE: The preferred method for determining the tensile properties of line pipe conforming with API Spec 5L is given in Appendix A.

3.5.2 Pipe yield to tensile ratio

The yield to tensile strength ratio of bare pipe shall not be greater than 0.93 unless it has a design factor less than 0.65 or is used in a PIPELINE ASSEMBLY.

Where heat treatment subsequent to manufacture is expected to increase the yield to tensile strength ratio, a lower specification may be required for the bare pipe to achieve acceptable as-coated properties.

NOTES:

- 1 See Clauses 3.6.2 and 5.3.6.1.
- 2 API 5L does not limit Y/T for PSL2 pipe $\leq$ DN300 or PSL1 pipe.

3.5.3 Strength de-rating

Carbon steel and carbon manganese steel flanges and valves conforming with NOMINATED STANDARDS may be used without derating at design temperatures not exceeding 120°C.

NOTES:

- 1 Refer to ASME B31.3, ASME VIII and MSS SP44—At temperatures up to 120°C flange designs are based on (a constant) ultimate tensile strength resulting in no strength derating requirement.
- 2 The temperature limit for flanged valves applies only to the flanges. Assurance should be sought from the valve manufacturer that the valve body and seals are suitable for the required service conditions.
- 3 The adoption of a higher design temperature for flanges requires that the MAINLINE PIPE and the PIPING each meet the stress limits required by the design standard.
- 4 This permission does not currently apply to vessels designed in accordance with AS 1210 (e.g. filter vessels). In these cases, a design check in accordance with AS 1210 or ASME *Boiler and Pressure Vessel Code (BPVC)*, Section VIII, should be considered, or a higher grade of flange material considered, e.g. material group 1.2 instead of 1.1 in ASME B16.5.

Where the pipeline design temperature is above 65°C the yield strength of the pipe steel shall be de-rated. The reduction in yield strength shall be 0.07%/°C by which the design temperature exceeds 23°C.

NOTE: The use of 65°C as a boundary below which no de-rating needs to be applied covers common gas pipeline compressor discharge temperatures. This exemption results in a step change in de-rating above 65°C.

3.5.4 Fracture toughness

Fracture toughness of MAINLINE PIPE, and PIPELINE ASSEMBLIES designed in accordance with this Standard, shall not be less than is required by a fracture control plan which shall be prepared in accordance with Clause 5.3.

NOTE: See Clause 6.3 for requirements for PIPING designed to a STATION PIPING standard.

3.5.5 Tensile data for Type 2 and Type 3 strength tests

For test sections subject to a Type 2 STRENGTH TEST a statistically estimated lowest actual yield strength (AYS_{min}) is required for the MAINLINE PIPE with the highest design factor. Sufficient measurements of line pipe yield strength to enable a valid statistical estimate shall be made using appropriate test methods.

The design of test sections for Type 3 STRENGTH TESTS requires the use of engineering software to analyse the strain in each individual pipe within the test section. Accurate and complete strength data, determined by appropriate test methods, is required for every TEST UNIT. Characteristic stress-strain curves shall be provided to enable the use of engineering software.

NOTES:

- 1 The minimum number of yield strength results for the determination of AYS_{min} is six for each process group (all pipe that has the same grade and cross-section and has been subject to the same manufacturing process and, if applicable, coating process).
- 2 Normally the appropriate method for yield strength determination is the ring expansion test method.
- 3 According to the requirements of the design, strength data may be for uncoated or coated pipes.
- 4 See Clause 5.12 of this Standard and AS/NZS 2885.5 for further information.

3.6 REQUIREMENTS FOR TEMPERATURE AFFECTED ITEMS

3.6.1 General

Properties of materials may be altered by exposure to non-ambient temperatures during manufacture and construction by processes such as hot bend manufacture, application of corrosion prevention coatings including joint coating, pre-weld and post-weld heat treatment, and where pipe coating is exposed to cryogenic temperatures. Exposure to above ambient temperatures during operation such as downstream of compressor STATIONS or in hot oil, or gas gathering service may also affect material properties.

Where these processes are applicable their effect on the integrity of the pipeline shall be identified and documented.

3.6.2 Items heated subsequent to manufacture

Where pipe or COMPONENTS are heated as part of processes subsequent to manufacture, the effect of the heating on yield strength and fracture properties shall be established.

Materials that are heated, or hot-worked at temperatures above 280°C, after completion of the manufacturing and testing processes, shall not be used unless it is demonstrated that the materials meet the minimum strength and fracture toughness requirements for the pipeline design after the heat treatment or hot-work is performed.

Where carbon manganese steel COMPONENTS are subject to temperatures above 100°C during coating, field weld heat treatment or similar processes, strain-ageing effects shall be determined by representative tests on samples subjected to simulated or actual heat treatment cycles. Flattened strap test pieces shall not be used for yield strength determination.

The mechanical property limits of the relevant material Standard (e.g. API Spec 5L) are not required to be achieved in the strain-aged condition. Characteristic changes in strength and toughness due to strain aging should be assessed against design requirements, including the fracture control plan.

NOTES:

- 1 Limiting the yield to tensile strength ratio to 0.90 for bare pipe will usually result in the majority of the pipe order having a yield to tensile strength ratio less than 0.93 after strain ageing.
- 2 Research on yield to tensile ratio and its causes and effects has been undertaken in Australia and recommendations adopted in this Standard. The reference is M. Law and G. Bowie, 'High Y/T and low strain to failure effects in coated high strength pipe', CRC-WS Report 2003-328.

3.6.3 Pipe operated at elevated temperatures

Where pipe is operated at elevated temperatures, the yield strength shall be de-rated in accordance with Clause 3.5.3. The effect of exposure to the design maximum temperature on the competing processes of increased strength due to strain ageing and loss of strength due to the elevated temperature shall be identified and recorded. Other mechanical properties including toughness need not be considered.

3.6.4 Pipe exposed to cryogenic temperatures

Exposure of carbon manganese steel to cryogenic temperatures is deemed not to alter subsequent properties within the design temperature range. The effect of cryogenic temperatures on the pipeline coating shall be identified and documented.

3.7 MATERIALS TRACEABILITY AND RECORDS

All pressure-containing materials installed on a PIPELINE SYSTEM shall be traceable to the purchase documentation, the manufacturing Standard, the testing standard, and to inspection and acceptance documents. The pipeline LICENSEE shall maintain the records until the pipeline is abandoned or removed.

Special traceability procedures shall be applied to materials whose markings are destroyed in processes following their manufacture, e.g. coated pipe.

Consideration should be given to the need in subsequent operation, maintenance and development of the pipeline for the materials to be identified spatially, by item, e.g. identification of each pipe by coordinate, and each COMPONENT by mark to the as constructed drawing. Where such identification is applied, the requirement shall be documented and the quality procedure implemented shall be sufficient to ensure the accuracy of the data.

Electronic records that can be accessed by common text, database or spreadsheet programs are preferred. Where documents are only available on paper, they should be scanned into an appropriate format.

SECTION 4 PIPELINE SYSTEM DESIGN

4.1 BASIS OF SECTION

Every PIPELINE SYSTEM shall be designed to safely withstand all reasonably predictable influences to which it may be exposed during the whole of its design life. Every pressure-containing item shall be leak tight.

A structured design process, appropriate to the requirements of the specific PIPELINE SYSTEM, shall be carried out to ensure that all safety, performance and operational requirements are met during the design life of the PIPELINE SYSTEM.

The design of a PIPELINE SYSTEM shall be based on the following principles for design, construction and operation:

- (a) Safety of PIPELINE SYSTEM and public is paramount.
- (b) Design is specific to the nominated fluid(s).
- (c) Route selection identifies existing land use and allows for known future land planning requirements and the environment.
- (d) The pipeline and associated equipment are fit for purpose.
- (e) Engineering calculations are done for expected load cases.
- (f) Stresses, strains, displacements and deflections are within nominated limits.
- (g) Materials for pressure containment meet standards and be traceable.
- (h) Brittle and ductile fracture are controlled.
- (i) Pressure is positively controlled and limited.
- (j) The pipeline is designed to be suitable for pressure testing and pipeline integrity is established before service by pressure testing.
- (k) For gas pipelines, the likelihood, extent and consequences of the formation of condensates and hydrates in the pipeline is established and prevention or mitigation measures are put in place to ensure the safe operation and integrity of the pipeline.
- (l) Pipeline design includes provision for protection of the safety and integrity by—
 - (i) external interference protection;
 - (ii) corrosion mitigation;
 - (iii) integrity monitoring capability where applicable; and
 - (iv) operation and maintenance in accordance with defined plans.
- (m) Design review is required if there are changes in the design criteria.
- (n) The pipeline has a design life, for calculation of time dependent effects.
- (o) Contaminants such as water, solids, compressor oils and other liquids may occur.

The design process shall be undertaken in parallel with and as an integrated part of the SAFETY MANAGEMENT PROCESS (refer to AS/NZS 2885.6) and shall reflect the obligation to provide protection for the pipeline, people, and the environment.

Figure 4.1 describes the separation of a PIPELINE SYSTEM into the MAINLINE PIPE, PIPELINE ASSEMBLIES and STATIONS.

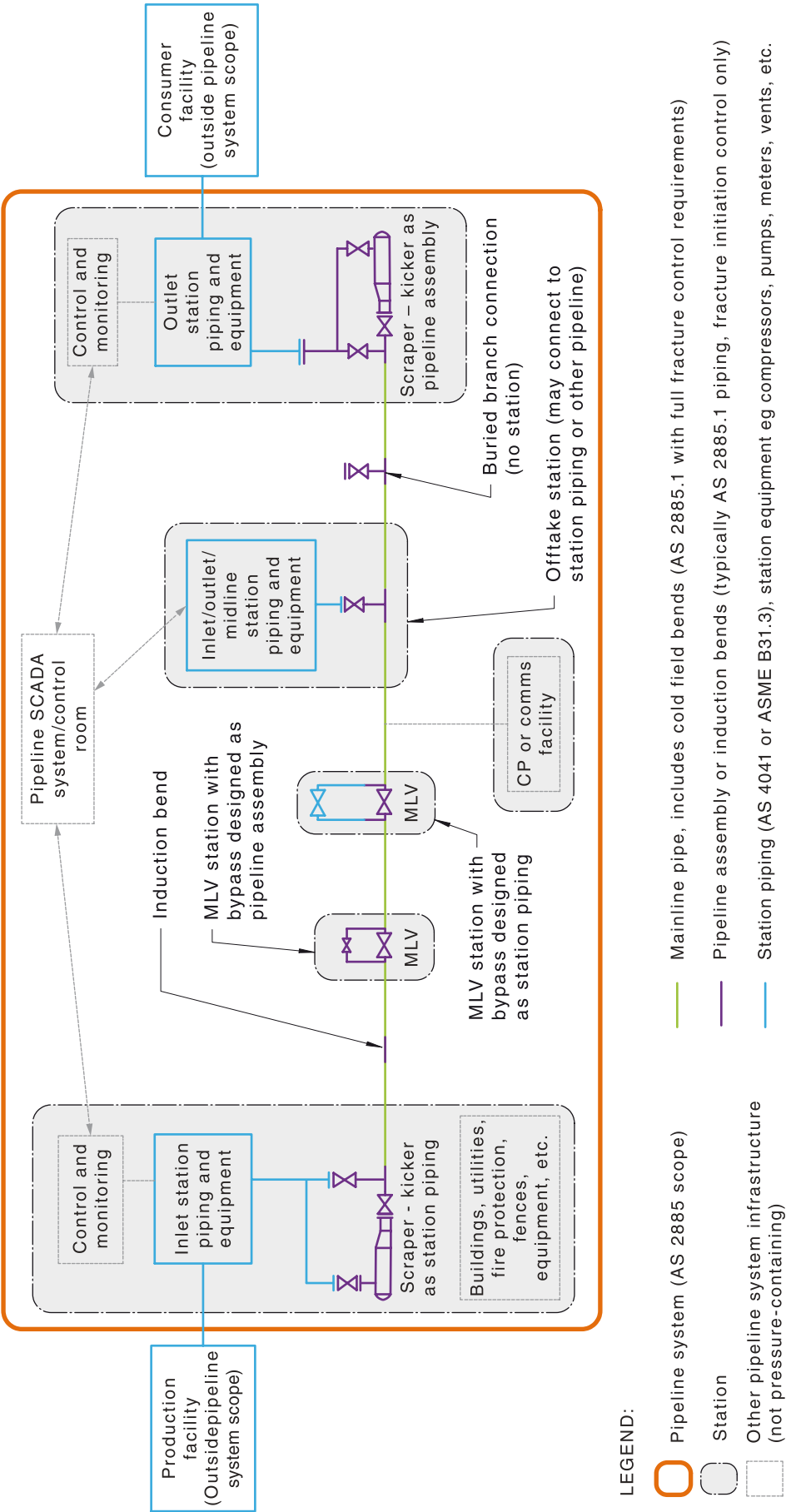


FIGURE 4.1 PIPELINE SYSTEM SCHEMATIC

The demarcation point between PIPING in accordance with this Standard and STATION PIPING shall be defined for each STATION.

NOTE: The demarcation point should preferably be at or adjacent to the first valve off the pipeline on the side of the valve remote from the pipeline. Other suitable location may be a flange, a weld or a point defined by dimensions. Where the demarcation point is not at a flange, consideration should be given to means of carrying out separate pressure tests for the STATION PIPING and piping in accordance with this Standard.

The requirements of Section 5 shall apply to the MAINLINE PIPE and to PIPING associated with PIPELINE ASSEMBLIES (except in accordance with Clause 5.9.1) and shall be met notwithstanding the use of any other Standard for design of elements of the pipeline.

The requirements of Section 6 shall apply where an element of the PIPELINE SYSTEM has been designated as a STATION.

4.2 SYSTEM DESIGN

4.2.1 Design basis

The basis for design of the PIPELINE SYSTEM, including each STATION or PIPELINE ASSEMBLY, and for each modification to the PIPELINE SYSTEM shall be documented in the design basis.

The purpose of the design basis is to document principles that will be applied during the development of the detailed design, and specific design criteria that will be applied throughout the design.

The design basis is usually an output of the planning and preliminary design phase of a project.

The design basis shall be revised during the development of the project to record changes required to the design basis as a result of additional knowledge of the project requirements as the detailed design is developed.

The design basis shall be revised at the completion of the project to reflect the as-built design.

The design basis shall define, at a minimum, the following:

- (a) A description of the project covered by the design basis.
- (b) Statutory legislation and industry codes and Standards applicable to the pipeline and its facilities.
- (c) Specific physical criteria to be used in the design including, at a minimum, the following:
 - (i) The design capacity of the pipeline and of each associated STATION and PIPELINE ASSEMBLY, and where applicable the pressure and temperature conditions at which this applies, and including initial and final capacity where this is significant to the design.
 - (ii) Design life of PIPELINE SYSTEM and design lives of subsystems as applicable.
 - (iii) DESIGN PRESSURE(S), internal and external.
 - (iv) Design temperature(s).
 - (v) Corrosion allowance, internal and external.
 - (vi) Fluids to be carried.
 - (vii) Where required, the maximum fluid property excursion and the duration of any excursion beyond which the fluid shall be excluded from the pipeline.

- (viii) Damage resistance requirements including special requirements for HIGH CONSEQUENCE AREAS.
- (ix) Pipeline MEASUREMENT LENGTH.
- (d) Materials and applicable materials standards.
- (e) The methods by which conformity with PRESSURE STRENGTH, ductility, fracture toughness, weldability, temperature rating and design life specified by the engineering design for the materials will be demonstrated.
- (f) Minimum design and installation criteria for the pipeline, PIPELINE ASSEMBLIES and STATIONS.
- (g) Design requirements for internal inspection tools, including bend radius, internal pipe diameter and SCRAPER TRAP dimensions and design criteria.
- (h) Specific process and maintenance criteria to be used in the design including, at a minimum, the following:
 - (i) Operating and maintenance philosophy.
 - (ii) Pressure control philosophy.
 - (iii) The basis for fracture control design, including gas composition.
 - (iv) Performance requirements for pipeline depressurization, repressurization, and isolation valve bypass.
 - (v) Pipeline pressure/flow regime established by commercial objectives for the PIPELINE SYSTEM.
 - (vi) Isolation principles.
 - (vii) Limiting conditions.
 - (viii) Corrosion mitigation methods.
- (i) Design principles established as the basis of detailed design.
- (j) Design principles for pressure testing.
- (k) The location of pipeline facilities and their functionality.
- (l) Communications and control principles.
- (m) Inspection and testing principles.
- (n) System reliability principles.

4.2.2 Maximum velocity

The design shall establish the presence in the fluid of any contaminants that could reduce the pipe wall thickness during the pipeline design life through erosion or erosion-corrosion. Where erosion or erosion-corrosion mechanisms exist and where these mechanisms can be controlled by limiting the maximum velocity in the PIPELINE SYSTEM, the maximum velocity in the MAINLINE PIPE and in PIPING within PIPELINE ASSEMBLIES and STATIONS shall be determined and documented in the design basis.

NOTES:

- 1 Transmission pipelines (and the associated facilities) usually transport clean fluids that can be transported at any practical velocity without causing any reduction of wall thickness as a result of wear.
- 2 API RP 14E is one experience based method of determining limiting velocity for control of erosion in piping systems containing solids and liquids. PD 8010.1 contains information that is more specific to clean fluid transmission pipelines.
- 3 Where erosion-corrosion mechanisms exist, specific designs should be developed.

- 4 The recommendations of API RP 14E only apply to steel pipe. Where other materials are adopted the maximum velocity should be established based on the material's wear characteristics.
- 5 High velocities in gas service may promote corrosion from gases containing CO₂.

4.2.3 Design for in-line inspection

New pipelines or modifications to existing pipelines should be designed so that nothing in the design will restrict the future loading, passage and retrieval of in-line inspection tools.

4.3 PRESSURES

4.3.1 Pressure design

4.3.1.1 Internal pressure

The internal DESIGN PRESSURE of any COMPONENT or section of a pipeline shall be not less than the highest internal pressure to which that COMPONENT or section will be subjected, except during low flow conditions (see Clause 4.3.2.1 for limits) or transient conditions (see Clause 4.3.2.2 for limits).

Where the hydraulic gradient is used as the basis of establishing the internal DESIGN PRESSURE at any location the method of detecting and controlling the internal pressure at any location within the design limit shall be documented in the design basis.

4.3.1.2 External pressure

The pipeline shall be designed to accommodate any external hydrostatic pressure.

NOTE: Clause 5.7 covers design to resist non-hydrostatic external loads such as soil pressure.

4.3.2 Hydraulic design

4.3.2.1 Steady state conditions

Pipeline design shall include a hydraulic design to establish the steady state and dynamic performance of the pipeline at design and other credible operating conditions that could impact on the internal pressure of the pipeline at any location.

The hydraulic design shall include analysis of the pressure added by fluid density at low points along the pipeline by comparing the hydraulic gradient line and the ground elevation at any location.

For liquid pipelines, the hydraulic gradient line may be used to justify reduced wall thickness as the operating pressure is reduced along the pipeline by friction loss, provided that downstream shut-in or flow restrictions cannot result in operating pressure exceeding DESIGN PRESSURE.

For gas pipelines, the analysis shall be undertaken for a credible minimum throughput and an inlet pressure equal to the DESIGN PRESSURE. The minimum design flow shall be defined in the design basis.

NOTES:

- 1 The minimum credible flow will depend on the proposed operating conditions for each pipeline.
- 2 Zero flow conditions (e.g. for a storage pipeline), or flow reversal scenarios (for bi-directional pipelines) may need to be considered.
- 3 Conditions arising from control failure or operational error (e.g. a non-storage pipeline fully packed with inlet at DESIGN PRESSURE and zero flow) are more appropriately considered through the SAFETY MANAGEMENT STUDY and/or HAZOP and do not need to be considered in the hydraulic analysis unless required by the SAFETY MANAGEMENT STUDY.

Where, due to static head, the pipe pressure at any location is calculated to exceed the DESIGN PRESSURE but will be $\leq 101\%$ of the DESIGN PRESSURE, for conditions of minimum design flow and inlet pressure equal to DESIGN PRESSURE, then the wall thickness is not required to exceed the pressure design thickness t_p . Where predicted pressure exceeds 101% of DESIGN PRESSURE, the DESIGN PRESSURE shall be increased locally by increasing pipe wall thickness, steel grade or design factor (provided that the original design factor is less than 0.8). Pressure test design shall recognize the locally increased DESIGN PRESSURE.

4.3.2.2 Transient conditions

Transient pressure is the over pressure that is associated with an unsteady flow situation when flow changes from one steady-state situation to another steady-state situation. The transient pressure at any point in the pipeline shall not exceed 110% of the DESIGN PRESSURE.

For a pipeline transporting liquids (including HVPL, two phase and dense phase fluids), a transient hydraulic analysis shall be undertaken to confirm conformity with the requirements of this Clause under all credible operating scenarios.

For a pipeline transporting gas, an analysis shall be made of its control systems to determine whether there are fast acting events that could cause transient pressures. Control systems to be analysed include shutdown and pressure control systems that may exist downstream of the point of interconnection, e.g. customer controls. Where this analysis suggests that the transient pressure limit may be exceeded, a transient hydraulic analysis shall be undertaken.

NOTES:

- 1 A transient event is one with a duration typically measured in seconds for liquids and, depending on the size of the pipeline, seconds, minutes or perhaps a few hours for gases.
- 2 Transient pressure limits for STATIONS are dictated by the STATION PIPING design codes and may differ from the above limits for pipelines.

4.3.3 Maximum allowable operating pressure (MAOP)

The MAOP of a new PIPELINE SYSTEM shall be determined after it has been constructed and tested in accordance with this Standard and AS/NZS 2885.5. The MAOP shall be APPROVED before the PIPELINE SYSTEM is placed in operation.

The MAOP shall be not more than the lesser of the following:

- (a) The DESIGN PRESSURE (P_D).
- (b) The pressure limit (P_L) derived from the measured STRENGTH TEST pressure (P_M) using Equation 4.3.3(1)—

$$P_L = \frac{P_M}{F_{TPE}} \quad \dots 4.3.3(1)$$

The equivalent test pressure factor F_{TPE} shall be calculated from the following formula in Equation 4.3.3(2):

$$F_{TPE} = \frac{F_{TP} (t_N - H)}{(t_N - G - H)} \quad \dots 4.3.3(2)$$

NOTE: For the purpose of this equation, G need include only allowances that are consumed after pressure testing.

F_{TP} shall be 1.25. A value of 1.1 may be used in a TELESOPED PIPELINE for all except the weakest section.

NOTE: The lower value for a TELESOPED PIPELINE is consistent with the lower design factor permitted by Table 5.2.4.

The equivalent test pressure factor F_{TPE} shall be calculated for MAINLINE PIPE. Where a pipeline contains pipes of various thickness and/or steel grades F_{TPE} shall be calculated for the pipe that has the weakest combination of strength and thickness.

NOTE: F_{TPE} is not required to be calculated for PIPELINE ASSEMBLIES.

4.3.4 Minimum strength test pressure

The minimum STRENGTH TEST pressure (P_{TMIN}) of the MAINLINE PIPE shall be calculated from the following formula in Equation 4.3.4:

$$P_{TMIN} = P_D F_{TPE} \quad \dots 4.3.4$$

COMPONENTS should be designed to withstand the pipeline STRENGTH TEST pressure and should be tested with the pipeline.

Where the value of F_{TPE} calculated from Equation 4.3.3(2) would require a STRENGTH TEST pressure that exceeds the pressure test strength of a COMPONENT such as a flanged valve, the STRENGTH TEST for a new pipeline shall be completed in accordance with this Standard and AS/NZS 2885.5 before the COMPONENT is attached to the pipeline.

All COMPONENTS not included in the STRENGTH TEST shall be pressure tested to a STRENGTH TEST pressure of not less than 1.5 times the DESIGN PRESSURE of the pipeline before installation.

4.4 DESIGN TEMPERATURES

Design temperatures and their associated DESIGN PRESSURES shall be determined. The low temperature limit for continuous operation at a HOOP STRESS in excess of 85 MPa shall be established and documented.

NOTE: Most PIPELINE SYSTEMS will have multiple design temperatures appropriate to different parts of the system including possibly different segments of MAINLINE PIPE.

The following conditions shall be reviewed and documented, and, where necessary, a design temperature selected for that aspect of the PIPELINE SYSTEMS:

- (a) Fracture control.
- (b) Material strength.
- (c) Coating performance.
- (d) STRESS CORROSION CRACKING.
- (e) Fluid/phase changes.
- (f) Stress analysis.
- (g) Temperature excursions during depressurization, repressurization and COMMISSIONING activities.
- (h) Temperature excursions associated with operating conditions, (e.g. temporary pressure reduction by throttling using a MLV bypass valve).

NOTE: Clause 4.5 provides requirements for low temperature excursions but in some cases it may also be necessary to consider possible high temperature excursions.

Where necessary, the design shall accommodate the effect of temperature differential during installation, operation and maintenance and the temperature differential shall be specified.

Where there is a large temperature differential between the pipe contents and the external environment (such as downstream of a depressurization valve), the mid-wall temperature should be used for design.

For a pipeline wholly or partially above-ground the design shall accommodate variations in ambient temperature.

Where a pipeline is above-ground, the temperature resulting from the combined effect of ambient temperature and solar radiation shall be specified for both operating and shut-in conditions.

Special consideration may be required where the temperature of the fluid is changed by pressure reduction, compression or phase change.

4.5 LOW TEMPERATURE EXCURSIONS

A PIPELINE SYSTEM design shall define safe combinations of high stress and low temperature. These limits and their basis shall be documented in the design basis. Where operation within these limits relies on operating procedures the procedures shall be included in the PIPELINE MANAGEMENT SYSTEM.

Excursions below the temperature for brittle fracture control (TBFC), shall not be coincident with operating HOOP STRESS greater than 85 MPa. See also Clause 5.3.5.

Low temperature conditions are associated with unusual operations, particularly in gas pipelines including—

- (a) initial fill and pressurization;
- (b) depressurization;
- (c) purging prior to repressurization;
- (d) repressurization;
- (e) throttling through a valve designed for the purpose of temporarily reducing the pressure in a downstream pipe (required, for example, for a pipe that has experienced damage); and
- (f) throttling through a valve designed for the purpose of releasing gas to atmosphere.

The design shall address each operating condition that has the potential to cause temperatures lower than the applicable minimum design temperature for continuous operation. The design shall document the controls incorporated in the design, and any operational procedures required to conform with the high stress-low temperature limits.

NOTES:

- 1 For guidance on the effect of temperature on fracture control, see Appendix D.
- 2 Care is required when using commercial software in predicting minimum metal temperatures expected to arise from pipeline operations, including pipeline depressurization. EPCRC research reports Project RP3-12 Pressure and Thermal Transients provide background information to assist analysis of the problem. This report includes pressure-temperature data from pipeline blowdowns that may be used to calibrate software. When accurate design minimum temperatures are required for other problems, designers should consider either advanced analysis (such as CFD) or conducting experiments on similar or simulated plant to provide valid data for the design.
- 3 The bolts used in flanged valves intended to provide high pressure drops should be assessed to determine whether they are suitable for the low temperatures that may arise, e.g. mainline valve bypass valves. Downstream equipment should also be considered.
- 4 Since line pipe is usually the most highly stressed pressure-containing item exposed to low-temperature excursions, the design should establish the transition temperature of line pipe intended for operation at low ambient temperatures and pressures higher than 10.2 MPa.
- 5 At operating pressures around 15 MPa or more, it is critical that low temperatures created during blowdown and repressurization activities be addressed in the design of both MAINLINE PIPE and the PIPING of surface facilities used during these activities.

4.6 DESIGN LIFE

The design life for a PIPELINE SYSTEM shall be determined and documented. Design lives include the following:

- (a) *System design life* A design life shall be nominated for the PIPELINE SYSTEM, and shall be used for design. The system design life shall be APPROVED.

NOTE: The system design life should be set at a value that is meaningful in terms of the ability of the designers to reasonably foresee the impact of time dependent parameters.

- (b) *Engineering design lives* For each metallic, non-metallic, electrical and electronic item (or sub-system) that may be expected to have a service life that is different from the system design life, an engineering design life should be nominated, and applied when specifying each sub-system or item. The individual engineering design lives should be considered when preparing operating and maintenance plans and SAFETY MANAGEMENT STUDIES.

Where an item cannot meet the nominated engineering design life, the reduced life shall be nominated in the project records, and the plans and procedures dependent on the life shall be reviewed. Items that cannot be replaced without shutting down the PIPELINE SYSTEM should be designed for the system design life.

NOTE: Normally, replaceable items (e.g. seals and gaskets) that are required to have essentially an indefinite life if left in position and untouched should be selected from materials whose properties will not diminish during that service. Replaceable items may have a lesser design life, reflecting the ease with which it can be maintained, without impacting on the safe operation of the pipeline.

4.7 ROUTE

4.7.1 General

The route of a pipeline shall be selected having regard to public safety, pipeline integrity, environmental impact, and the consequences of escape of fluid.

A pipeline shall be designed in accordance with the requirements of this Standard—

- (a) for the land use existing at the time of design; and
- (b) for the future land use that can be reasonably determined by research of public records and consultation with land planning agencies in the jurisdiction through which the pipeline is proposed.

The pipeline route shall be allocated LOCATION CLASSES in accordance with AS/NZS 2885.6.

The land use and LOCATION CLASSES for which the pipeline is designed shall be documented and APPROVED.

4.7.2 Land use investigation

A detailed investigation of the route and the environment in which the pipeline is to be constructed shall be made. The appropriate authorities shall be contacted to obtain details of any known or expected future development along the route, the location of underground obstructions, services and structures and all other pertinent data.

NOTE: Understanding potential future land use is critical to design of a pipeline for a long life. Investigation of land use should be informed by the APGA publication, 'Guideline for investigations of land use around pipelines to guide initial location classification under AS 2885'. In particular, any land use study in the vicinity of an urban area should be done by or take advice from land use planning professionals.

4.7.3 Route selection

The following items should be considered as part of pipeline route selection:

- (a) Public safety.
- (b) Proximity to populated areas, including the likelihood of external interference and the consequences of escape of fluid.
- (c) Present land use and any expected LAND USE CHANGE.
- (d) Easement width.
- (e) Future access to pipelines and pipeline facilities, e.g. in a particular route option, the possibility of future developments by others limiting access to the pipeline.
- (f) Special concerns associated with the use of common infrastructure corridors.
- (g) Proximity of existing cathodic protection ground beds.
- (h) Proximity of sources of stray direct current sources.
- (i) Proximity of other underground services.
- (j) Proximity of high voltage transmission lines.
- (k) Environmental impact.
- (l) Cultural heritage.
- (m) Prevailing winds.
- (n) Topography.
- (o) Geology.
- (p) Soil types, e.g. for effect of soil properties on corrosion and cathodic protection (CP).
- (q) Possible inundation.
- (r) Constructability.
- (s) Ground stability, including other land uses which may create instability, e.g. mine subsidence, land development/excavation.
- (t) Minimization of bends and placement of bends at appropriate locations.

NOTE: Changes of direction increase the difficulty third parties experience in identifying pipeline location and thereby increase risk of third party damage. Bends should wherever possible be co-located with other features such as fences or roads and should avoid the middle of farm paddocks where marker signs often cannot be relied upon.

4.7.4 Route identification and communication

The pipeline route and the location of the pipeline in the route shall be identified and documented. The following should be considered in developing an appropriate strategy for communicating the location of the pipeline:

- (a) Identification for public information.
- (b) Identification for services information.
- (c) Identification for emergency services.
- (d) Identification on maps.
- (e) Identification on land titles.
- (f) Identification using visible markers conforming with Clause 4.10, as an aid to protection from external interference damage.
- (g) As-built location of the pipeline relative to permanent external references.

4.8 ISOLATION

4.8.1 General

Equipment shall be provided for the isolation of segments of the PIPELINE SYSTEM for maintenance purposes or in the event of a loss of containment within the segment.

Equipment shall be provided to isolate a PIPELINE SYSTEM or segment of a pipeline from sources of pressure higher than the MAOP of the PIPELINE SYSTEM or segment.

Where isolation is used to separate parts of a PIPELINE SYSTEM with a different MAOP, the minimum requirement for separation by isolation shall be two isolation elements, two valves or one valve and a blind. A method of venting the space between the two isolation elements shall be provided.

Where flow is required between sections with a different MAOP pressure shall be controlled in accordance with Clause 7.2.2.

Equipment shall be provided for evacuation of the fluid from a pipeline where required for maintenance and for repairs after a loss of containment.

This isolation and depressurization equipment shall be defined in an isolation plan.

4.8.2 Isolation plan

The isolation plan shall define the operations and maintenance functions and the loss of containment events for which isolation and depressurization are required.

The isolation plan shall be APPROVED prior to COMMISSIONING of the pipeline or segment of the pipeline.

The loss of containment events to be addressed in the isolation plan shall include—

- (a) in LOCATION CLASSES T1 and T2, an unplanned loss of containment with ignition; and
- (b) the environmental consequence of the loss of containment.

The isolation plan shall define the facilities provided to perform the functions required and shall include, at a minimum, the following items:

- (i) The locations of, and facilities for isolation of a pipeline from a source of pressure higher than the MAOP.
- (ii) The MAINLINE PIPE segments to be isolated, including the isolation valve locations and controls.
- (iii) The STATIONS and PIPELINE ASSEMBLIES to be isolated from MAINLINE PIPE, including isolation valves and controls.
- (iv) The segments of the pipeline for which depressurizing facilities are required, including length, stored volume, depressurization time, repressurization time, plans for depressurizing and repressurizing each section and the implications of those factors for acoustically or flow induced vibration.
- (v) The isolation requirements for operation and maintenance of separable segments within PIPELINE ASSEMBLIES and STATIONS.
- (vi) The response time to effect isolation of MAINLINE PIPE, PIPELINE ASSEMBLY and STATION segments in all LOCATION CLASSES in the event of a loss of containment, and, for a liquid pipeline, likely release volume until isolation is effected.
- (vii) For branches from the main pipeline, the consequence of a loss of containment in the branch on the supply to other locations along the main pipeline.

- (viii) The isolation plan for pipelines carrying liquid products shall include automatic leak detection systems.

NOTE: The practicability of automatic leak detection on other pipelines should be considered. Where automatic failure detection systems are installed, the practicability of automatic shutdown should be considered.

- (ix) A plan for isolating and depressurizing STATIONS.
(x) Short lengths of higher LOCATION CLASS within lower LOCATION CLASS.

4.8.3 Isolation valves

Valves shall be provided to isolate the PIPELINE SYSTEM in segments in accordance with the isolation plan. The location and the spacing of valves shall be APPROVED.

The factors listed below shall be taken into account and documented in determining the location of valves.

NOTE: For guidance for the spacing of mainline valves, see Table 4.8.3.

- (a) The consequences of fluid release.
- (b) The security of supply required.
- (c) The response time to events.
- (d) The access to isolation points.
- (e) The ability to detect events which may require isolation.
- (f) The volume between isolation points.
- (g) The pressure.
- (h) Operating and maintenance procedures.
- (i) Capability of personnel to implement the isolation plan, particularly in emergency.

Selection of spacing between isolation valves shall also take into account the design of blowdown and bypass piping and the time required for blowdown and repressurization of each segment of the pipeline, and the implications for acoustically or flow induced vibration in the blowdown or bypass piping or elsewhere.

Isolation valves shall be installed so that, in the event of a leak, the valves can be expeditiously operated. Designers shall determine the need for remote operation of individual mainline valves to limit the effect of any leak that may affect public safety and the environment. Where such a capability is provided, the individual mainline valves shall be equipped with a closing mechanism that can be activated from a control centre.

TABLE 4.8.3
GUIDE FOR THE SPACING OF MAINLINE VALVES

Location class	Recommended maximum spacing of valves, km	
	Gas and HVPL	Liquid petroleum
R1	As required	As required
R2	30	As required
T1 and T2	15	15

NOTE: A short length of higher LOCATION CLASS in a pipeline that is of predominantly lower LOCATION CLASS does not necessarily require conformity with this Table.

For liquid pipelines, the isolation plan shall address the requirement for isolation where they cross a river or public water supply reserve. Where required by the design and environmental impact considerations the valves shall be located to minimize the impact of

spilled liquid in the river or reservoir. The SAFETY MANAGEMENT STUDY shall review the residual risk associated with water crossings where valves are not included in the design. Typical valve requirements are as follows:

- (i) On an upstream section..... a mainline valve.
- (ii) On a downstream section a mainline valve or a non-return valve.

The valve locations may not necessarily be immediately adjacent to the river or water supply reserve.

NOTE: Similar assessment of isolation may be required where there is potential for a liquid spill to enter a river even if the pipeline does not cross it.

4.9 PROVISIONS FOR HIGH CONSEQUENCE AREAS

4.9.1 General

Locations may exist along a pipeline route where it is necessary to limit the consequence of pipeline failure on the community or the environment. For gas pipelines, the consequence is likely to result from ignition of the fluid released, while for liquid pipelines the environmental consequence from an unignited spill may be significant in addition to the consequence of ignition.

This Clause sets out the minimum requirements for HIGH CONSEQUENCE AREAS.

4.9.2 No rupture

In *Residential (T1)*, *High Density (T2)*, *Industrial (I)*, *Sensitive (S)* and *Environmental (E)* LOCATION CLASSES and in *Heavy Industrial (HI)* LOCATION CLASS (where pipeline failure would create potential for consequence escalation), and in *Crowd (C)* LOCATION CLASS (where determined by the SAFETY MANAGEMENT STUDY) the pipeline shall be designed such that RUPTURE is not a credible failure mode. For the purpose of this Standard, this shall be achieved by either one of the following:

- (a) The HOOP STRESS at MAOP shall not exceed 30% of SMYS.
- (b) The HOOP STRESS at MAOP shall be selected such that the CRITICAL DEFECT LENGTH is not less than 150% of the axial length of the largest hole produced by the THREATS identified in that location.

NOTES:

- 1 Clause 5.5.4 defines the method to be used in calculating the CRITICAL DEFECT LENGTH.
- 2 Where the identified THREAT is an excavator, Table E5, Appendix E provides a basis for estimating the hole length based on machine mass and tooth type.
- 3 API 579 and BS 7910 provide methods for converting actual DEFECTS into the equivalent through wall flaw.

4.9.3 Maximum energy release rate

In all locations, the design shall assess means of limiting the maximum energy release rate through a pipeline segment in the event of a loss of containment in that segment resulting from the largest equivalent DEFECT produced by the THREATS identified in that location.

In HIGH CONSEQUENCE AREAS where loss of containment can result in jet fires or vapour cloud fires the maximum energy release rate shall be determined and APPROVED.

For pipelines carrying flammable gases, HVPLs and other liquids with a flash point less than 20°C, the maximum energy release rate shall not exceed 10 GJ.s⁻¹ in *Residential and Industrial* locations or 1 GJ.s⁻¹ in *High Density* and *Sensitive* locations. The energy release rate shall be calculated for quasi-steady state conditions that exist 30 s after the pipeline puncture.

NOTES:

- 1 AS/NZS 2885.6 provides guidance on the methods for calculating energy release rate.
- 2 The limit of 10 GJ/s and 1 GJ/s were set following a study in 2001 which concluded that an incident resulting in energy release of these magnitudes in areas of worst-case population density could result in up to 100 fatalities, which at the time was considered to be tolerable if the frequency is 10^{-7} per annum or less. The design should consider the appropriateness of the energy release limit given the circumstances of the pipeline and the surrounding population, having regard to the consequence should a release of the maximum size occur.

For pipelines carrying other combustible fluids, the maximum allowable energy release rate shall be determined by the SAFETY MANAGEMENT STUDY specified in AS/NZS 2885.6.

NOTE: Operating pressure limit and flow restriction devices are two effective methods of limiting the maximum energy release rate. Designs that limit the maximum hole size may also be used to effectively control the maximum energy release rate.

4.10 PIPELINE MARKING

4.10.1 General

Signs shall be installed along the route so that the pipeline can be properly located and identified.

Signs should be located so that from any location along the PIPELINE CORRIDOR, a sign is visible in either direction from the observer.

NOTE: New technology for traceability or detection of buried pipe may also be considered (e.g. tracer wires, especially for non-metallic pipe) but not as a substitute for the requirements of this Standard for marker signs

In LOCATION CLASSES T1, T2, S, E, CIC, I, HI and C signs shall be intervisible.

Table 4.10.1 provides guidance on sign spacing in each LOCATION CLASS.

TABLE 4.10.1
SIGN SPACING

Location class	Location subclass	Recommended maximum sign spacing m
R1		500 (Note 1)
R2		250 (Note 1)
T1		100
T2		50
	S, C	50
	CIC	Note 2
	I, HI	100

NOTES:

- 1 In land subject to cropping or grazing where these activities mean that the recommended sign spacing is unacceptable to the landowner or cannot be maintained, an acceptable alternative is to place an appropriate sign at fence lines and at every gate giving access to each paddock where the spacing is greater than recommended.
- 2 In common infrastructure corridors the sign spacing should be as required by the LOCATION CLASS, except that where a pipeline is parallel to an overhead power line a sign should be placed adjacent to each power pole or pylon.
- 3 Where land has yet to be developed for the LOCATION CLASS used to govern design, sign spacing for LOCATION CLASS equivalent to the current land use may be applied.

Where the SAFETY MANAGEMENT STUDY demonstrates that adherence to the requirements of this Clause provides no increase in pipeline safety, alternative spacing may be developed.

4.10.2 Sign location

Signs shall be placed at the following locations:

- (a) Both sides of public road crossings.
- (b) Both sides of railway crossings.
- (c) At each property boundary (and at internal fence lines as appropriate).
- (d) Both sides of river crossings.
- (e) Vehicle tracks.
- (f) Each change of direction.
- (g) Utility crossings (buried or above-ground).
- (h) At the landfall of submerged crossings or submarine pipelines, which shall be legible from a distance of, at a minimum, 100 m on the water side of the landfall.
- (i) At all pipeline facilities.
- (j) At other locations where signs marking the location of the pipeline will contribute to pipeline safety by properly identifying its location.

Where a pipeline closely parallels a road, railway, powerline or other linear infrastructure a review shall determine if sign spacing is required to be closer than that recommended in Table 4.10.1.

A single sign shall be sufficient at sites where a number of the above locations coincide, e.g. utilities alongside a road, vehicle tracks.

At ephemeral streams signs should be placed where required to locate the pipeline.

Where signs are used to provide PROCEDURAL PROTECTION, the spacing to provide effective protection shall be established in the external interference protection design in accordance with Clause 5.4.

4.10.3 Sign design

Except as noted and shown in Figure 4.10.3, marker signs shall conform with the requirements of a 'DANGER' sign in accordance with AS 1319. Figure 4.10.3 shows a typical marker sign for a cross country pipeline. The sign dimensions and shape may be modified to suit the constraints of the location.

Marker signs shall—

- (a) indicate that a pipeline is buried within the vicinity of the marker post, its description, the name of the operator, and a telephone number for contact for assistance and in emergencies;
- (b) indicate that excavating near the pipeline is dangerous; and
- (c) include a direction to contact the pipeline operator before beginning excavation near the pipeline.

Signs may optionally include additional telephone or website contact information, such as the number for the ONE-CALL SERVICE.

NOTES:

- 1 A unique identifying number on each sign is recommended as a means for members of the public to report an incident location to the call center.
- 2 For guidance on the effectiveness of PROCEDURAL MEASURES, including signs, in contributing to pipeline awareness, refer to AS/NZS 2885.6.



NOTES:

- 1 For further information, refer to AS 1319. Strict conformity with AS 1319 would require that the 'DO NOT DIG' and contact information be separate from the 'DANGER' sign but this Standard accepts the composite sign.
- 2 The word OIL is to be used when the fluid is a liquid hydrocarbon or a mixture of liquid hydrocarbons.
- 3 The word GAS is to be used when the fluid is gas or a dual-phase mixture of gas and liquid.
- 4 The word LP GAS is to be used when the fluid is HVPL.

DIMENSIONS IN MILLIMETRES

FIGURE 4.10.3 TYPICAL PIPELINE MARKER

SECTION 5 PIPELINE DESIGN

5.1 BASIS OF SECTION

This Section sets out requirements for the design of the MAINLINE PIPE and PIPELINE ASSEMBLIES. STATIONS, including compressor and pump stations, meter stations and regulator stations are covered in Section 6.

The pipeline design requirements shall include, but are not limited to the following:

- (a) The wall thickness shall be no less than that required for pressure containment determined from the DESIGN PRESSURE and a design factor.
- (b) Additional wall thickness may be required to provide protection against damage by external interference and for resistance to other load conditions and failure mechanisms or to provide allowance for loss of wall thickness due to corrosion, erosion or other causes.
- (c) The pipeline shall be protected against corrosion and external interference.
- (d) The pipeline shall be designed to be pressure-tested to verify that it is leak tight and has the required strength.

A pipeline may be TELESKOPED where the DESIGN PRESSURE decreases progressively along the pipeline and a suitable pressure control is provided.

The pipeline should be designed so that its integrity can be monitored by the use of internal inspection devices without taking the pipeline out of service.

NOTES:

- 1 This Standard does not nominate design requirements for fibreglass pipe, or pipe made from other materials. Fibreglass material in particular has specific design methods that differ substantially from those used for steel.
- 2 See Appendix S for information on properties, design methods and performance of fibreglass materials which can be used as guidance for these materials.
- 3 Refer to ISO 14692-3 for guidance on design procedures for this material.

5.2 WALL THICKNESS

5.2.1 General

At any location along the pipeline the wall thickness shall conform with the requirements of this Clause.

5.2.2 Nominal wall thickness (t_N)

The NOMINAL WALL THICKNESS (t_N) is—

- (a) the thickness nominated on the pipe purchase order (design stage); or
- (b) the thickness nominated on the manufacturer's material certificates (for operating pipelines).

The NOMINAL WALL THICKNESS shall be not less than the greatest of the following:

- (i) The required wall thickness plus any allowances plus any manufacturing tolerances using Equation 5.2.2:

$$t_N \geq t_w + G + H \quad \dots 5.2.2$$

NOTE: Manufacturing tolerance (H) is zero except where the pipe is seamless and a tolerance is required by the design.

- (ii) The thickness necessary for constructability and operability of the pipeline.



- (iii) The thickness necessary for initial pressure testing plus manufacturing tolerance where necessary.

NOTE: Where the NOMINAL THICKNESS is determined by calculating a value and then adopting the next larger standard thickness the additional thickness can be considered as a provision for constructability, i.e. supply of readily available pipe.

5.2.3 Required wall thickness (t_w)

The REQUIRED WALL THICKNESS (t_w) shall be the greatest of the following:

- (a) The thickness required for pressure containment (t_p).
- (b) The thickness required for resistance to penetration by the design THREAT, if this is used as a method of providing external interference protection in accordance with Clause 5.4. In T1 and T2 LOCATION CLASSES, where thickness is the method chosen to provide penetration resistance, the thickness necessary to provide a minimum level of penetration resistance.
- (c) The thickness required to provide the minimum CRITICAL DEFECT LENGTH needed to prevent RUPTURE in LOCATION CLASSES T1 and T2 in accordance with Clause 4.9.2, or elsewhere if required by the design basis.
- (d) The thickness required to meet the stress and strain criteria.
- (e) The thickness required for fracture control.
- (f) The thickness required for special construction (see Clause 5.8).
- (g) The thickness required to meet the stress criteria in Clause 5.7.3.2 for pipelines crossing railways and roads.
- (h) The thickness required to achieve a design stress level selected for its contribution to SCC mitigation at locations where the SCC likelihood is increased.
- (i) The thickness required to achieve adequate fatigue life where this is determined to be relevant to the operating life of the pipeline, including particularly PIPELINE ASSEMBLIES subject to conditions that favour vibration.
- (j) The thickness required to prevent collapse from external pressure.

NOTE: Where calculations in this Standard include wall thickness as independent variable, the value to be used is the required wall thickness (t_w) unless specified otherwise.

5.2.4 Wall thickness for design internal pressure (t_p)

The WALL THICKNESS FOR DESIGN INTERNAL PRESSURE (t_p) of pipes and COMPONENTS made from pipe shall be the thickness determined by Equation 5.2.4.

$$t_p = \frac{P_D D}{2 F_D \sigma_Y} \quad \dots 5.2.4$$

In Equation 5.2.4, σ_Y shall be the SPECIFIED MINIMUM YIELD STRENGTH taken from the NOMINATED STANDARD for the material used for the pipe.

The design factor (F_D) for pressure design of pipe shall be not more than the values nominated in Table 5.2.4.

TABLE 5.2.4
MAXIMUM VALUE OF DESIGN FACTOR

Location	Maximum value of F_D
MAINLINE PIPE	0.8 (see Note 2)
PIPELINE ASSEMBLIES	0.67
Any section of a TELESKOPED pipeline for which the MAOP is based on a test pressure factor of less than 1.25	0.60
Pipelines on bridges or other structures	0.67

NOTES:

- 1 Additional conservatism provided by the mandated design factor in Table 5.2.4 is considered an appropriate method of providing a specific safety allowance for loads that may not be readily identified and calculated, and which as a result of construction methods or operating conditions, may significantly exceed the design load.
- 2 Design of a pipeline with design factor greater than 0.72 involves a number of complexities and risks that are discussed in Appendix B. In making a decision to adopt a design factor above 0.72 the designer should be fully aware of these issues and should assess whether they may reduce or negate the benefits of the high design factor.

5.2.5 Wall thickness for design internal pressure of bends

Cold field bends may be formed from straight pipe for which the wall thickness is t_p calculated from Equation 5.2.4.

For bends formed by other methods, including particularly induction bending, there may be a reduction in wall thickness at the extrados and an increase in thickness at the intrados. The thickness of the bend is acceptable for containment of internal pressure if, after bending, it is not less than the value determined from the following Equations 5.2.5(1) to 5.2.5(3):

$$t_p = \frac{P_D D F_p}{2 F_D \sigma_Y} \quad \dots 5.2.5(1)$$

At the extrados of the bend:

$$F_p = \frac{2R + r_M}{2(R + r_M)} \quad \dots 5.2.5(2)$$

At the intrados of the bend:

$$F_p = \frac{2R - r_M}{2(R - r_M)} \quad \dots 5.2.5(3)$$

NOTE: Equation 5.2.5(1) may calculate thicknesses that differ from calculations in either of the NOMINATED STANDARDS for induction bends. The designer may decide to adopt thicknesses that are greater than calculated from Equation 5.2.5(1).

The variation of wall thickness from the extrados to the intrados and along the length of the bend shall be gradual. The minimum pressure factor (F_p) at the end tangents shall have a value not less than unity uniformly around the pipe section. At the bend centreline the pressure factor F_p has a minimum value of 1.0.

The value of the design factor for pressure containment (F_D) shall conform with the limitations of Clause 5.2.4.

NOTE: For pipelines of high design factor it is recommended that induction bends have a lower design factor than straight MAINLINE PIPE. Where induction bends are formed from pipe of design factor above 0.72, the pressure test may need to be a Type 2 or Type 3 STRENGTH TEST and detailed material property data for the bends will be required, which may be impractical.

5.2.6 Wall thickness design for external pressure

The permitted external pressure (P_{EXT}) shall be determined from the minimum solution to Equation 5.2.6(1):

$$P_{EXT}^2 - \left[P_P + \left(1 + \frac{1.5f_o D}{t_W} \right) P_{EL} \right] P_{EXT} + P_{EL} P_P = 0 \quad \dots 5.2.6(1)$$

where

$$P_{EL} = \frac{2E}{(1-\nu^2)} \left(\frac{t_W}{D_M} \right)^3 \quad \dots 5.2.6(2)$$

$$P_P = 2F_D \sigma_Y \left(\frac{t_W}{D_M} \right) \quad \dots 5.2.6(3)$$

$$f_o = \frac{D_{max} - D_{min}}{D} \quad \dots 5.2.6(4)$$

$$D_M = D - t_W \quad \dots 5.2.6(5)$$

In Equation 5.2.6(3), σ_Y shall be the SPECIFIED MINIMUM YIELD STRENGTH taken from the NOMINATED STANDARD for the material used for the pipe.

5.2.7 Allowances (G)

Allowances shall be added to the required wall thickness of pipe to provide for identified factors that may, during construction or over the life of the pipeline result in loss of thickness. Allowance may be made to compensate for a reduction in thickness due to corrosion, erosion, threading, machining and any other necessary additions. The allowance G is the sum of all allowances made to the pipe wall thickness.

The STRENGTH TEST pressure requirements (see Clause 4.3.4) should be considered when determining the total allowance applied to any part of the pipeline.

The allowances shall conform with the following:

- (a) *Corrosion or erosion allowance* Where a pipe or COMPONENT made from pipe is subject to any corrosion or erosion, G shall include an amount equal to the expected loss of wall thickness.

NOTES:

- 1 A corrosion allowance is not required where satisfactory corrosion mitigation methods are employed (see Section 8).
 - 2 Further requirements for corrosion allowance are specified in Clause 8.5.
- (b) *Threading, grooving and machining allowance* Where a pipe or COMPONENT made from pipe is to be threaded, grooved or machined, G shall include an amount equal to the depth that will be removed. Where a tolerance for the depth of cut is not specified, the allowance shall be increased by 0.5 mm.

5.2.8 Pipe manufacturing tolerance (H)

For line pipe manufactured from strip or plate to NOMINATED STANDARDS, such as API Spec 5L, manufacturing tolerance shall not be added to the REQUIRED WALL THICKNESS t_W .

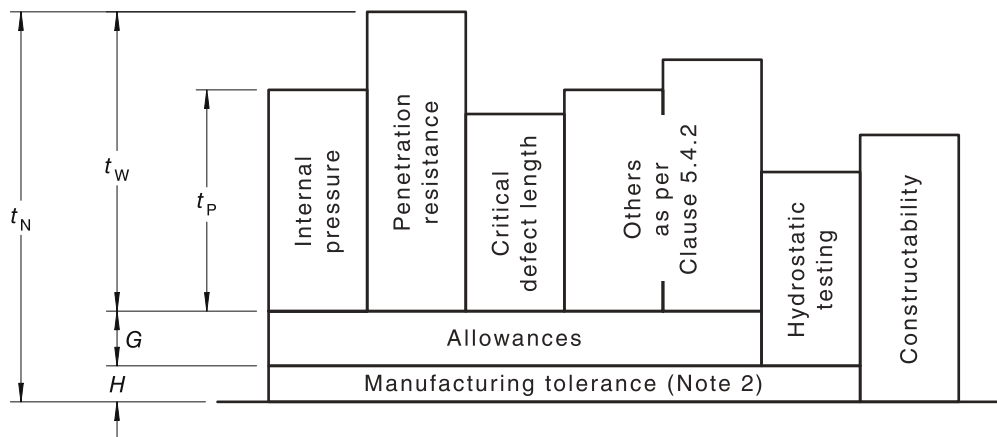
Seamless pipe manufacturing can result in local thinning or minimum thickness along the length of one side while still conforming with specified weight tolerance. Pipe manufactured by the seamless process may require addition of a manufacturing tolerance (H) to the REQUIRED WALL THICKNESS (t_w).

NOTE: This Standard limits the manufacturing tolerance for pipe manufactured for use at design factors above 0.72, see Clause 3.2.2(a).

5.2.9 Wall thickness summary

Figure 5.2.9 shows the relationships between the various factors to be evaluated in determination of wall thickness.

Table 5.2.9 provides further examples using hypothetical numerical values.



- NOTES:
- 1 In this example it happens that the NOMINAL THICKNESS is governed by the thickness required for penetration resistance plus allowances, but any of the other requirements may govern depending on the circumstances of the pipeline.
 - 2 Manufacturing tolerance is zero except where the pipe is seamless and a tolerance is required by the design.

FIGURE 5.2.9 WALL THICKNESS FACTORS