

Australian Standard

SAA SUBMARINE PIPELINE CODE

The following scientific, industrial and governmental organizations and departments were officially represented on the committee entrusted with the preparation of this standard:

Australasian Corrosion Association
Australasian Institute of Mining and Metallurgy
Australian Gas Association
Australian Institute of Energy
Australian Institute for Non-Destructive Testing
Australian Institute of Petroleum
Australian Liquefied Petroleum Gas Association
Australian Petroleum Exploration Association
Australian Pipelines Industry Association
Australian Welding Institute
Australian Welding Research Association
Bureau of Steel Manufacturers of Australia
Department of Industrial Relations, N.S.W.
Department of Minerals and Energy, Victoria
Department of Mines and Energy, S.A.
Department of Mines, Queensland
Department of Mines, W.A.
Energy Authority of New South Wales
Institution of Engineers, Australia
Institute of Petroleum, U.K.
Metal Trades Industry Association of Australia
National Association of Australian State Road Authorities
New South Wales Institute of Technology
Pipelines Authority of South Australia
Railways of Australia Committee
Snowy Mountains Engineering Corporation
The Pipeline Authority

This standard, prepared by Committee ME/38, Gas and Liquid Petroleum Piping Systems, was approved on behalf of the Council of the Standards Association of Australia on 23 January 1981, and was published on 1 August 1981.

Review of Australian Standards. To keep abreast of progress in industry, Australian Standards are subject to periodic review and are kept up to date by the issue of amendments or new editions as necessary. It is important therefore that Standards users ensure that they are in possession of the latest edition, and any amendments thereto.

Full details of all Australian Standards and related publications will be found in the Standards Australia Catalogue of Publications; this information is supplemented each month by the magazine 'The Australian Standard', which subscribing members receive, and which gives details of new publications, new editions and amendments, and of withdrawn Standards.

Suggestions for improvements to Australian Standards, addressed to the head office of Standards Australia, are welcomed. Notification of any inaccuracy or ambiguity found in an Australian Standard should be made without delay in order that the matter may be investigated and appropriate action taken.

This standard was issued in draft form for public review as DR 79059.

Australian Standard

GAS AND LIQUID PETROLEUM SUBMARINE PIPELINES KNOW AS THE SAA SUBMARINE PIPELINE CODE

First published		1976
Second edition		1981

PUBLISHED BY STANDARDS AUSTRALIA
(STANDARDS ASSOCIATION OF AUSTRALIA)
1 THE CRESCENT, HOMEBUSH, NSW 2140

ISBN 0 7262 2206 2



Documents

Document Sharing Hub

PREFACE

This edition of this standard was prepared by the Association's Committee on Gas and Liquid Petroleum Piping Systems.

This edition includes a major revision of Section 8—Corrosion Mitigation, and also includes the changes made in Amendment No 1 which, in the main, incorporated requirements for determining a safe operating pressure for a corroded pipeline. The items which have been technically revised in this edition are listed in the 'Annex' following the Index.

The purpose of this standard is to establish requirements for safe design, construction, inspection, testing, operation, and maintenance of submarine petroleum pipelines constructed from steel pipe. Such requirements are necessary for the protection of the general public, the Operating Authority personnel, and the environment as well as to provide reasonable protection for the pipeline against accidental damage resulting from activities other than those of the Operating Authority.

The standard sets out requirements for good engineering practice based on known experience and on appropriate existing Australian and overseas standards. Close attention has been given to AS 1697, SAA Gas Pipeline Code; AS 2018, SAA Liquid Petroleum Pipeline Code; AS 1978, SAA Code for Field Pressure Testing of Pipelines; API 1104, Standard for Welding Pipe Lines and Related Facilities; USA Minimum Federal Safety Standards for Liquid Pipelines (Part 195, Title 49, Code of Federal Regulations); the USA Department of Transportation—Office of Pipeline Safety Register Volume 35, No 161 Part III—Transporting of Natural Gas by Pipelines; the UK Institute of Petroleum Model Code of Safe Practice, Part 6—Submarine Pipeline Supplement 1971, and other standards. Acknowledgement is made of the assistance provided from these sources.

Although safety is the basic consideration of this standard, other requirements will also control the specifications for any pipeline and these must be considered. The standard is not a design handbook and, although certain sections contain specific

requirements, does not replace the need for appropriate experience and competent engineering judgement. Fundamental engineering principles should be followed. Provided that there is no specific prohibition, materials and procedures not included in this standard may be qualified for use as described in the applicable sections.

Environmental conditions are of importance in the design of submarine pipelines and must be considered fully in the design stage. In view of the wide range of conditions likely to be encountered in the submarine environment and the wide variations in available information concerning it, specific requirements cannot be incorporated in this standard; however recommendations for a route survey together with meteorological and hydrographic investigations are given in Appendix E. Whilst each recommendation requires consideration, the extent of the investigations necessary in a particular location will depend on the amount and reliability of the environmental information already available.

Attention is drawn to the requirements of both Commonwealth and State legislation, and to guides and codes issued by statutory authorities and local government bodies which may affect pipelines; this standard should be regarded as complementary to such requirements where these are applicable. Notes on Statutory Requirements are included as Appendix D.

This standard does not deal with, and is not intended to supplant, any matter of personnel safety with respect to work practices or such matters as the safe use of equipment and machinery in construction which may be required by law or which are current industrial practice.

This standard makes reference to a wide range of materials and components listed in standards originating from Australia, Great Britain, and the United States of America. Many of these standards require the reporting of results of tests. Such reporting should be in the form of approved test certificates. Listings of relevant standards are given in Appendices A and B.

© Copyright — STANDARDS AUSTRALIA

Users of Standards are reminded that copyright subsists in all Standards Australia publications and software. Except where the Copyright Act allows and except where provided for below no publications or software produced by Standards Australia may be reproduced, stored in a retrieval system in any form or transmitted by any means without prior permission in writing from Standards Australia. Permission may be conditional on an appropriate royalty payment. Requests for permission and information on commercial software royalties should be directed to the head office of Standards Australia.

Standards Australia will permit up to 10 percent of the technical content pages of a Standard to be copied for use exclusively in-house by purchasers of the Standard without payment of a royalty or advice to Standards Australia.

Standards Australia will also permit the inclusion of its copyright material in computer software programs for no royalty payment provided such programs are used exclusively in-house by the creators of the programs.

Care should be taken to ensure that material used is from the current edition of the Standard and that it is updated whenever the Standard is amended or revised. The number and date of the Standard should therefore be clearly identified.

The use of material in print form or in computer software programs to be used commercially, with or without payment, or in commercial contracts is subject to the payment of a royalty. This policy may be varied by Standards Australia at any time.

CONTENTS

	Page		Page
SECTION 1. GENERAL REQUIREMENTS		4.13 Inspection and Testing of	
1.1 Scope	5	Production Welds	54
1.2 Application	5	4.14 Non-destructive Testing	54
1.3 Safety	7	4.15 Standards of Acceptability for	
1.4 Symbols and Definitions	7	Non-destructive Testing	55
1.5 Standards and Specifications	11	4.16 Removal of Unacceptable	
1.6 Interpretation	11	Defects in Welds	60
SECTION 2. MATERIALS AND COMPONENTS		4.17 Welding or Cutting on Steel	
2.1 General	12	Pipelines Containing Hydro-	
2.2 Qualification Categories of		carbons	60
Materials and Components	12	4.18 Attachment of Electrical	
2.3 Qualifying Procedures—General	12	Connections	61
2.4 Qualifying Requirements for			
New or Used Pipe Complying		SECTION 5. CONSTRUCTION AND INSTALLATION	
with a Standard or Specification		5.1 General	63
not Listed in the Standard	13	5.2 Inspection	63
2.5 Fracture Toughness	14	5.3 Location	63
2.6 Valves, Fittings, and Accessories	16	5.4 Survey	63
2.7 External Protective Coating	16	5.5 Handling, Transportation and Storing	63
2.8 Internal Protective Lining	17	5.6 Repair of Fabricated Items and Pipes	63
2.9 Weight Coating	17	5.7 Bends, Mitres and Elbows	64
2.10 Galvanic Anodes	17	5.8 Pipelines	64
SECTION 3. DESIGN		5.9 Protective Coatings	64
3.1 Design Considerations	18	5.10 Pipeline Crossings	64
3.2 Design Pressure	18	5.11 Valves	64
3.3 Design Temperatures	19	5.12 Connections to Pipelines	64
3.4 Stability of Pipeline	19	5.13 Warnings and Markers	64
3.5 Allowable Hoop Stress	19	5.14 Corrosion Control	65
3.6 Stress Limits	19	5.15 Safety Devices and Instruments	65
3.7 Allowances	19	5.16 Fire Protection	65
3.8 Design of Components	19	5.17 Electrical Installations	65
3.9 Design of Closures for Pipe Ends	24	5.18 Assembly of Components	65
3.10 Design of Flanges	24	5.19 Manifolds	65
3.11 Design of Reducers	24	5.20 Hot Taps	65
3.12 Design of Other Pressure-			
containing Components	24	SECTION 6. INSPECTION AND TESTING	
3.13 Limits to Selection of Components	25	6.1 Inspection	67
3.14 Used Components	27	6.2 Repair of Defects	67
3.15 Limits to Selection of Joints	27	6.3 Testing	68
3.16 Pipeline Flexibility, Supports,		6.4 Pressure Testing	68
and Restraints	27	6.5 Records	69
3.17 Cathodic Protection	27		
3.18 Instrument, Control, and		SECTION 7. OPERATION AND MAINTENANCE OF	
Sampling Piping	29	PIPELINES	
3.19 Control of Pipeline Pressure	32	7.1 Operation and Maintenance Pro-	
3.20 Records	32	cedures Affecting the Safety of	
SECTION 4. WELDING		Pipelines	70
4.1 General	33	7.2 Pipeline Operation and Main-	
4.2 Safety in Welding	33	tenance	70
4.3 Welding Equipment	33	7.3 Pipeline Repairs	71
4.4 Electrodes, Fluxes, Filler Rods,		7.4 Safe Working with Gas and	
and Gas Mixtures	33	Liquid Petroleum	71
4.5 Prohibition of Welding	34	Records	72
4.6 Definitions and Terms	34	7.6 Abandoning a Pipeline	73
4.7 General Provisions for Welding	34	7.7 Corrosion	73
4.8 Preheating	37		
4.9 Postweld Heat Treatment	41	SECTION 8. CORROSION MITIGATION	
4.10 Qualification of Welding Procedures	42	8.1 General	74
4.11 Qualification Testing of Welded		8.2 Qualification of Personnel	74
Joints	44	8.3 Rate of Corrosion	74
4.12 Welder Qualification	48	8.4 Corrosion Mitigation Methods	75
		8.5 Internal Corrosion Mitigation	75

8.6	External Corrosion Mitigation . . .	75	C	Identification and Addresses of Standards-issuing and Other Bodies Referred to in this Code . .	84
8.7	Installation of Galvanic Anodes . .	77	D	Notes on Statutory Requirements .	85
8.8	Timing of Application of Corrosion Mitigation	77	E	Recommendations for Navigational Systems, and Hydrographic and Meteorological Investigations	86
8.9	Inspection for the Detection of Corrosion	77	F	Fracture Toughness for Steel Pipelines	88
8.10	Corrosion Defects	78	G	Figures Relating to Weld Reinforcement	90
8.11	Records	78	H	Recommended Welding Sequence for Hot Tap Fittings	95
SECTION 9.	CHANGES IN MAXIMUM ALLOWABLE OPERATING PRESSURE OF EXISTING PIPELINES		J	Assessment of Corroded Pipelines .	96
9.1	General	79	INDEX		104
9.2	Increasing the Maximum Allowable Operating Pressure	79	ANNEX		110
9.3	Records	79	RECORD OF AMENDMENTS		111
APPENDICES					
A	Nominated Standards and Specifications	80			
B	Reference Standards	83			

STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard

for

GAS AND LIQUID PETROLEUM SUBMARINE PIPELINES

SECTION 1. GENERAL REQUIREMENTS

1.1 SCOPE. This standard sets out minimum requirements for materials, design, construction, installation, inspection, testing, operation, and maintenance of submarine petroleum pipelines located on or in the sea bed of bays, estuaries, and the territorial sea and on or in the continental shelf, and used for the transport of hydrocarbon fluids such as natural gas, crude oils, natural gasoline, natural gas liquids, liquefied petroleum gas, and liquid petroleum products, in either a single or a dual phase condition, where—

- (a) those pipelines are manufactured from steel and qualify for use in terms of the relevant sections of the standard; and
- (b) the temperature of the pipe transporting the fluid does not exceed 230°C and is not less than -30°C at any point in the pipeline.

1.2 APPLICATION. This standard is applicable to those parts of a pipeline which are located sea-

ward of a mark which is not more than 100 m landward from the point where the pipeline crosses the highest high-water mark recorded (see Fig. 1.1) and to those parts of a pipeline that are located on platforms, piers, trestles, jetties, wharves, quays, and other structures (see Fig. 1.2).

The standard is applicable also to off-shore pipeline manifolds, whether sub-sea or on a structure, and to the launching and receiving traps for either scrapers or spheres and their associated piping, other than those located more than 100 m landward of the highest high-water mark.

Flowlines and gathering pipelines between subsea production facilities and fixed or floating processing or storage facilities will usually be covered by the standard, but it is not possible to define the terminal points of such lines more precisely than to say that they are those points at which the pipeline is connected to facilities designed according to other standards.

The terminal point of a pipeline associated with off-shore loading or discharge of a tanker is that

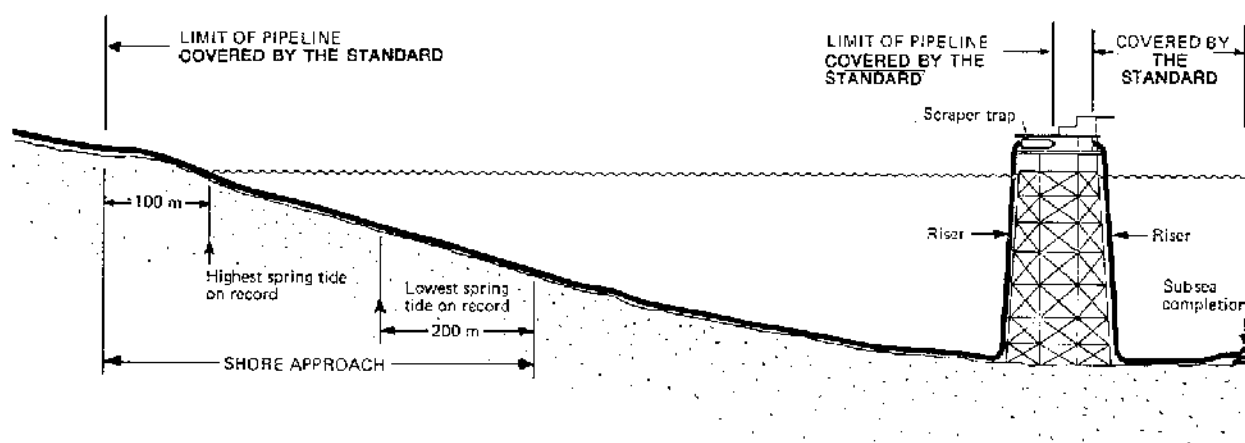


Fig. 1.1. LIMITATIONS OF STANDARD—SUBSEACOMPLETION TO PLATFORM AND PLATFORM TO SHORE (The arrangement shown is typical only)

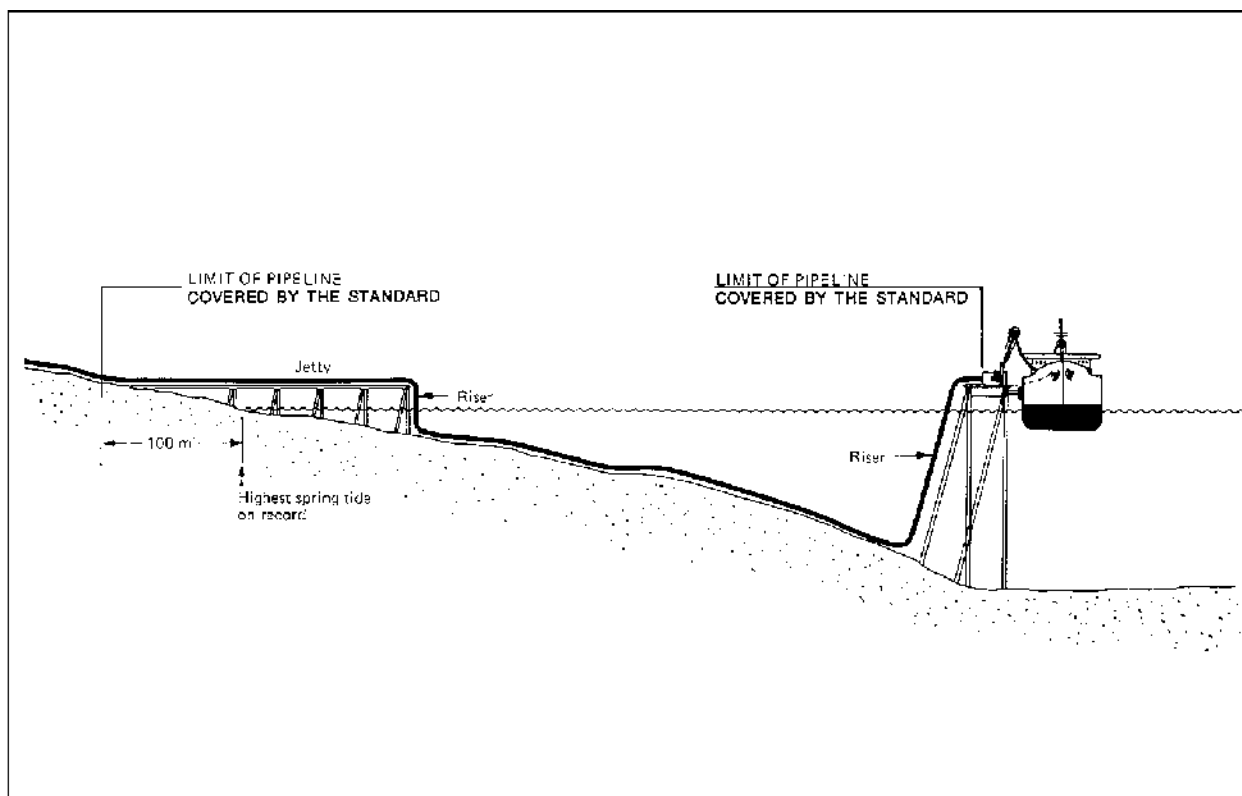


Fig. 1.2 LIMITATIONS OF STANDARD—LANDWARD JETTY SYSTEM OFFSHORE LOADING/DISCHARGE PLATFORM SYSTEM (The arrangement shown is typical only)

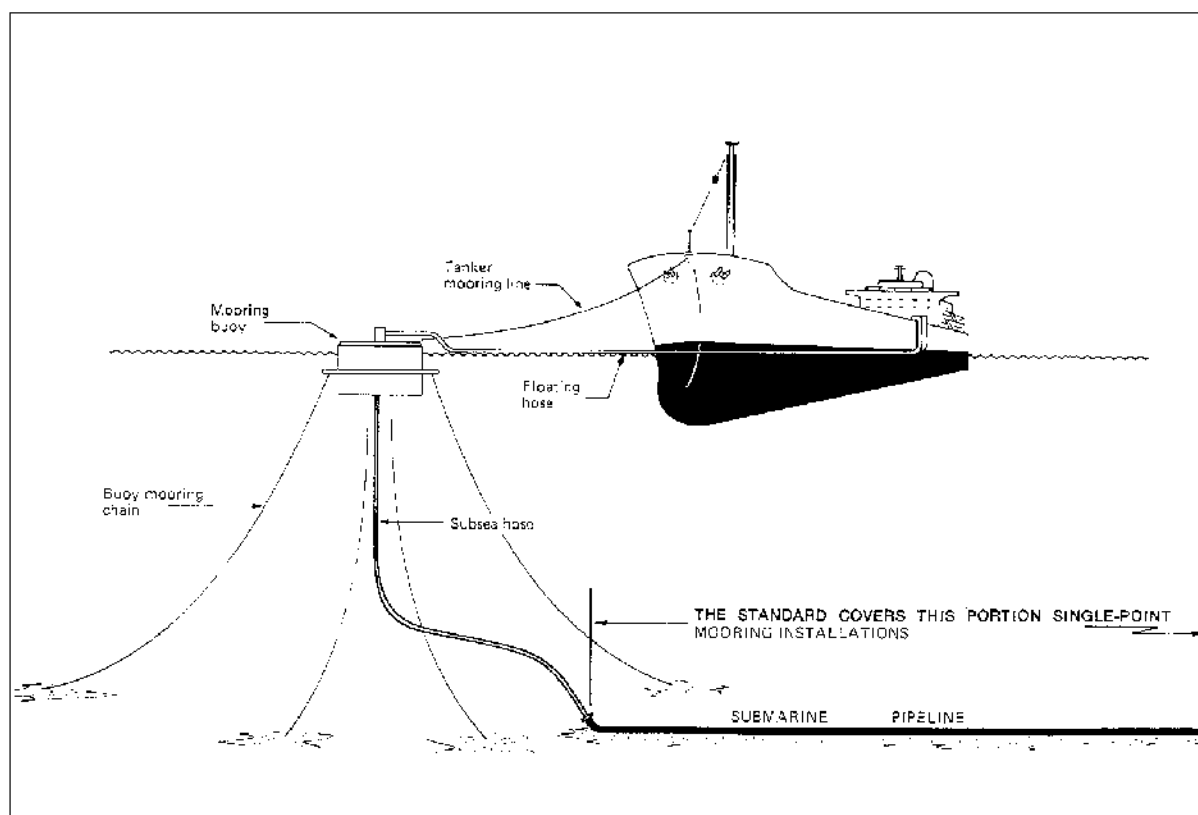


Fig. 1.3. LIMITATIONS OF STANDARD—SINGLE-POINT MOORING SYSTEM (The arrangement shown is typical only)

point at which a rigid pipeline made of steel is connected to a flexible line (see Fig. 1.3).

The standard contains provisions for the use of anchors, clamps, supports, and other means to prevent the overstressing of components.

The standard is not applicable to —

- (a) auxiliary piping such as that required for water, air, steam, lubricating oil, and fuel;
- (b) pressure vessels, heat exchangers, pumps, meters and other similar equipment or piping and piping connections integral with them;
- (c) casing, tubing, or piping used in petroleum wells, gathering systems at well heads, tankage, and other production facilities;
- (d) piping associated with hydrocarbon processing, handling, or storage in refineries or terminals;
- (e) the design and fabrication of proprietary items of equipment;
- (f) instrumentation, telemetry and remote control equipment;
- (g) compressor and pump stations;
- (h) flexible hose connecting a rigid pipeline to a buoy or tanker.

It is not intended that the standard be applied retroactively to existing pipelines insofar as design, construction, installation and testing at the time of construction are concerned. However, the standard is applicable to the operation and maintenance of existing installations and to the increasing of established operating pressures.

1.3 SAFETY. The requirements and recommendations of the standard are considered to be adequate to ensure the safety of the general public and all persons engaged in pipeline construction and operation under conditions usually encountered to the extent that safety is affected by—

- (a) basic design;
- (b) quality of materials and workmanship;
- (c) testing requirements; and
- (d) maintenance and operation.

The standard has provision for extra protection of a pipeline where necessary to avoid damage to the pipeline which may occur as a result of bottom scour and erosion, snagging by fishing gear and ships' anchors, sea-bed subsidence, or other conditions which may be unique to the area in which the pipeline is constructed.

Existing industrial safety regulations pertaining to work areas, safety devices, and safe working practices are not supplanted by this standard.

1.4 SYMBOLS AND DEFINITIONS.

1.4.1 Symbols. For the purpose of this standard, unless otherwise defined, the symbols used shall have the following meanings:

A_1 = reinforcement area required as a result of excessive wall thickness of header, in square millimetres (see Fig. G3.8.5(A), Clause 3.8.7.4, and Fig. G3.8.7(C) and (D))

A_2 = reinforcement area required as a result of excessive wall thickness of branch, in square millimetres (see Fig. G3.8.5(A), Clause 3.8.7.4, and Fig. G3.8.7(C) and (D))

A_3 = summation of area at the added reinforcement, including welded areas which lie within the area of reinforcement, in square millimetres (see Fig. G3.8.5(A); alternatively, area with reinforcement zone required as a result of excessive thickness in extruded outlet lip, in square millimetres (see Clause 3.8.7.4 and Fig. G3.8.7(C) and (D))

A_R = required cross-sectional area of reinforcement at a branch connection or extruded outlet, in square millimetres (see Clause 3.8.5.3, Fig. G3.8.5(A), Clause 3.8.7.3, and Fig. G3.8.7(C) and (D))

a = distance between flattening plates for flattening test of pipe weld, specified in Table 2.4.2, in millimetres

b = distance between flattening plates for flattening test of pipe body, specified in Table 2.4.2, in millimetres

C = correction factor (see Table 3.16.2.4 and Fig. 3.16.2.4)

CT = joint combined thickness, in millimetres (see Fig. 4.8.3(A))

D = outside diameter of pipe, in millimetres (see Table 2.4.2, Clause 3.8.2.2, Clause 3.8.2.3, and Figs 3.13.3.2 and 5.20.4)

D_h = outside diameter of header, in millimetres (see Clause 3.8.7.3 and Fig. G3.8.7 (A), (C) and (D))

D_e = internal diameter of header, in millimetres (see Clause 3.8.7.3 and Fig. G3.8.7 (A), (C) and (D))

D_o = internal diameter of extruded outlet measured at the level of the outside surface of the header, in millimetres (see Clauses 3.8.7.3 and 3.8.7.4, and Fig. G3.8.7 (A), (C) and (D))

d = length of opening in branch connection, in millimetres (see Clause 3.8.5.3 and Fig. G3.8.5 (A))

d_b = outside diameter of branch pipe, in millimetres (see Clauses 3.8.7.2 and 3.8.7.3, and Fig. G3.8.7(A), (C) and (D))

d_e = internal diameter of branch pipe, in millimetres (see Fig. G3.8.7(A), (C) and (D))

E = modulus of elasticity (Young modulus), in megapascals (see Clause 3.16.2.2 and Table 3.16.2.4)

e = deformation per unit length, constant for a given grade of steel (see Table 2.4.2)

F = design factor (see Clause 3.5)

f_H = maximum design hoop stress in pipe wall, in megapascals (see Clauses 3.5, 3.8.2.2, and 3.16.2.2)

f_L = longitudinal compression stress, in megapascals (see Clause 3.16.2.2)

f_b	=	equivalent bending stress, in megapascals (see Clause 3.16.2.3)	r_1	=	half width of reinforcement zone, in millimetres (see Fig. G3.8.7 (A), (C) and (D))
f_e	=	maximum calculated expansion stress, in megapascals (see Clause 3.16.2.3)	r_o	=	radius of curvature of external contoured portion of outlet measured in the plane containing the axis of the header and branch, in millimetres (see Clauses 3.8.7.1, 3.8.7.2 and 3.8.7.4, and Fig. G3.8.7(A), (B), (C) and (D))
f_t	=	torsional stress, in megapascals (see Clause 3.16.2.3)	S	=	specified minimum yield stress, in megapascals, stipulated in the specification to which the pipe was purchased from the manufacturer (see Table 3.5)
G	=	sum of allowances for corrosion, protection against damage, and threading and grooving, in millimetres (see Clause 3.8.2.1)	(or SMYS)		
GN	=	group number (see Fig. 4.8.3(A))	s	=	mitre spacing at centreline, in millimetres (see Table 3.16.2.4)
H	=	height of reinforcement for branch connection, in millimetres (see Fig. G3.8.5(A))	T	=	temperature derating factor (see Clause 3.5)
h	=	flexibility characteristic (see Table 3.16.2.4 and Fig. 3.16.2.4)	T_1	=	temperature at the time of installation, in degrees Celsius (see Clause 3.16.2.2)
h_o	=	height of the extruded lip, in millimetres (see Clause 3.8.7.1 and Fig. G3.8.7(A), (C) and (D))	T_2	=	maximum or minimum operating temperature, in degrees Celsius (see Clause 3.16.2.2)
i	=	stress intensification factor (see Table 3.16.4.2 and Fig. 3.16.2.4)	T_b	=	nominal thickness of branch, in millimetres (see Clause 3.8.7.4, Figs G3.8.5(A) and G3.8.7(A), (C) and (D))
i_i	=	stress intensification factor under bending in plane of member (see Clause 3.16.2.3 and Table 3.16.2.4)	T_h	=	nominal thickness of header, in millimetres (see Clause 3.8.7.4, Figs G3.8.5(A) and G3.8.7(A), (C) and (D))
i_o	=	stress intensification factor under bending out of, or transverse to, the plane of member (see Clause 3.16.2.3 and Table 3.16.2.4)	T_o	=	finished thickness of extruded outlet measured at a height equal to r_o above the outside surface of the header, in millimetres (see Clause 3.8.7.4 and Fig. G3.8.7 (A), (B), (C) and (D))
J	=	longitudinal joint factor (see Clause 3.5)	t	=	minimum calculated thickness of pipe or header, in millimetres (see Table 2.4.2 and Clauses 3.8.2.1, 3.8.2.2 and 3.8.2.3)
K	=	required reinforcement factor (see Clause 3.8.7.3)	t_1	=	thickness of material adjacent to weld, in millimetres (see Fig. 4.8.3 (A))
k	=	flexibility factor (see Table 3.16.2.4 and Fig. 3.16.2.4)	t_2	=	thickness of material adjacent to weld, in millimetres (see Fig. 4.8.3(A))
L	=	height of reinforcement zone for extruded outlet, in millimetres (see Clause 3.8.7.4 and Fig. G3.8.7(A), (C) and (D))	t_3	=	thickness of material adjacent to weld, in millimetres (see Fig. 4.8.3 (A))
l	=	length of crotch, in millimetres (see Fig. 3.13.3.2)	t_b	=	minimum calculated thickness of branch, in millimetres (see Fig. G3.8.5(A), Clause 3.8.7.4 and Fig. G3.8.7(A), (C) and (D))
M	=	actual (by measurement) or nominal thickness of added reinforcement, in millimetres (see Fig. G3.8.5(A) and (C))	t_h	=	minimum calculated thickness of header, in millimetres (see Clause 3.8.5.3, Fig. G3.8.5 (A), Clauses 3.8.7.3, 3.8.7.4 and Fig. G3.8.7(A), (C) and (D))
M_b	=	nominal wall thickness of saddle at branch end, in millimetres (see Fig. G3.8.5(C))	t_n	=	nominal thickness of pipe, in millimetres (see Clause 3.8.2.1 and Tables 3.8.2 and 3.16.2.4)
M_h	=	nominal wall thickness of saddle at header end, in millimetres (see Fig. G3.8.5(C))	t_p	=	pad or saddle thickness, in millimetres (see Table 3.16.2.4)
M_i	=	bending moment in plane of member, in millinewton metres (see Clause 3.16.2.3)	W_1	=	size of weld, in millimetres (see Fig. G3.8.5(B) and (C))
M_o	=	bending moment out of, or transverse to, plane of member, in millinewton metres (see Clause 3.16.2.3)	W_2	=	size of weld, in millimetres (see Fig. G3.8.5(C))
M_t	=	torsional moment, in millinewton metres (see Clause 3.16.2.3)	W_3	=	size of weld, in millimetres (see Fig. G3.8.5 (C))
N	=	gap, in millimetres (see Figs G3.8.5 (B) and G3.8.5(C))	W_4	=	size of weld, in millimetres (see Fig. G3.8.5 (C))
P	=	internal design pressure, in megapascals or, where convenient, kilopascals (see Clause 3.8.2.2 and Table 3.16.2.4)	Z	=	section modulus of pipe, in millimetres cubed (see Clause 3.16.2.3)
P_c	=	collapse pressure, in megapascals (see Clause 3.8.2.3)			
R	=	radius of pipe bend or welding elbow, in millimetres (see Table 3.16.2.4)			
r	=	mean radius of matching pipe bend, in millimetres (see Table 3.16.2.4)			

- α = coefficient of linear expansion (see Clause 3.16.2.2)
- θ = half angle of deflection of mitre joint (see Fig. 3.13.3.4 and Table 3.16.2.4)
- μ = Poisson ratio (see Clause 3.16.2.2).

1.4.2 Definitions. For the purpose of this standard the following definitions apply:

1.4.2.1 Accessory—a component of a pipeline other than pipe, valves, and fittings, but including relief devices, pressure containing items, hangers, supports and all other items necessary to make the pipeline operative whether or not such items are covered by the standard (exclusions from the standard are outlined in Clause 1.2).

1.4.2.2 Ambient temperature—the temperature of the surrounding medium, usually used to refer to the temperature of the medium in which the pipeline is situated or operates.

1.4.2.3 Approved and approval—approved by the Operating Authority, which includes obtaining the approval of the relevant Statutory Authority where this is legally required.

1.4.2.4 Authority, Operating—the organization responsible for the design, construction, testing, inspection, operation, and maintenance of facilities within the scope of the standard.

1.4.2.5 Authority, Statutory—the State or Commonwealth body empowered by an Act of Parliament to exercise jurisdiction over facilities within the scope of the standard.

1.4.2.6 Cathodic protection—a means of controlling corrosion by the application of an electric current which may be externally applied or induced by a sacrificial anode.

1.4.2.7 Component—any part of a pipeline.

1.4.2.8 Control piping—piping that conveys pneumatic or hydraulic pressure to controlling apparatus and pneumatic piping between instrument transmitters and receivers.

1.4.2.9 Corrosion—the deterioration of a material, usually a metal, because of a reaction with its environment.

1.4.2.10 Electrical isolation—the condition of being electrically separated from other metallic structures or the environment.

1.4.2.11 Electrolyte—a substance in which the passage of an electric current is accompanied by the movement of matter. For the purpose of the standard, electrolyte refers to the soil or liquid adjacent to and in contact with a buried or submerged metallic structure including the moisture and other chemicals contained therein.

1.4.2.12 Elongation, specified minimum—the minimum elongation (expressed as a percentage of the gauge length) in the tensile test specimen, prescribed by the specification according to which the material is purchased from the manufacturer.

1.4.2.13 Fitting—a component, including the associated flanges, bolts, and gaskets used to join pipes, to change direction or diameter of a pipeline, provide a branch, or terminate a pipe.

1.4.2.14 Half-cell reference electrode—see reference electrode, Clause 1.4.2.46.

1.4.2.15 Holiday—a discontinuity of protective coating.

1.4.2.16 Hot tap—connection made to a pipeline containing hydrocarbon fluid. The pipeline may or may not be in operation at the time of the hot tapping.

1.4.2.17 Inspector—a person appointed by the Operating Authority to carry out inspections required by the standard.

1.4.2.18 Instrument piping—all piping, valves, and fittings used to connect instruments to main piping, to other instruments and apparatus, or to measuring equipment.

1.4.2.19 Liquefied petroleum gas—a material composed predominantly of any of the following hydrocarbons or mixtures of all or any of them: propane (C_3H_8), propylene (C_3H_6), butanes (C_4H_{10}) or butylenes (C_4H_8).

1.4.2.20 Mitre bend—a bend consisting of one or more mitre joints.

1.4.2.21 Mitre joint—two straight sections of pipe that are matched and joined on a plane bisecting the angle of junction so that a change in direction exceeding 3 degrees is produced.

1.4.2.22 Over-pressure protection—provision of devices or equipment for the purpose of preventing the pressure in a pipeline from exceeding a predetermined value.

1.4.2.23 Petroleum—hydrocarbon fluids such as hydrocarbon gases, natural gases, crude oils, liquid petroleum products, and all liquid/vapour mixtures of these fluids.

1.4.2.24 Pipe (tube)—a tubular product made as a production item for sale. A cylinder formed from plate in the course of the fabrication of auxiliary equipment is not defined as a pipe.

1.4.2.25 Pipe, cold expanded—pipe which has received a permanent increase in circumference while at ambient mill temperature, such as by internal hydraulic pressure in closed dies, or by internal expanding mechanical dies.

1.4.2.26 Pipe, cold springing—the fabrication of a component to an actual length shorter than its nominal length, and forcing it into position, so that it is stressed in the installed condition, thus compensating partially for the effects produced by the expansion due to an increase in temperature.

1.4.2.27 Pipe, continuous welded—furnace-welded pipe produced in continuous lengths from coiled strip and subsequently cut into individual lengths, having its longitudinal butt joint forge-welded by the mechanical pressure developed in rolling the hot-formed strip through a set of round pass welding rolls.

1.4.2.28 Pipe, double-submerged arc-welded—pipe having a longitudinal or spiral butt joint produced by at least two welds, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode

or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used and the filler metal for the inside and outside welds is obtained from the electrode or electrodes.

1.4.2.29 Pipe, electric-flash welded—pipe having a longitudinal butt joint wherein coalescence is produced simultaneously over the entire area of abutting surfaces by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and up-setting are accompanied by expulsion of metal from the joint.

1.4.2.30 Pipe, electric-fusion welded—pipe having a longitudinal or spiral butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The joint may be single or double welded and may be made with or without the use of filler metal.

1.4.2.31 Pipe, electric-resistance welded—pipe having a longitudinal or spiral butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is part, and by the application of pressure.

1.4.2.32 Pipe length—a piece of pipe of the length delivered from the mill. Each piece is called a length regardless of its actual dimension. The alternative term 'joint', commonly used in the pipeline industry, is not used in this sense in the standard.

1.4.2.33 Pipe, seamless—pipe produced by piercing a billet followed by rolling or drawing, or both.

1.4.2.34 Pipe supports—consist of fixtures and structural attachments, as follows:

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

1.4.2.35 Pipeline—a system consisting of pipe, valves, fittings, and accessories used to transmit petroleum fluids. A pipeline may have branch connections but these would normally be few in number.

1.4.2.36 Piping—an assembly of pipe, valves, and fittings connecting ancillary components associated with a pipeline, e.g. water, air or steam piping, piping in control systems, or tank farm piping.

1.4.2.37 Polarization—the deviation from the open-circuit potential of an electrode resulting from the passage of current. Polarization is considered to be the change of potential of a metal surface resulting from the passage of current directly to or from an electrolyte.

1.4.2.38 Pressure—unless otherwise stated, is expressed above atmospheric pressure, i.e. gauge pressure, in kilopascals (kPa).

1.4.2.39 Pressure, design—the internal or the external design pressure.

1.4.2.40 Pressure, external design—the pressure exerted by the water above the submerged pipeline.

1.4.2.41 Pressure, internal design—the maximum internal pressure to which a component will be exposed in service as a result of the influence of the inlet and outlet pressures, the internal hydrostatic head, and the flow conditions for which a pipeline is to be designed, or in the case of an existing pipeline, the maximum operating pressure permitted by the standard as determined by the design procedures applicable to the materials, locations, and the testing carried out.

1.4.2.42 Pressure, maximum actual operating—the maximum operating pressure existing in a pipeline during a normal operation.

1.4.2.43 Pressure, maximum allowable operating—the maximum pressure at which a pipeline may be operated in accordance with the provisions of the standard.

1.4.2.44 Pressure, maximum allowable test—the maximum internal pressure to which a component may be subjected during a pressure test.

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

1.4.2.46 Pulse-type holiday detector—an instrument used to detect a holiday by generating a high voltage pulse of a very short duration which can arc across the air gap to the metal surface at the holiday. The location of the holiday is determined by the arc which may be seen, heard or signalled.

1.4.2.47 Reference electrode—an electrolytic device which has a constant open-circuit potential under similar conditions of use.

1.4.2.48 Sampling piping—all piping, valves, and fittings used for the collection of samples from the contents of the pipeline.

1.4.2.49 Shall—'shall' is used to indicate that a requirement is mandatory.

1.4.2.50 Shore approach—that part of a submarine pipeline route which lies between a point 200 m seaward of the lowest low water mark recorded and a point 100 m landward of the highest high water mark recorded. This definition does not apply to pipelines located on piers, jetties, or offshore structures.

1.4.2.51 Should—'should' is used to indicate that a requirement is not mandatory but recommended as good practice.

1.4.2.52 Steel, alloy—steel having a specification which requires a minimum content, of definite range, of alloying elements such as nickel, chromium, or aluminium; or steel which contains more than 2.00 percent manganese, 0.60 percent copper, or 0.60 percent silicon.

1.4.2.53 Steel, carbon—steel having a specification which neither requires a minimum content of alloying elements such as nickel, chromium, aluminium, or molybdenum, nor contains more than 2.00 percent manganese, 0.60 percent copper, or 0.60 percent silicon.

NOTE: In all carbon steels small quantities of certain residual elements, unavoidably retained from raw materials, are sometimes found which are not specified or required, such as copper, nickel, molybdenum, or chromium. These elements are considered 'incidental' and are not normally determined or reported.

1.4.2.54 Stress—the internal force per unit area that resists changes in the size or shape of a body when acted on by a force or forces external to the body.

1.4.2.55 Stress, allowable hoop (or design)—the hoop stress permitted by the standard for the design of the particular pipeline.

1.4.2.56 Stress, hoop—the stress in a pipe wall, acting circumferentially in a plane perpendicular to the longitudinal axis of the pipe and produced by the pressure of the fluid in the pipe.

1.4.2.57 Stress, operating—the stress in a pipe or structural member under normal operating conditions.

1.4.2.58 Stress, specified minimum tensile—the minimum tensile stress prescribed by the specification to which pipe is purchased from the manufacturer.

1.4.2.59 Stress, specified minimum yield (SMYS)—the minimum yield stress prescribed by the specification to which pipe is purchased from the manufacturer.

1.4.2.60 Stress, yield (sometimes referred to as yield strength or yield point)—the stress at that point in a tensile test at which plastic deformation, soon after it has been initiated, continues to occur at nearly constant force.

1.4.2.61 Telescoped pipeline—a pipeline which has sections, not separated by valves, of different wall thickness or specified minimum yield stress.

1.4.2.62 Temperatures, design—the metal temperatures to be expected in construction, testing, and normal operation.

1.4.2.63 Thickness, actual—the actual thickness of the material used, which may be taken as the nominal thickness minus any applicable manufacturing tolerances.

1.4.2.64 Thickness, minimum calculated—the minimum thickness of material, calculated according to the formulas in Section 3, required for the material to be capable of withstanding applied stresses.

1.4.2.65 Thickness, nominal—the thickness named in the pipe specification and selected according to design procedures of the standard for the intended purposes.

1.4.2.66 Uniform pipeline—a pipeline which has sections of similar wall thickness or specified minimum yield stress.

1.4.2.67 Voltage—an electromotive force, or a difference in electrode potential, expressed in volts.

1.4.2.68 Welding symbols and welding terms. Symbols relating to welding shall have the meanings given in AS 1101, Part 3. Welding terms shall be interpreted in accordance with AS Z5 except as otherwise defined in Section 4 herein.

1.5 STANDARDS AND SPECIFICATIONS.

1.5.1 General. Where standards or specifications listed in this standard have not been produced in the metric form, the conversion of values shall be made in accordance with AS 1377, Parts 1 to 6.

1.5.2 Nominated Standards. Standards and specifications nominated for use under this standard are listed in Appendix A.

1.5.3 Application of Nominated Standards. Some standards listed in Appendix A are supplemented by specific requirements elsewhere in this standard. Users of the standard are advised against attempting direct application of any of those standards without carefully observing the reference herein to that standard. All standards are taken to be the current edition unless otherwise approved or indicated.

1.5.4 Supplementary Standards Standards and specifications which are of a supplementary nature are listed in Appendix B.

1.6 INTERPRETATION. If any ambiguity be found or doubts arise as to the meaning or effect of any requirement of this standard or as to whether anything ought to be done or omitted to be done in order that the standard should be complied with in full, the question may be referred to SAA Committee ME/38, Gas and Liquid Petroleum Piping Systems, whose interpretation of the requirements of the standard upon the matter at issue shall be final and conclusive as to questions of interpretation but this does not confer on the Committee any power or jurisdiction to adjudicate on the contractual rights or duties of any person under any relevant contract. Findings of the Committee may be incorporated as Interpretations or Amendments to the standard.

SECTION 2. MATERIALS AND COMPONENTS

2.1 GENERAL.

2.1.1 Safety and Suitability. All materials and components which are intended to become a permanent part of a pipeline constructed under this standard shall be suitable and safe for the conditions under which they are to be used.

2.1.2 Qualification. All materials and components used in a pipeline shall be qualified for the conditions of their use by compliance with the appropriate specifications, standards, and special requirements of this standard or otherwise as provided herein.

2.2 QUALIFICATION CATEGORIES OF MATERIALS AND COMPONENTS. Materials and components fall into four categories insofar as methods of qualification for use under this standard are concerned. These categories are as follows:

- (a) Materials and components which comply with standards or specifications listed in this standard (see Appendix A).
- (b) Materials and components which comply with standards or specifications not listed in this standard.
- (c) Components, other than pipe, for which no standards or specifications exist, e.g. proprietary items such as pressure-regulating devices or mechanical connectors.
- (d) Used pipe.

2.3 QUALIFYING PROCEDURES—GENERAL.**2.3.1 Materials and Components Complying with Standards or Specifications Listed in this Standard.**

Materials and components complying with standards or specifications listed in this standard (Clause 2.2(a)) may be used for appropriate applications, as specified and limited by this standard, without further qualification.

2.3.2 Materials and Components Complying with Standards or Specifications Not Listed in this Standard. Materials and components complying with standards or specifications not listed in this standard (Clause 2.2(b)) may be qualified by one of the following means:

- (a) Petition to SAA Committee ME/38, Gas and Liquid Petroleum Piping Systems, for inclusion of the standard or specification of the material or component in this standard by established procedure.
- (b) Compliance with a standard or specification which does not vary materially from a listed standard or specification and by complying with the minimum requirements of this standard with respect to quality of materials and workmanship. This Clause shall not be construed as permitting deviations which would tend to adversely affect weldability or ductility. If deviations tend to reduce strength, full allowance for the reduction shall be provided for in the design.
- (c) Tests and investigations of components to demonstrate their safety, provided that their use is not specifically prohibited by this standard.

2.3.3 Components, other than Pipe, for which no Standards or Specifications Exist. Components, other than pipe, for which no standards or specifications exist (Clause 2.2(c)) may be qualified by investigation and tests (if needed) that demonstrate that the component is suitable and safe for the proposed service and provided also that the component is recommended for that service from the standpoint of safety by the manufacturer.

2.3.4 Pipe. Pipe complying with a standard or specification listed in Table 3.5(B) should be used subject to the limitations imposed in that table. Attention is drawn to the inclusion, in some of these approved standards or specifications, of manufacturing methods, grades, and products not included in Table 3.5(B). Approval for use in pipelines designed in accordance with this standard is restricted to the manufacturing methods, grades and products listed in Table 3.5(B).

Some materials complying with the approved pipe standard or specification may not have properties suitable for the lower portion of the temperature band covered by this standard. Pipe which may be subjected to low temperatures during construction or operation shall be manufactured from materials suitable for the service temperature expected, and shall have adequate fracture toughness as determined in accordance with Clause 2.5.

2.3.5 Used Pipe Complying with a Standard or Specification Listed in this Standard. Used pipe complying with a standard or specification listed in this standard (see Clause 2.2(d)) shall be visually inspected to reveal any defects which could impair its strength or pressure tightness.

Where this inspection shows mechanical damage or deterioration, the coating or lining (if present) shall be removed to the extent necessary to check the soundness of the pipe metal.

The pipe shall be inspected in such a manner that any distortion, denting, flattening, gouging, grooves, notches, and all similar harmful defects will be revealed. Any such defects shall be either repaired or removed in accordance with the requirements of Clause 5.6.

Pipe which may be subjected to low temperatures during construction or operation shall have been manufactured from materials suitable for the service temperature expected and shall have adequate fracture toughness as determined by the test in Clause 2.5.

The pipe may be then treated as new pipe to the same standard or specification, subject to the provisions of Clause 2.4.7.

2.3.6 New or Used Pipe Complying with a Standard or Specification not Listed in this Standard.

2.3.6.1 Hoop stress less than 42 MPa. New or used pipe complying with a standard or specification not listed by this standard may be used at low stresses (hoop stress less than 42 MPa) where—

- (a) no close coiling or bending is to be carried out;

- (b) careful visual examination indicates that—
 - (i) it is in good condition;
 - (ii) it is free from split seams or other defects which would cause leakage;
- (c) the pipe satisfactorily passes the weldability test specified in Clause 2.4.5 (where the pipe is to be welded and is of unknown specification, unless the chemical composition is known and approved);
- (d) the pipe is hydrostatically tested either length by length in a mill type test or as a whole in the field to at least the test pressure required to establish the maximum allowable operating pressure for which the pipe will be used in service.

2.3.6.2 Hoop stress 42 MPa and higher; or for close coiling or bending service. New or used pipe complying with a standard or specification not listed in this standard may be used for service at hoop stress levels of 42 MPa or higher, or for service requiring close coiling or bending, provided that it is qualified for the intended service by compliance with all the requirements of Clause 2.4.

2.4 QUALIFYING REQUIREMENTS FOR NEW OR USED PIPE COMPLYING WITH A STANDARD OR SPECIFICATION NOT LISTED IN THIS STANDARD.

2.4.1 Inspection. All pipe shall be inspected to reveal any defects which could impair its strength or pressure tightness. Where this inspection shows mechanical damage or deterioration, the coating or lining (if present) shall be removed to the extent necessary to check the soundness of the pipe metal.

The pipe shall be inspected in such a manner that any distortion, denting, flattening, gouging, grooves, notches, and all similar harmful defects will be revealed. Any such defects shall be either repaired or removed in accordance with the requirements of Clause 5.6.

2.4.2 Bending and Flattening Tests.

- (a) For pipe up to and including 60.3 mm outside diameter, a sufficient length of pipe shall be bent cold through 90 degrees around a cylindrical mandrel the diameter of which is twelve times the outside diameter of the pipe, without developing cracks at any portion and without opening the weld. The pipe shall be bent with the weld (if any) at 90 degrees to the plane of bending.
- (b) For pipe over 60.3 mm outside diameter, with a diameter/thickness ratio not exceeding 10, which is seamless or electric-resistance welded, test pieces of pipe shall be subjected to the following flattening test and meet the requirements thereof:
 - (i) The number of pieces to be tested and the method of selection shall be the same as those required to determine the minimum yield stress (see Clause 2.4.6).
 - (ii) All test pieces shall be not less than 50 mm in length.

- (iii) The welded joint of electric-resistance welded pipe shall be placed at the point of maximum bending.
- (iv) The test shall consist of flattening a piece of pipe between parallel plates until the opposite walls meet. For seamless pipe no cracks or breaks shall occur until the distance between the plates is less than b in Table 2.4.2. For welded pipe, no opening in the weld shall take place until the distance between the plates is less than a in Table 2.4.2, and no cracks or breaks in the metal elsewhere than in the weld metal shall occur until the distance between the plates is less than b in Table 2.4.2. There shall be no evidence of lamination or burnt metal during the entire flattening process and the weld shall not show injurious defects.

**TABLE 2.4.2
DISTANCE BETWEEN PLATES**

Method of manufacture	Distance between plates, mm	
	Dimension a (weld)	Dimension b (body)
Electric-resistance welded pipe	0.67 of original outside diameter	0.33 of original outside diameter but in no case less than 5 times the wall thickness
Seamless pipe	Not applicable	$\frac{(1 + e)t}{e + dD}$ where $*e = 0.09$ for Grade A and Grade A25 $= 0.07$ for Grade B, Grade X42 and Grade X46 $= 0.05$ for Grade X 5 2 a n d Grade X56 $= 0.04$ for Grade X60, Grade X 6 5 a n d Grade X70

* The value of e is based on SMYS for the API 5L and API 5LX respectively. For pipes covered by other nominated standards the appropriate value of e (calculated *pro rata* on SMYS) is to be substituted.

- (c) For pipe over 60.3 mm outside diameter, with a diameter/thickness ratio exceeding 10, which is seamless or electric-resistance welded, flattening tests shall be carried out in accordance with and meet the requirements of Clause 2.4.2(b) except that every pipe shall be tested. In addition, for electric-resistance welded pipe, both crop ends from each length of pipe shall be tested with the weld at the point of maximum bending.
- (d) For submerged-arc welded pipe, guided bend tests as specified by API 5L or API 5LX shall be made.

The jig dimension for tests shall be determined by the known yield stress or yield stress as determined by Clause 2.4.6 and the known nominal wall thickness or nominal wall thickness as determined by Clause 2.4.3. Where it is elected to take the minimum yield stress as not more than 166 MPa, the jig dimension for tests shall conform to API 5L Grade A requirements for the known nominal wall thickness, or nominal wall thickness as determined by Clause 2.4.3.

2.4.3 Determination of Wall Thickness. Unless the nominal wall thickness is known with certainty, it shall be determined by measuring the thickness at quarter points on one end of each length of pipe. If the batch of pipe is known to be of uniform grade, size, and nominal thickness, measurements shall be made on not less than 10 percent of the individual lengths, but on not less than ten lengths; thickness of the other lengths may be verified by applying a gauge set to the minimum thickness. Following such measurement, the nominal wall thickness shall be taken as the next commercial thickness below the average of all the measurements taken but in no case greater than—

- (a) 1.14 times the least measured thickness for all pipe under 508 mm outside diameter;
- (b) 1.11 times the least measured thickness for all pipe 508 mm outside diameter and larger.

2.4.4 Longitudinal Joint Factor. The welding process, mill quality control, and mill non-destructive testing requirements shall be demonstrated to be not less stringent than those required by pipe specifications approved for use by this standard. If this is not the case, such pipe shall not be qualified for use.

2.4.5 Weldability. Weldability shall be determined as follows:

A qualified welder shall make a circumferential weld in the pipe. The weld shall then be tested in accordance with requirements of Clause 4.11. The qualifying weld shall be made under the most severe conditions under which welding will be permitted in the field and by the same procedure as is to be used in the field. The pipe shall be considered weldable if the requirements specified in Clause 4.11 are met.

At least one such test weld shall be made—

- (a) for each 400 lengths of pipe in sizes up to and including 114.3 mm outside diameter;
- (b) for each 100 lengths of pipe in sizes over 114.3 mm outside diameter.

2.4.6 Determination of Yield Stress. Where the manufacturer's specified minimum yield stress, tensile strength, or elongation for the pipe is unknown, and no mechanical tests are made, the minimum yield stress for purposes of design shall be taken as not more than 166 MPa. Alternatively, the tensile properties may be established by performing the tensile tests prescribed by API 5LX, except that the frequency of such tests shall be as given in Table 2.4.6. All test specimens shall be selected at random.

TABLE 2.4.6
FREQUENCY OF TENSILE TESTS —
ALL SIZES OF PIPE

Lot consisting of	Frequency of tests
10 lengths or less	1 set of tests from each length
11 to 100 lengths	1 set of tests for each 5 lengths
Over 100 lengths	1 set of tests for each 10 lengths

The yield stress used in calculations required by this standard shall be either—

- (a) the lowest yield stress obtained in any set of tests on a lot; or
- (b) 80 percent of the average of all the yield stresses determined on a lot;

whichever is the lesser value, but in no case shall a value higher than 358 MPa be used.

2.4.7 Hydrostatic Test. Used pipe, the strength of which may have been reduced by corrosion or other deterioration, and pipe manufactured to a specification which does not specify a mill test shall be tested hydrostatically either length by length in a mill type test or as a whole in the field to at least the test pressure required to establish the maximum allowable operating pressure for which the pipe will be used in service.

2.5 FRACTURE TOUGHNESS.

2.5.1 General. In order to limit fracture propagation during pressure testing and operation of a pipeline, the need for specified minimum fracture toughness requirements for the components in the pipeline shall be fully investigated and the findings of the investigation shall be approved.

The investigation shall include consideration of the advisory information given in Appendix F, the design of the pipeline, and the assessment of the need to conduct fracture toughness tests.

Components in pipelines intended to operate at a hoop stress greater than 0.3 SMYS or with an operating stress greater than 85 MPa shall meet the requirements of this Clause (2.5).

Where the approved findings of the investigation show that measurement of resistance to brittle fracture is required, the requirements of Clause 2.5.4 shall be applied and where measurement of resistance to ductile fracture is required, the requirements of Clauses 2.5.4 and 2.5.5 shall be applied.

NOTE: The statistical system described in Clauses 2.5.4 and 2.5.5 enables pipes to be accepted on a heat basis.

2.5.2 Test Specimens. Test specimens for establishing the appearance of the surface of the fracture (Clause 2.5.4) and for determining the transverse energy absorption value (Clause 2.5.5) shall be removed from a sample pipe so that the length of a test piece is in the circumferential direction of the pipe and in the approximate position shown in Fig. 2.5.2.

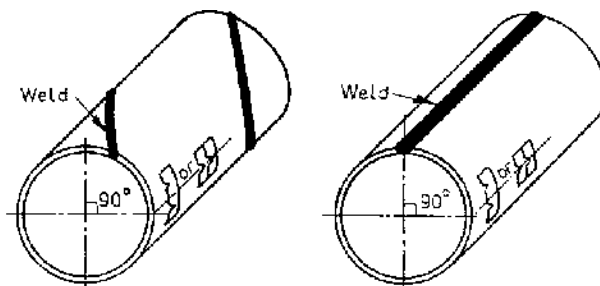


Fig. 2.5.2. FRACTURE TOUGHNESS—TEST SPECIMEN ORIENTATION

2.5.3 Test Temperature. The test temperature selected following the investigation shall be one of the following:

20, 10, 0, -10, -15, -20, -25, -30, -35°C.

2.5.4 Fracture Surface Appearance.

2.5.4.1 Tests. The fracture surface appearance shall be determined by either the dropweight tear test (Clause 2.5.4.2) or the Charpy test (Clause 2.5.4.3). Both tests are not required except when correlation between the two is required by Clause 2.5.4.2 (f).

2.5.4.2 Dropweight tear test. Dropweight tear tests shall be made in accordance with the following requirements:

- Two transverse test specimens shall be taken from one length of sample pipe from each heat as shown in Fig. 2.5.2.
- The testing procedure and the evaluation of the fracture surface appearance shall be in accordance with AS 1330.
- The test temperature shall be in accordance with Clause 2.5.3.
- The heat is acceptable if the average value of the fracture surface shear area of the two specimens representing the heat is not less than 75 percent.

Where the average of the two specimens is less than 75 percent, additional tests on two additional pipes (two specimens each) may be made to establish a new heat average. If the original values are excluded from a new average, the corresponding pipe shall be rejected. Where the new heat average is not less than 75 percent, the heat is acceptable.

Where the new heat average is less than 75 percent, all the pipes in the heat may be tested (two specimens each). Where 80 percent of the pipes have an average that equals or exceeds 75 percent, the heat is acceptable.

Where the heat is not acceptable, individual pipes are acceptable where each pipe average equals or exceeds 75 percent.

- Test pieces or specimens showing material defects or defective preparation, whether observed before or after breaking, may be discarded and replaced by other test pieces or specimens. Replacement test pieces or specimens shall be considered as original test pieces or specimens.

- Pipe tested in accordance with this Clause (2.5.4.2) shall be identified by an approved method.

2.5.4.3 Charpy V-notch impact test. Charpy V-notch fracture surface appearance tests shall be made in accordance with the following requirements:

- Three transverse test specimens shall be taken from one length of sample pipe from each heat as shown in Fig. 2.5.2.
- The test specimens shall be either 10 mm wide by 6.7 mm thick, or 10 mm wide by 5 mm thick. The test specimen thickness shall be the greatest that can be obtained by cutting and machining from the pipe wall.
- The testing procedure and the presentation of results of the test shall be in accordance with AS 1544, Part 2.
- The test temperature shall be in accordance with Clause 2.5.3.
- The fracture appearance shall be determined in accordance with AS 1544, Part 5.
- The fracture appearance requirement shall be determined by correlation with the dropweight tear test requirements of 75 percent shear. The correlation shall be made on the initial production heat and may be made on plate specimens. Sufficient dropweight tear test specimens shall be tested in accordance with AS 1330 to establish the transition temperature curve from 20 percent shear to 100 percent shear.

Three Charpy V-notch test specimens shall be tested at the temperatures equivalent to 75 percent shear in the dropweight tear test. The average of the shear areas at this temperature shall be the acceptable figure.

In determining the average, it shall be rounded to the nearest 5 percent figure above the average value of the three test specimens, e.g. where the shear areas of the results obtained from the three test specimens are 70, 85, 95, the average is 83.3 and the Charpy V appearance requirement is 85 percent.

Where changes in steelmaking practices occur and these changes may affect the fracture toughness of the pipe steel, the correlation shall be re-established.

- (g) Where the average fracture appearance fails to meet the requirements of paragraph (f) above or the assessment is in dispute, the pipe or heat shall only be retested in accordance with Clause 2.5.4.2.
- (h) Test pieces or specimens showing material defects or defective preparation, whether observed before or after breaking, may be discarded and replaced by other test pieces or specimens. Replacement test pieces or specimens shall be considered as original test pieces or specimens.
- (j) Pipe tested in accordance with this Clause (2.5.4.3) shall be identified by an approved method.

2.5.5 Transverse Energy Absorption. The transverse energy absorption value shall be determined by using the Charpy V-notch impact test in accordance with the following requirements; the minimum average energy value and the minimum individual energy value shall be approved:

- (a) Three transverse test specimens shall be taken from one length of sample pipe from each heat, as shown in Fig. 2.5.3.
- (b) The test specimens shall be either 10 mm wide by 6.7 mm thick, or 10 mm wide by 5 mm thick. The test specimen thickness shall be the greatest that can be obtained by cutting and machining from the pipe wall.
- (c) The testing procedure and the presentation of results of the test shall be in accordance with AS 1544, Part 2.
- (d) The test temperature shall be in accordance with Clause 2.5.3.
- (e) The heat is acceptable if both the average and individual energy values comply with the specified requirements. If either the average or individual energy values do not comply with the specified requirements, additional tests on two additional pipes (three specimens each), taken from the same heat as the original pipe, may be made. The heat is acceptable if the average of the nine test specimens complies with the specified requirements. The requirements of minimum individual values shall not apply to retests.
- (f) Test pieces or specimens showing material defects or defective preparation, whether observed before or after breaking, may be discarded and replaced by other test pieces or specimens. Replacement test pieces shall be considered as original test pieces or specimens.
- (g) Pipe tested in accordance with this Clause (2.5.5) shall be identified by an approved method.

2.6 VALVES, FITTINGS AND ACCESSORIES.

2.6.1 General. Valves, fittings and accessories shall be manufactured in compliance with a design based on a nominated standard (see Appendix A) or approved calculation criteria. A prototype or a production unit shall be tested or investigated to demonstrate that the item is suitable and safe for use in the proposed service and that it is capable of withstanding the field hydrostatic test pressure.

If the component is to be welded to the pipeline it shall be made of steel that can be welded on site to the requirements of Section 4 herein.

Valves, fittings, and accessories that are to be incorporated in the pipeline after it has been tested hydrostatically shall either—

- (a) be tested hydrostatically to the same pressure as the pipeline is to be tested; or
- (b) have pressure and temperature ratings equivalent to those for the pipe to which they are to be attached.

2.6.2 Valves, Flanges and Flanged Fittings. Valves, flanges, and flanged fittings shall be so designed and manufactured that they will be capable of withstanding the service conditions for which the pipeline is designed.

2.6.3 Steel Butt-welding Fittings. Steel butt-welding fittings shall be capable of withstanding the field hydrostatic test pressure of the pipeline specified in the design, without failure or leakage and without impairment of serviceability. A purchase order for such items should specify that the manufacturer shall supply the purchaser with the test pressure that he has established for each item.

2.6.4 Fabricated Steel Fittings. Every fitting fabricated from steel and produced in accordance with this Clause (2.6), shall comply with the requirements of Clause 3.5.

2.6.5 Gaskets and Ring Joints. Gaskets and ring joints shall be made of materials which are not injuriously affected by the fluid in the pipeline and shall be capable of withstanding the pressure, temperature, and environment to which they will be subjected in service.

2.6.6 Bolting. Bolting material shall be resistant to corrosion from the environment.

Bolting for steel flanges shall comply with ANSI B16.5 or BS 4882.

Bolts for insulated flanges may be of alloy steel and 3 mm under size, provided that the material complies with the requirements of ASTM A 193 or ASTM A 354.

Nuts shall be manufactured from steel complying with the relevant requirements of ASTM A 194, except that ASTM A 307 Grade B steel may be used for nuts used for ANSI 150 and ANSI 300 primary service rating flanges.

2.7 EXTERNAL PROTECTIVE COATING.

2.7.1 Pipeline Coating. Materials used to coat a pipeline shall be such that, in the particular environment, they will effectively protect the external surface of the pipeline from corrosion. The coating shall be able to resist damage due to storage, handling, installation, pressure testing, environmental and operational loads, strains and stresses.

The method of the application of the coating shall be approved and shall be continuously inspected. The criteria for acceptance, repair and rejection of the coating before final burial or submersion shall be approved.

The material shall have been demonstrated by tests, investigation or experience to be suitable for the method of installation, the service conditions of the pipeline and the environment.

For buried or submerged pipelines, the coating should—

- (a) be resistant to chemical, biological and microbiological attack in service;
- (b) be resistant to deterioration at the pipeline operating temperature;
- (c) have high electrical resistance and dielectric strength;
- (d) have electrical properties that are not significantly reduced by water absorption;
- (e) be compatible with the level of cathodic protection applied;
- (f) have a strong and durable bond with the pipe metal;
- (g) have sufficient mechanical strength and thickness to resist anticipated service conditions;
- (h) be sufficiently resistant to pinholing, embrittlement or cracking or other inherent mechanical weaknesses to enable a high electrical resistance to be maintained in service;
- (j) be capable of being repaired;
- (k) be resistant to deterioration due to ultraviolet radiation; and
- (l) where necessary, be suitable for the application of weight coating, anchors, clamps and supports.

NOTE: Some materials may not possess all these properties but may be suitable for a particular environment.

Consideration shall be given to any additional requirements that may be needed in areas where the environment of the pipeline changes, e.g. in the shore approach, at risers and water/air interfaces (see Clause 8.6.11).

2.7.2 Joint and Repair Coating. Materials used to coat joints and repair the external coating shall be compatible with the original coating and shall have been demonstrated by tests, investigation or experience to be suitable for the method of installation, the service conditions of the pipeline and the environment.

The method of the application of the coating shall be approved and shall be continuously inspected.

2.8 INTERNAL PROTECTIVE LINING.

2.8.1 Pipeline Lining. Materials used to line a pipeline shall be such that they will effectively protect the internal surface of the pipeline from corrosion. The lining shall be able to resist damage due to storage, handling, installation, pressure testing, environmental and operational loads, strains and stresses.

Where a 2-component catalyzed epoxy lining is specified, the method of application, inspection and acceptance procedures should comply with API RP 5L2.

The material shall have been demonstrated by tests, investigations or experience to be suitable for the method of installation, the service conditions of the pipeline and the environment.

The internal lining should—

- (a) have mechanical and chemical properties necessary to provide protection under the anticipated conditions;
- (b) have a strong and durable bond with the pipe metal; and
- (c) not deteriorate significantly on exposure to the fluid used in the pressure test or that to be transmitted.

2.8.2 Joint and Repair Lining. Where joints made in the pipe are to be lined and repairs made to the internal lining, the material used shall be compatible with the original lining and shall have been demonstrated by tests, investigations or experience to be suitable for the method of installation, the service conditions of the pipeline and the environment.

2.9 WEIGHT COATING. Weight coating shall —

- (a) be of sufficient thickness to give the required mass;
- (b) be applied over an external protective coating meeting the requirements of Clause 2.7;
- (c) contain sufficient reinforcement to avoid excessive cracking and spalling during laying operations and service.

2.10 GALVANIC ANODES. Galvanic anodes shall comply with AS 2239.

SECTION 3. DESIGN

3.1 DESIGN CONSIDERATIONS.

3.1.1 General. The requirements of this Section of the standard are intended to satisfy the minimum requirements of Clause 1.3(a).

In addition to the requirement that a pipeline shall be capable of withstanding the hoop stress generated by internal pressure when it is in operation, the submarine pipeline shall be able to withstand, without damage, the stresses imposed by the external hydrostatic head (see Clause 3.8.2.3) and the influence of the factors enumerated in this Clause (3.1). In some cases these additional requirements will result in the need to use pipe of greater wall thickness or SMYS, or both, than that necessary to meet the internal pressure design requirement. For this reason the standard provides for the design, construction, and operation of two types of pipeline as follows:

- (a) A pipeline designed throughout its length with uniform wall thickness and SMYS.
- (b) A pipeline designed with sections, not separated by valves, of different wall thicknesses or SMYS, or both. A pipeline designed in this manner is designated in the standard as a 'telescoped pipeline'.

3.1.2 Design Criteria. The design requirements of the standard are considered adequate for public safety under conditions usually encountered; however, the design shall provide reasonable protection against damage to the pipeline from unusual external conditions which may be encountered. Some of the protective measures that may be included are encasing the pipeline with pipe of larger diameter or protective concrete, or increasing the wall thickness of the pipe.

3.1.3 Environmental Data. A detailed knowledge of the environment in which the pipeline is to be laid is essential for satisfactory design. The appropriate authorities should be contacted to obtain details of any known obstructions along the proposed pipeline route, the location of shipping routes, anchorages, and fishing grounds, and other pertinent data.

A hydrographic survey should be made along the proposed route to ascertain the following specific information:

- (a) Water depths.
- (b) Profile of the sea bed.
- (c) Soil characteristics of the sea bed.
- (d) Strength and direction of tidal and other currents.
- (e) Water temperatures.
- (f) Location of obstructions on the sea bed.

NOTE: Appendix E gives recommendations for the hydrographic and meteorological investigations required for forecasting the probable maximum wind, waves, swell, and currents to which the pipeline may be exposed.

3.1.4 Environmental and Other Influences. The pipeline shall be designed in such a manner that it

should be capable of withstanding the effects of the following influences, in addition to those for which specific design requirements are included in the standard:

- (a) Forces on the pipeline itself resulting from the action of wind, swell, wave, and current during construction and operation.
- (b) Subsidence or scour of the sea bed, or erosion of the shore line, by wind, swell, wave, and current.
- (c) Marine growth on the pipeline and its coating, especially in connection with (a).
- (d) Dredging operations in the vicinity of the pipeline
- (e) Snagging of the pipeline by fishing gear and ships' anchors.
- (f) Buoyancy.
- (g) Forces resulting from construction of the pipeline.
- (h) Forces resulting from the attachment of branch connections.
- (j) Forces resulting from the attachment of the pipeline to a structure.
- (k) Forces resulting from anchoring or burying the pipeline.
- (l) Expansion and contraction resulting from internal and external pressures and from temperature changes.
- (m) Vibration from any source.

Competent engineering judgement, based on accepted engineering principles, experience, and practice, shall be used to ensure that the design meets the requirements of this Clause (3.1).

3.1.5 Application of Other Pipeline Standards. The design requirements in this standard are applicable to those parts of a pipeline that are located seaward of a point not more than 100 m landward of the highest high-water mark on record and to those parts of the pipeline that are to be located on platforms, piers, jetties, wharves, quays, trestles, and other structures.

Those parts of a pipeline located in the shore approach shall be designed according to the appropriate standard which covers, or would cover, the land section of that pipeline. For example, the design of the shore approach for a submarine gas pipeline would be governed by the design requirements of AS 1697, and, for a submarine liquid petroleum pipeline, AS 2018 would apply.

Compressor and pump stations located off shore in connection with submarine pipelines may be designed in accordance with the relevant requirements of AS 1697 or AS 2018.

3.2 DESIGN PRESSURE.

3.2.1 Internal Design Pressure. The internal design pressure of each component of a pipeline shall be the maximum internal pressure to which the component will be subjected during normal service.

3.2.2 External Design Pressure. The external design pressure of each component of a pipeline shall be the maximum external pressure to which the component will be subjected during construction, operation, and maintenance.

3.3 DESIGN TEMPERATURES. The design temperatures for components shall be the metal temperatures expected during construction, testing, and operation. Attention should be given to the properties of all materials which may be subjected to low temperatures during the construction or operation of the pipeline.

3.4 STABILITY OF PIPELINE. The design shall be such that will ensure that the pipeline is stable under all anticipated service conditions.

The pipeline shall be buried or anchored in the shore approach. Seaward of the shore approach the pipeline shall be buried, anchored, or provided with sufficient weight to limit undue movement from—

- (a) forces on the pipeline created by wave action and currents;
- (b) scour of the sea bed caused by wave action and currents.

NOTE: Burial may be necessary to afford protection against damage to the pipeline that could be caused by external conditions such as trawls and ships' anchors, even though it may not be required by consideration of stability.

3.5 ALLOWABLE HOOP STRESS. The hoop stress, f_H , used in design calculations for components shall be based on the pressure in the component and the metal temperature thereof under normal operating conditions and shall not be greater than that determined by the following equation:

$$f_H = F \times J \times S \times T$$

where

F = design factor which shall not be greater than that shown in Table 3.5(A) for components in the specified location

J = longitudinal weld joint factor which shall be 1.0 for pipe manufactured in accordance with an approved specification listed in Table 3.5(B); for other than listed approved pipe, Clause 2.4.4 applies

S = specified minimum yield stress, in megapascals, which shall be the value specified

in Table 3.5(B) for pipe manufactured in accordance with an approved specification; for other than approved pipe, Clause 2.4.6 applies.

T = temperature derating factor which shall be the value determined from Table 3.5(C).

3.6 STRESS LIMITS.

3.6.1 Internal Pressure Stresses. The calculated stresses due to internal pressure shall not exceed the applicable allowable stress value, f_H , determined by the formula in Clause 3.5.

3.6.2 External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the component is sufficient to prevent collapse due to the maximum external hydrostatic head expected during the service life of the pipeline.

3.6.3 Other Stresses. The sum of the longitudinal stresses produced by pressure, and other applicable influences (except those produced during construction), shall not exceed 80 percent of the specified minimum yield stress.

3.6.4 Test Condition Stresses. Stresses due to test conditions shall not exceed those established by Clause 6.4.

3.7 ALLOWANCES.

3.7.1 Corrosion. Where a wall thickness allowance is made for corrosion, it shall be included as part of the formula given in Clause 3.8.2.1. A wall thickness allowance for corrosion is not required if corrosion mitigation procedures are maintained to protect the pipeline against external and internal corrosion.

3.7.2 Protection Against Damage. Where the wall thickness of a component is increased in order to provide protection against damage from unusual external conditions (see Clause 3.1.2), the additional thickness shall be included as part of G in the formula given in Clause 3.8.2.1.

3.7.3 Threading and Grooving. Where a component is to be threaded or grooved, a wall thickness allowance for thread or groove depth shall be included as part of G in the formula given in Clause 3.8.2.1.

3.8 DESIGN OF COMPONENTS.

3.8.1 General. The design of components shall provide for the design criteria given in Clause 3.1.2 and the environmental factors in Clause 3.1.4, and shall be in accordance with this Clause (3.8).

TABLE 3.5(A)
DESIGN FACTOR FOR COMPONENTS

Location	Maximum value of F
Underwater except in shore approach	0.72
Shore approach	As required by relevant pipeline code for land construction
On piers, jetties, quays, and other structures	0.6
Risers on structures	0.6
Scraper traps, sphere senders, and sphere receivers	0.6

TABLE 3.5(B)
APPROVED PIPE SPECIFICATIONS, SMYS, AND LONGITUDINAL JOINT FACTORS

Specification	Grade or class	SMYS MPa	J factor
<i>Seamless:</i>			
API 5L, ASTM A 53, ASTM A 106	A	207	1
API 5L, ASTM A 53, ASTM A 106	B	241	1
ASTM A 524	I	241	1
ASTM A 524	II	207	1
API 5LX	X42	290	1
API 5LX	X46	317	1
API 5LX	X52	359	1
API 5LX	X56	386	1
API 5LX	X60	414	1
API 5LX	X65	448	1
API 5LX	X70	483	1
AS 1835	TS1, TS2	195	1
AS 1835	TS4, TS5	215	1
AS 1835	TS9, TS9H, TS10	235	1
AS 1835	TS13, TS14	265	1
<i>Electric resistance welded:</i>			
API 5L, API 5LS, ASTM A 53	A	207	1
API 5L, API 5LS	B	24	1
API 5LS, API 5LX	X42	290	1
API 5LS, API 5LX	X46	317	1
API 5LS, API 5LX	X52	359	1
API 5LS, API 5LX	X56	386	1
API 5LS, API 5LX	X60	414	1
API 5LS, API 5LX	X65	448	1
API 5LS, API 5LX	X70	483	1
AS 1836 Test Category IV	TW1, TW2	195	1
AS 1836 Test Category IV	TW4, TW5	215	1
AS 1836 Test Category IV	TW9, TW9H, TW10	235	1
AS 1836 Test Category IV	TW13, TW14	265	1
<i>Submerged arc welded:</i>			
API 5L, API 5LS	A	207	1
API 5L, API 5LS	B	241	1
API 5LS, API 5LX	X42	290	1
API 5LS, API 5LX	X46	317	1
API 5LS, API 5LX	X52	359	1
API 5LS, API 5LX	X56	386	1
API 5LS, API 5LX	X60	414	1
API 5LS, API 5LX	X65	448	1
API 5LS, API 5LX	X70	483	1
AS 1836 Test Category IV	TW1, TW2	195	1
AS 1836 Test Category IV	TW4, TW5	215	1
AS 1836 Test Category IV	TW9, TW9H, TW10	235	1
AS 1836 Test Category IV	TW13, TW14	265	1

TABLE 3.5(C)
TEMPERATURE DERATING FACTOR FOR STEEL PIPE

Metal temperature °C	Temperature derating factor, T
120 or less	1.000
150	0.972
180	0.929
200	0.905
230	0.869

NOTE: The temperature derating factor to be used for intermediate metal temperatures may be interpolated.

3.8.2 Straight Pipe.

3.8.2.1 Nominal wall thickness. The nominal wall thickness of straight sections of pipe and cylindrical components shall be equal to or greater than that determined by—

$$t_n = t + G \dots\dots\dots (3.8.2.1)$$

where

t_n = nominal wall thickness

t = minimum calculated thickness which shall be either—

(a) the wall thickness determined for internal pressure in accordance with Clause 3.8.2.2; or

(b) the wall thickness determined for external pressure in accordance with Clause 3.8.2.3;

whichever is the greater

G = sum of allowances for corrosion as required (see Clause 3.7.1), additional wall thickness if used as a protective measure (see Clause 3.7.2), and threading and grooving (see Clause 3.7.3).

3.8.2.2 Wall thickness of straight pipe under internal pressure. The minimum calculated wall thickness, t (expressed in millimetres) shall be determined by—

$$t = \frac{PD}{2f_H} \dots\dots\dots (3.8.2.2)$$

where

D = outside diameter of pipe, in millimetres

$f_H = F \times J \times S \times T$ (see Clause 3.5), in megapascals

P = internal design pressure, in megapascals and in no case shall t be less than the nominal wall thickness, t_n , shown in Table 3.8.2.

3.8.2.3 Wall thickness of straight pipe under external pressure. The minimum wall thickness of pipe shall be sufficient to prevent collapse of the pipe as a result of external hydrostatic pressure during both construction and service and in no case shall it be less than that shown in Table 3.8.2. For steel pipelines with a modulus of elasticity of 206×10^3 MPa and a yield stress in excess of 185 MPa, the following formula may be used to determine the collapse pressure, P_c , in megapascals:

$$P_c = 350 \times 10^3 (t/D)^3 \dots\dots\dots (3.8.2.3)$$

where

D = outside diameter of the pipe, in millimetres

t = minimum calculated wall thickness of the pipe, in millimetres.

3.8.3 Bends Made From Pipe. The wall thickness of pipe used in bends shall be not less than that for straight pipe (see Clause 3.8.2).

3.8.4 Valves and Fittings. The pressure/temperature rating of valves and fittings shall be in accordance with the approved standards (see Appendix A) and shall not be lower than the design pressure and temperature of the pipeline.

**TABLE 3.8.2
MINIMUM NOMINAL WALL THICKNESS**

Outside diameter	Nominal wall thickness, t_n millimetres	
	Plain pipe	Threaded pipe
60.3	2.3	4.0
73.0	2.3	5.0
88.9	2.3	5.6
101.6	2.3	5.9
114.3	2.3	5.9
141.3	2.3	7.1
168.3	2.9	7.1
219.1	3.3	8.8
273.0	3.6	
323.9	4.0	
355.6	4.5	
406.4	4.5	
457.0	4.8	
508.0	5.6	
559.0	5.6	
610.0	5.9	
660.0	5.9	
711.0	6.3	
762.0	6.3	
813.0	6.3	
864.0	6.3	
914.0	6.3	
965.0	8.0	
1016.0	8.8	

3.8.5 Welded Branch Connections.

3.8.5.1 General. Where branch connections are made to pipe in the form of a single connection, or in a header or manifold as a series of connections, the design shall be adequate to control the stresses in the pipe within safe limits. The stresses in the remaining pipe wall due to the opening in the pipe or header, the shear stresses produced by the pressure acting on the area of the branch opening, and any external loadings due to thermal movement, mass, vibration, etc, shall be taken into account.

3.8.5.2 Connection. Welded branch connections shall conform to an acceptable type as shown in Appendix G, Fig. G3.8.5A, B, C, and D.

All welds joining the headers, branch, and reinforcing member shall be equivalent to those shown in Fig G3.8.5(B) and (C).

Where a reinforcing member is required, and the branch diameter is such that a localized type of reinforcing member would extend around more than half the circumference of the header, then a completely encircling type of reinforcing member shall be used, regardless of the design hoop stress; alternatively a smoothly wrought steel tee of proven design or an extruded header may be used.

The reinforcement shall be designed in accordance with Clause 3.8.5.3 and the welded branch connections shall comply with the relevant additional requirements

described in the following paragraphs (a) to (d) and specified in Table 3.8.5:

- (a) Smoothly contoured wrought tees or crosses of proven design or integrally reinforced extruded headers are preferred. Where such tees, crosses, or headers are not used, the reinforcing member shall extend completely around the circumference of the header (see Fig. G3.8.5(D)). The inside edges of the finished opening, wherever possible, shall be rounded to 3 mm radius. If the encircling member is thicker than the wall of the header, the ends shall be tapered to a thickness not greater than the thickness of the wall of the header and continuous fillet welds shall be made. Pads, partial saddles, or other types of localized reinforcement shall not be used.
- (b) The reinforcing members may be of the completely encircling type (see Fig. G3.8.5 (D)), pad or saddle type (see Fig. G3.8.5 (C)), or a welding-outlet fitting. Where the reinforcing member is attached to the header by fillet welding, the edges of the reinforcing member shall be tapered to a thickness not in excess of twice the thickness of the header.
- (c) Reinforcement of openings is not mandatory. However, it may be required for special cases involving pressure over 700 kPa, thin-wall pipe, or severe external loads.
- (d) Reinforcement is not required for openings 60.3 mm or less in diameter (see Fig. G3.8.5(B) for typical details); however, care shall be taken to provide suitable protection against vibration and other external forces to which these small openings are frequently subjected.

TABLE 3.8.5
REINFORCEMENT OF WELDED BRANCH
CONNECTIONS—SPECIAL REINFORCEMENT

Ratio of design hoop stress to specified minimum yield stress in the header	Relevant paragraph of Clause 3.8.5.2, according to ratio of nominal branch diameter to nominal header diameter		
percent	< 25 percent	≥ 25 < 50 percent	≥ 50 percent
< 20	(c)	(c)	(c)
≥ 20 < 50	(b), (d)	(b)	(a)
≥ 50	(a), (d)	(a)	(a)

3.8.5.3 Reinforcement of single openings. Where reinforcement of a welded branch connection is required (see Clause 3.8.5.2), the design shall be in accordance with the following requirements:

- (a) The reinforcement required in the crotch section of a welded branch connection shall be determined by the rule that the metal area available for reinforcement shall be equal to or greater than the required cross-sectional area, as defined in paragraph (b), and in Fig. G3.8.5(A).
- (b) The required cross-sectional area, A_R , is expressed in square millimetres and defined as—

$$A_R = d t_h$$

where

d = length of the finished opening in the header wall measured parallel to the axis of the header, in millimetres

t_h = minimum calculated wall thickness of the header (see Clause 3.8.2.2), in millimetres.

- (c) The area available for reinforcement shall be the sum of—
 - (i) the cross-sectional area resulting from any excess thickness available in the header thickness over the minimum required for the header as defined in paragraph (b) and which lies within the reinforcement area as defined in paragraph (d);
 - (ii) the cross-sectional area resulting from any excess thickness available in the branch wall thickness over the minimum thickness required for the branch and which lies within the reinforcement area as defined in paragraph (d);
 - (iii) the cross-sectional area of all added reinforcing metal which lies within the reinforcement area, as defined in paragraph (d), including that of solid weld metal which is attached to the header or branch, or both.

- (d) The area of reinforcement is shown in Fig. G3.8.5(A) and is defined as a rectangle whose length shall extend a distance d on each side of the transverse centreline of the finished opening and whose width shall extend a distance of 2.5 times the header wall thickness on each side of the surface of the header wall, except that in no case shall it extend more than 2.5 times the thickness of the branch wall from the outside surface of the header or of the reinforcement, if any.

- (e) The material of any added reinforcement shall have an allowable working stress at least equal to that of the header wall, except that material of lower allowable stress may be used if the area is increased in direct proportion to the allowable stresses for header and reinforcement material respectively.

- (f) The material used for ring or saddle reinforcement may be of specifications differing from those of the pipe, provided that the cross-sectional area is made in correct proportion to the relative strength of the pipe and reinforcing material at the operating temperatures and provided that it has welding qualities compatible with those of the pipe. No allowance shall be made for the additional strength of material having a higher strength than that of the part to be reinforced.
- (g) Where rings or saddles are used that cover the weld between branch and header, a vent hole shall be provided in the ring or saddle to reveal leakage in the weld between branch and header and to provide venting during welding and heat treatment. Vent holes should be plugged during service to prevent the entry of matter which could cause corrosion between the pipe and the reinforcing member, but the plugging material should not be capable of retaining pressure within the crevice.
- (h) The use of ribs or gussets should not be considered as contributing to reinforcement of the branch connection. This does not prohibit the use of ribs or gussets for purposes other than reinforcement, such as stiffening.
- (j) The branch shall be attached by a weld for the full thickness of the branch or header wall plus a fillet weld, W_1 , as shown in Fig. G3.8.5(B) and (C). Concave fillet welds should be used to further minimize corner stress concentration. Ring or saddle reinforcement shall be attached as shown by Fig. G3.8.5(C). Where a full fillet weld is not used, it is recommended that the edge of the reinforcement be relieved or bevelled at approximately 45 degrees to merge with the edge of the fillet.
- (k) Reinforcement rings and saddles shall be accurately fitted to the parts to which they are attached. Fig. G3.8.5(C) and (D) illustrates some acceptable forms of reinforcement.
- (l) As branch connections attached at any angle less than 85 degrees to the header become progressively weaker as the angle becomes smaller, the design shall therefore be given individual study and sufficient reinforcement shall be provided to compensate for the inherent weakness of this construction. The use of encircling ribs to support the flat or re-entering surfaces is permissible, and may be included in the strength calculations. It should be noted that stress concentrations near the ends of partial ribs, straps, or gussets may negate their reinforcing value.
- (m) All unwelded sections of saddles or rings (such as are illustrated as 'optional weld' in Fig. G3.8.5(D)) shall be sealed at the edges with a suitable compound to prevent the entry of corrosive matter.

3.8.6 Reinforcement of Multiple Openings.

3.8.6.1 Overlapping of effective reinforcement areas. Where two or more adjacent branches are spaced at less than twice their average diameter (so that their effective areas of reinforcement overlap), the group of openings shall be reinforced in accordance with Clause 3.8.5.2. The reinforcing metal shall be added as a combined reinforcement, the strength of which shall equal the combined strengths of the reinforcements that would be required for the separate openings. In no case shall any portion of a cross-section be considered to apply to more than one opening, or be evaluated more than once in a combined area.

3.8.6.2 Minimum distance between adjacent openings. Where more than two adjacent openings are to be provided with a combined reinforcement, the minimum distance between centres of any two of these openings shall be at least 1.5 times the average diameter of both openings, and the area of reinforcement between them shall be at least equal to 50 percent of the total required for these two openings on the cross-section being considered.

When the distance between centres of two adjacent openings is less than 1.33 times their average diameter, no allowance shall be made for the reinforcement metal between these two openings.

3.8.6.3 Closely spaced openings. Any number of closely spaced adjacent openings, in any arrangement, may be reinforced provided that the group is treated as one opening which has a diameter that would enclose all the closely spaced openings.

3.8.7 Extruded Outlets.

3.8.7.1 Application. This Clause (3.8.7) applies to extruded outlets in which the reinforcement is integral. An extruded outlet is defined as an outlet in which the extruded lip at the outlet has a height above the surface of the header which is equal to or greater than the radius of curvature of the external contoured portion of the outlet, i.e. —

$$h_o \geq r_o$$

(see Clause 1.4.1 and Appendix G, Fig. G3.8.7(A), (B), (C) and (D) for nomenclature).

This Clause does not apply to any nozzles or branch connections in which additional material is applied in the form of rings, pads, or saddles. It applies only to cases where the axis of the outlet intersects, and is perpendicular to, the axis of the header.

3.8.7.2 Dimensions. Fig. G3.8.7(A), (B), (C), and (D) in Appendix G defines the pertinent dimensions and limiting conditions. Limitations applicable to Fig G3.8.7(A), (B), (C), and (D) are as follows:

- (a) Minimum value of r_o . This dimension shall not be less than $0.05d_b$ except that on branch outside diameters larger than 762 mm it need not exceed 38 mm.

- (b) *Maximum value of r_o .* For outlet pipe of outside diameter 168 mm and larger, this dimension shall not exceed $0.10d_b + 12$ mm. For outlet pipe less than 219 mm in outside diameter, it shall not exceed 30 mm.
- (c) Where the external contour contains more than one radius, the radius of any arc sector of approximately 45 degrees shall meet the requirements of paragraphs (a) and (b).
- (d) Machining shall not be employed in order to meet the requirements of paragraphs (a), (b), and (c).

3.8.7.3 Required area. The required area A_R is defined as equal to $K(D_o t_h)$, where K shall be taken as follows:

$$d_d/D_h > 0.60 \quad \dots \quad K = 1.00$$

$$d_d/D_h > 0.15 \leq 0.60 \quad K = 0.60 + 0.66(d_b/D_h)$$

$$d_d/D_h \leq 0.15 \quad \dots \quad K = 0.70$$

3.8.7.4 Reinforcement area. The area of reinforcement shall be the sum of the areas $A_1 + A_2 + A_3$ as defined below:

A_1 = the area lying within the reinforcement zone resulting from any excessive thickness available in the header wall, in square millimetres, i.e.—

$$A_1 = D_o (T_h - t_h)$$

A_2 = the area lying within the reinforcement zone resulting from excessive thickness available in the branch pipe wall, in square millimetres, i.e.—

$$A_2 = 2L (T_b - t_b)$$

A_3 = the area lying within the reinforcement zone resulting from excessive thickness available in the extruded outlet lip, in square millimetres, i.e.—

$$A_3 = 2r_o (T_o - T_b)$$

3.8.7.5 Reinforcement of multiple openings. The requirements in Clause 3.8.6 shall be followed except that the required area and reinforcement area shall be as given in Clauses 3.8.7.3 and 3.8.7.4, respectively.

3.8.7.6 Markings. A section containing extruded outlets shall be indelibly marked to show the following:

- (a) Manufacturer's name, identification, or trademark.
- (b) Design pressure.
- (c) Design temperature.

3.8.8 Attachments. External and internal attachments to a pipeline shall be designed so they will not cause flattening of the pipe or excessive localized bending stresses. (For the design of supporting elements, see Clause 3.16.3.)

3.9 DESIGN OF CLOSURES FOR PIPE ENDS. Pipe ends may be closed by suitable fittings such as valves, blank flanges, or bullplugs which comply with the requirements of specifications listed in Appendix A for the maximum pressure and temperature to which they will be exposed during testing and operation.

Alternatively, dished ends, designed in accordance with the appropriate requirements of AS 1210 may be used; they shall be designed using the same design pressure and temperature as used for the design of the pipeline.

Fishtails and orange peel bullplugs shall not be used to close the end of a pipe.

A flat plate attached to a pipe end by welding shall not be used where it is intended that the pipeline will operate at a hoop stress level greater than 20 percent of specified minimum yield stress.

3.10 DESIGN OF FLANGES. Flanges manufactured in accordance with Clause 3.13.5 and the standards listed in Appendix A shall be considered suitable for use at the pressure/temperature ratings specified by such standards.

The hubs on welding neck flanges that have dimensions complying with ANSI B16.5 may be taper bored when they are to be attached to thin-wall pipe. It is recommended that the taper not exceed one to three. Flanges for attachment to thin-wall pipe should be designed to the requirements of MSS SP-44.

Slip-on flanges of rectangular cross-section shall be designed so that flange thickness is increased to provide strength equal to that of the corresponding hubbed slip-on flange specified in ANSI B16.5, as determined by calculations made in accordance with AS 1210.

Special flanges shall be designed in accordance with AS 1210.

3.11 DESIGN OF REDUCERS. The design of reducer fittings manufactured in accordance with ANSI B16.5 and B16.9, MSS SP-75, or BS 1640 shall be considered suitable for use at the pressure/temperature ratings specified by such standards. Smoothly contoured reducers fabricated to the same nominal wall thickness and type of steel as the adjoining pipes shall be considered suitable for use at the pressure/temperature ratings of these pipes. Reducer fittings not manufactured in accordance with the standards listed in this Clause shall be designed in accordance with Clause 3.12. Where appropriate, changes in diameter may be accomplished by the use of elbows, reducing outlet tees, or valves.

3.12 DESIGN OF OTHER PRESSURE-CONTAINING COMPONENTS. Pressure-containing components which are not included in the standards listed in Appendix A, and for which design formulas or procedures are not given herein, may be used where the design of similarly shaped, proportioned, and sized components has been proven satisfactory by successful performance under comparable service conditions. Interpolation may be made between similarly-shaped proved 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 at least one of the following:

- (a) Proof tests (as are described in AS 1210).

- (b) Experimental stress analysis.
- (c) Theoretical calculations.

The design of special components, other than assemblies consisting of standard pipe and fittings joined by circumferential welds, fabricated by welding, shall be in accordance with recognized engineering practice and applicable requirements of this standard. Where the strength of such components cannot be calculated or determined with reasonable accuracy under the provisions of the standard, the maximum allowable operating pressure shall be established in accordance with AS 1210.

3.13 LIMITS TO SELECTION OF COMPONENTS.

3.13.1 Steel Pipe.

3.13.1.1 New pipe. New steel pipe of a known specification listed in Appendix A may be used in accordance with the design formulas of Clause 3.8.2.2 and Clause 3.8.2.3, subject to the inspection and testing requirements of Section 6.

3.13.1.2 Used pipe. Used steel pipe of a known specification listed in Appendix A and complying with the requirements of Clause 2.3.5 may be used in accordance with the design formulas in Clause 3.8.2.2 and Clause 3.8.2.3, subject to the inspection and testing requirements of Section 6.

3.13.1.3 Coatings and linings. External or internal coatings or linings of cement, plastics, or other materials may be used on pipe complying with the requirements of the standard. These coatings or linings shall not be considered to add strength to the pipe.

3.13.2 Fittings. Where steel butt-welding fittings are used, they shall comply with ANSI B 16.9, B16.18, MSS SP-75, or BS 1640.

Where steel flanged fittings are used, they shall comply with ANSI B16.5 or BS 3293.

Fittings larger than those included in the nominated standards or otherwise departing from dimensions listed in the standards referred to in this Clause may be used provided that the designs meet the requirements of Clause 3.12.

3.13.3 Bends, Mitres and Elbows.

3.13.3.1 Bends made from pipe. Bends may be made, in accordance with Clause 5.7.2, by bending pipe when it is designed in accordance with Clause 3.8.2.2 or Clause 3.8.2.3.

The minimum radius of cold bends made in the field shall be as shown in Table 3.13.3.

TABLE 3.13.3
MINIMUM RADIUS OF COLD BENDS
MADE IN THE FIELD

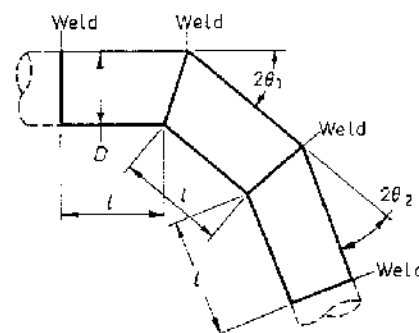
Pipe outside diameter	Minimum radius of bend
mm	pipe outside diameters
323.8 and smaller	18
353.6	21
406.4	24
457.0	27
508 and larger	30

NOTE: In some cases, thin-wall pipe will require the use of an internal mandrel when being bent to the minimum radius.

3.13.3.2 Mitred ends. Where it is intended that the pipeline will be 'pigged', the bend shall be designed so that the passage of the pig is unimpeded.

A mitre bend shall be designed, constructed, and tested in accordance with the following requirements:

- (a) All sections of the bend shall be made from pipe having the same wall thickness and grade.
- (b) The minimum distance, measured at the crotch, between the welds shall be not less than one pipe diameter (see Fig. 3.13.3).



2θ = angle of deflection
 D = diameter of pipe
 l = length of crotch (not less than D)

Fig. 3.13.3. A MITRE BEND CONSISTING OF TWO MITRE JOINTS

- (c) The hoop stress shall be calculated by treating each section as a straight pipe and applying the formulas in Clauses 3.8.2.2 and 3.8.2.3.
- (d) A mitre bend shall be subjected to a hydrostatic pressure test, in accordance with Clause 6.4, either before or after it is incorporated into the pipeline. The minimum test pressure shall be 1.25 times the maximum allowable operating pressure.
- (e) A mitre bend shall not be used where it is intended to operate at a hoop stress greater than 40 percent of specified minimum yield stress, calculated in accordance with Clause 3.5.
- (f) A mitre bend intended to operate at a hoop stress 40 percent or less but greater than 20 percent of specified minimum yield stress, calculated in accordance with Clause 3.5, shall be welded from one or both sides in accordance with the requirements of Section 4, shall be visually inspected in accordance with the requirements of the standard, and shall be examined radiographically. In addition to complying with the requirements of Clause 4.13, each weld shall have full penetration.

The angle of deflection shall not exceed 12.5 degrees at each mitre joint.

- (g) A mitre bend intended to operate at a hoop stress 20 percent or less but greater than 10 percent of specified minimum yield stress, calculated in accordance with Clause 3.5, shall be welded in accordance with the requirements of Section 4. Each weld shall be visually examined and shall have full penetration. It should also be subjected to non-destructive testing.

The angle of deflection shall not exceed 12.5 degrees at each mitre joint.

- (h) A mitre bend intended to operate at a hoop stress 10 percent or less of specified minimum yield stress, calculated in accordance with Clause 3.5, shall be welded in accordance with the requirements of Section 4. Each weld shall be visually examined.

The angle of deflection shall not exceed 90 degrees at each mitre joint.

3.13.3.3 Fittings not complying with a standard listed in this standard. Where it is intended that the pipeline be 'pigged', the bends or elbows shall be so designed that the passage of the pig is unimpeded.

Factory-made bends and factory-made wrought steel elbows may be used provided that they comply with the design requirements of Clause 3.8.2.2 or Clause 3.8.2.3, and the construction requirements of Clause 5.7. Such fittings shall have approximately the same physical and chemical properties as the pipe to which they are welded.

3.13.3.4 Wrinkle bends. Wrinkle bends shall not be used.

3.13.3.5 Couplings. Threaded couplings of cast, malleable or wrought iron shall not be used.

3.13.3.6 Reducers. The diameter of a pipeline may be reduced by the use of smoothly contoured reducers manufactured in accordance with ANSI B16.5, B16.9, MSS SP-75, or BS 1640, or designed to the requirements of Clause 3.12.

3.13.3.7 Orange-peel swages. Orange-peel swages shall not be used in pipelines operating at hoop stresses of more than 20 percent of the specified minimum yield stress of the pipe.

3.13.3.8 Intersections. Intersection fittings and welded branch connections may be used if they meet the requirements of Clause 3.13.2 and are designed in accordance with Clause 3.12.

3.13.3.9 End closures. Closure fittings may be used when they meet the requirements of Clause 3.9.

3.13.3.10 Special fittings and connections. Cast, forged, wrought, or welded steel fittings and connections differing from those specified in the applicable ANSI, MSS, or BSI standards may be used, provided that their design meets the requirements of Clause 3.12.

3.13.4 Valves.

3.13.4.1 Valves complying with standards and specifications listed in this standard. Steel valves complying with standards and specifications listed in this standard may be used, subject to the following requirements:

- (a) The valves may contain certain cast, malleable or wrought iron parts as provided for in API 6D.
- (b) Cast iron valves shall not be used in hydrocarbon service.
- (c) Working pressure ratings of the steel parts of steel valves are applicable within the temperature limits of -30°C to $+120^{\circ}\text{C}$. Where resilient, rubber-like, or plastics materials are used for valves or seats, they shall be capable of withstanding the design pressure and temperature.
- (d) Each part of the valve that will be in contact with the fluid stream shall be made of materials that are compatible with each fluid that it is anticipated will flow through the pipeline.
- (e) Each gate, ball, plug, or non-return valve shall be both hydrostatically shell tested and hydrostatically seat tested without leakage to the relevant requirements of API 6D.
- (f) Each valve other than a non-return valve shall be equipped with a means for clearly indicating the position of the valve (open, closed, etc).
- (g) Each valve shall be indelibly marked on the body or on a permanently attached nameplate to show at least the following:
 - (i) Manufacturer's name or trademark.
 - (ii) Class designation or the maximum working pressure to which the valve may be subjected.
 - (iii) Body material designation (and the end connection material if more than one type is used).
 - (iv) Nominal valve size.

3.13.4.2 Valves manufactured to standards and specifications not nominated in this standard. Valves that comply with standards and specifications not listed in Appendix A may be used, provided that their design is of at least equal strength and tightness and they are capable of withstanding the same test requirements as in these standards and their structural features satisfy the material specifications and test procedures of valves in similar service specified in the nominated standards.

3.13.5 Flanges and Flanged Fittings.

3.13.5.1 General. Flanges and flanged fittings shall comply with the following requirements:

- (a) Each flange or flanged fitting shall comply with the minimum requirements of ANSI B16.5 for steel pipe flanges and flanged fittings, or MSS SP-44 for steel pipeline flanges, or the equivalent.
- (b) Each flanged assembly shall be capable of withstanding the maximum pressure at which the pipeline is to be operated and of maintaining its mechanical properties at all temperatures to which it is anticipated that it may be subjected in service.

- (b) Experimental stress analysis. **3.13.5.2 Flange facings.** Steel flanges shall have contact faces in accordance with ANSI B16.5 or MSS SP6.

Special facings are permissible provided that they are capable of withstanding the same tests as those in ANSI B16.5.

3.13.6 Gaskets and Ring Joints.

3.13.6.1 General. Gaskets and ring joints shall be made of materials which are not injuriously affected by the fluid in the pipeline and shall be capable of withstanding the pressure, temperature, and environmental conditions to which they will be subjected in service.

3.13.6.2 Gaskets and rings for ring joints. Gaskets complying with ANSI B 16.20, ANSI B16.21, or BS 3381 may be used.

Metallic gaskets, other than ring type or spirally-wound metal asbestos, shall not be used with ANSI Series 150 Pound primary service rating or lighter flanges.

The use of metal or metal-jacketed asbestos (either plain or corrugated) is not limited according to pressure, provided that the gasket material is suitable for the service temperature. These types of gaskets are recommended for use with the small male and female, or the small tongue and groove, facings. They may also be used with steel flanges with any of the following facings: lapped, large male and female, large tongue and groove, or raised.

Asbestos composition gaskets may be used as permitted in ANSI B16.20. This type of gasket may be used with any of the various flange facings except small male and female, or small tongue and groove.

Rings for ring joints shall be of dimensions established in ANSI B16.20. The materials for these rings shall be suitable for the service conditions encountered and shall be softer than the flanges.

3.13.6.3 Special gaskets. Special gaskets, including insulating gaskets, may be used provided they are suitable for the temperatures, pressure, fluid, and other conditions to which they may be subjected.

3.13.7 Bolting. Threads on bolts or stud bolts shall extend completely through the nuts.

Nuts shall comply with ASTM A 194, except that ASTM A 307 Grade B nuts may be used on ANSI 150 and ANSI 300 flanges.

Bolting for steel flanges shall comply with ANSI B 16.5 or BS 4882.

Bolts for insulated flanges may be of alloy steel and 3 mm undersize, provided that the material complies with the requirements of ASTM A 193 or ASTM A 354.

Bolting for special flanges, designed in accordance with Clause 3.10, shall comply with the applicable section of AS 1210.

3.14 USED COMPONENTS. Used components such as fittings, elbows, bends, intersections, couplings, reducers, closures, flanges, and valves may be re-used. Such components shall be cleaned, examined, and reconditioned, if necessary, to ensure they comply

with all requirements for the intended service, and shall be sound and free of defects.

In addition, the re-use shall be contingent on the identification of the specification under which the item was originally produced.

Where the specification cannot be identified, reuse of a component shall be restricted to a maximum operating pressure based on a yield stress of 166 MPa or less.

3.15 LIMITS TO SELECTION OF JOINTS.

3.15.1 Welded, Flanged, and Threaded Joints. Welded joints shall comply with the relevant requirements of Section 4.

Flanged joints shall comply with Clauses 3.13.5, 3.13.6 and 3.13.7.

All external pipe threads on components shall be taper pipe threads. They shall be line pipe threads in accordance with API 5B or AS 1722 or NPT threads in accordance with ANSI B2.1. All internal pipe threads on components shall be taper threads, except for pipes 60.3 mm and less in diameter and designed for pressures not exceeding 1050 kPa, in which case parallel threads may be used.

3.15.2 Sleeve, Coupled, and Other Patented Joints. Sleeve, coupled, and other patented joints, except those manufactured from cast iron, may be used provided that—

- (a) a prototype joint has been subjected to proof tests to determine the safety of the joints under simulated service conditions (when vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or other severe conditions are anticipated, the applicable conditions shall be incorporated in the tests);
- (b) adequate provision is made to prevent separation of the joint and to prevent longitudinal or lateral movement beyond the limits provided for in the joining member.

3.16 PIPELINE FLEXIBILITY, SUPPORTS, AND RESTRAINTS.

3.16.1 Expansion and Flexibility. Formal calculations shall be required where reasonable doubt exists concerning the adequacy of the flexibility of the pipeline.

Sufficient flexibility shall be provided to prevent expansion or contraction from causing excessive stresses in the material of components, excessive bending moments at joints, or excessive forces at anchorage or guide points.

Expansion calculations are necessary for pipelines only if significant temperature changes are expected, such as when the pipeline is to carry heated oil. Thermal expansion may cause movement at points where the pipeline terminates, or changes direction or size. Unless such movements are restrained by suitable anchors, the necessary flexibility shall be provided.

3.16.2 Properties.

3.16.2.1 Stress values. There are fundamental differences in loading conditions between the restrained portions of the pipeline and the portions not subject to substantial axial restraint. Therefore, different limits

on allowable longitudinal expansion stresses are necessary.

3.16.2.2 Restrained pipelines. The net longitudinal compressive stress, f_L , due to the combined effects of changes in temperature and fluid pressure shall be calculated from the following formula, and expressed in megapascals:

$$f_L = E\alpha(T_2 - T_1) - \mu f_H \dots\dots\dots 3.16.2.2$$

where

- E = modulus of elasticity of steel at ambient temperature, in megapascals
 f_H = hoop stress due to fluid pressure, in megapascals
 T_1 = temperature at time of installation, in degrees Celsius
 T_2 = maximum or minimum operating temperature, in degrees Celsius
 α = coefficient of linear expansion
 = $11.7 \times 10^{-6}/^\circ\text{C}$ for carbon and low alloy high tensile steels
 μ = Poisson ratio
 = 0.30 for steel

The net longitudinal stress becomes compressive for a moderate increase of T_2 and according to the maximum shear theory of failure this compressive stress adds directly to the hoop stress to increase the equivalent tensile stress available to cause yielding. This equivalent tensile stress shall not exceed 90 percent of the specified minimum yield stress of the pipe, calculated for nominal pipe wall thickness. Beam bending stresses shall be included in the longitudinal stress for those portions of the restrained pipeline which are supported above ground.

3.16.2.3 Unrestrained pipelines. Stresses due to expansion in those portions of the pipeline that lack substantial axial restraint shall be combined in accordance with the following formula, thus giving the maximum calculated expansion stress, f_e , expressed in megapascals

$$f_e = \sqrt{(f_b^2 + 4f_t^2)} \dots\dots\dots 3.16.2.3$$

where

- f_b = $\sqrt{[(i_b M_i)^2 + (i_o M_o)^2]}/Z$ (equivalent bending stress), in megapascals
 i_b = stress intensification factor, under bending, in plane of member (see Table 3.16.2)
 i_o = stress intensification factor, under bending, out of or transverse to plane of member (see Table 3.16.2)
 M_i = bending moment in plane of member (the moments in the header and branch portions shall be considered separately for elbows or tees), in millinewton metres
 M_o = bending moment out of or transverse to plane of member, in millinewton metres
 Z = section modulus of pipe, in millimetres cubed
 f_t = $M_t/2Z$ (torsional stress), in megapascals
 M_t = torsional moment, in millinewton metres

The maximum calculated expansion stress, f_e , based on 100 percent of the expansion, with modulus of elasticity for cold condition, and without considering fluid pressure

stress, shall not exceed 72 percent of the specified minimum yield stress of pipe.

The sum of the longitudinal stresses due to pressure, and other sustained external loading shall not exceed 80 percent of the allowable stress at the highest temperature condition. It is not necessary to consider wind and earthquake loads as occurring concurrently.

3.16.2.4 Stress analysis. The following basic assumptions and requirements shall be included in the stress analysis of a pipeline:

- The effect of restraints (including but not limited to supports, friction, branch connections, and lateral interferences) shall be considered in the stress calculations.
- Calculations shall take into account stress intensification factors found to exist in components other than plain straight pipe. Credit may be taken for extra flexibility of such components. In the absence of more directly applicable data, the flexibility factors and stress intensification factors shown in Table 3.16.2 may be used.
- Nominal dimensions of pipes and fittings shall be used in flexibility calculations.
- Calculations of pipe stresses in loops, bends, and offsets shall be based on the total range of temperature, from minimum to maximum, normally expected regardless of whether the pipeline is cold sprung. In addition to expansion of the pipeline itself, the linear and angular movements of the structure to which it is attached shall be considered.
- Calculations of thermal forces and moments on anchors and structures shall be based on either the difference between the installation temperature and the minimum or maximum anticipated operating temperature, or the difference between the minimum or maximum operating temperature, whichever is the greater.

3.16.3 Supports and Anchors.

3.16.3.1 General. A pipeline shall be supported so that excessive vibration is prevented or damped. It shall be anchored sufficiently to prevent undue strains on connections. Provision shall be made for electrical insulation to guard against earthing of the pipeline, as deemed necessary. Bends or offsets in the pipe cause longitudinal forces which shall be resisted by anchorage at the bend, by restraint due to friction of the soil, or by longitudinal stresses in the pipe.

3.16.3.2 Materials, design and installation. Permanent clamps, supports, and anchors shall be fabricated from durable materials, and shall be designed and installed to suit the service conditions in the pipe.

Where steel materials of unknown specifications are used for structural supports and restraints, the stress value used in the design calculations shall not be greater than 117 MPa.

3.16.3.3 Forces on pipes above ground. Unrestrained pipe shall have sufficient strength to withstand without failure the maximum end-force due to the internal pressure, as well as any additional forces due to thermal expansion or contraction, or to the mass of the pipe and contents.

3.16.3.4 Attachment of anchors, supports, and clamps. Anchors, supports, and clamps shall be designed and attached to the pipe in such a way that excessive local stress concentrations in the pipe wall are avoided.

Where a pipeline is designed to operate at a hoop stress of 50 percent or more of the specified minimum yield stress, the support or clamp shall completely encircle the pipe. Where it is necessary to provide positive attachment, the pipe may be welded to the encircling member only; the support or clamp shall be attached to the encircling member and not to the pipe. The connection of the pipe to the encircling member shall be by continuous, rather than intermittent, welds.

Where a pipeline is designed to operate at a hoop stress of less than 50 percent of the specified minimum yield stress, structural supports or anchors may be welded directly to the pipe. The dimensions and welding strength of such attachments shall comply with standard structural practice.

3.16.3.5 Restraint due to soil friction. The adequacy of anchorage by soil friction for protection against movement due to bottom currents shall be checked.

3.16.3.6 Settlement, scour, and erosion. A pipeline which is highly stressed by internal pressure shall be provided with uniform and adequate supports. Unequal settlements and scour or erosion of the sea bed may produce additional bending stresses in the pipe. The design shall include provisions for these possibilities.

3.16.3.7 Anchorage at connections. Pipelines may be subject to longitudinal forces due to bottom currents or other forces. It is essential that the interconnection of pipelines shall have ample flexibility to cater for possible movement, or that the lines be provided with an anchor sufficient to develop the forces necessary to limit the movement. Lateral thrusts at branch connections may greatly increase the stresses in the branch connection itself unless provisions are made to resist the thrust.

3.17 CATHODIC PROTECTION. Cathodic protection shall be in accordance with the requirements of Section 8.

3.18 INSTRUMENT, CONTROL, AND SAMPLING PIPING.

3.18.1 Scope of Clause. The requirements given in this Clause (3.18) apply to the design of instrument, control, and sampling piping for safe and proper operation of the piping itself and do not cover design of piping to secure proper functioning of the instrument for which the piping is installed.

This Clause (3.18) does not apply to permanently closed piping systems, such as fluid-filled temperature-responsive devices.

3.18.2 Materials and Design.

3.18.2.1 General. The materials for construction of valves, fittings, tubing or piping shall be suitable for the particular conditions of service.

3.18.2.2 Take-off fittings. Take-off connections and attaching bosses, fittings, or adaptors shall be made of material complying with the requirements of ANSI B16.5 and shall be capable of withstanding the maximum service pressure and temperature of the piping or equipment to which they are attached. They shall be of sufficient strength to withstand installation and maintenance stresses. Consideration shall be given to design for fatigue stresses and external mechanical loading.

A shut-off valve shall be installed in each takeoff line as near as practicable to the point of takeoff. Blowdown valves shall be installed where necessary for the safe operation of the piping instruments and equipment.

3.18.2.3 Piping. The following requirements for piping shall apply:

- (a) Brass, copper, or aluminium pipe or tubing shall not be used for metal temperatures exceeding 205°C, or in locations where there is a fire risk. Brass tubing subject to dezincification shall not be buried.
- (b) Piping subject to clogging from solids or deposits shall be provided with suitable connections for cleaning.
- (c) Piping which may contain liquids shall be protected by heating or other suitable means from damage due to freezing.
- (d) Piping in which liquids may accumulate shall be provided with drains or drips.
- (e) The arrangement of piping and supports shall be designed to provide not only for safety under operating stresses, but also for protection for the piping against detrimental sagging, external mechanical injury, abuse, and damage due to unusual service conditions other than those connected with pressure, temperature, and service vibration.
- (f) Suitable precautions, such as increasing the wall thickness of the pipe, shall be taken where internal corrosive conditions may exist. All underground instrument, control, and sampling piping shall be protected against corrosion.

3.18.2.4 Joints. Joints shall be made in a manner suitable for the pressure and temperature conditions, such as by means of fittings that are flared, flareless, or of the compression type, or equivalent; or the fittings may be of the brazed, screwed, or socket-welded type. If screwed-end valves are to be used with fittings of the flareless or compression type, adaptors shall be used.

Slip-on expansion joints shall not be used; expansion shall be accommodated by providing flexibility within the piping or tubing system itself.

TABLE 3.16.2
FLEXIBILITY FACTOR AND STRESS INTENSIFICATION FACTOR

Description	Flexibility factor k	Stress intensification factor		Flexibility characteristic h	Sketch
		i_i^*	$i_o^\dagger$		
Welding elbow or pipe bend (Notes 1, 2, 3, 6, 7)	$\frac{1.65}{h}$	$\frac{0.9}{h^{0.67}}$	$\frac{0.75}{h^{0.67}}$	$\frac{t_n R}{r^2}$	
Closely spaced mitre bend (Notes 1, 2, 3, 7) $s < r (1 + \tan \theta)$	$\frac{1.52}{h^{0.83}}$	$\frac{0.9}{h^{0.67}}$	$\frac{0.75}{h^{0.67}}$	$\frac{\cot \theta}{2} \frac{t_n s}{r^2}$	
Widely spaced mitre bend (Notes 1, 2, 4, 7) $s \geq r (1 + \tan \theta)$	$\frac{1.52}{h^{0.83}}$	$\frac{0.9}{h^{0.67}}$	$\frac{0.75}{h^{0.67}}$	$\frac{1 + \cot \theta}{2} \frac{t_n}{r}$	
Welding tee per ANSI B16.9 (Notes 1, 2)	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{0.67}}$	$4.4 \frac{t_n}{r}$	
Reinforced fabricated tee with pad or saddle (Notes 1, 2, 5)	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{0.67}}$	$\frac{(t_n + 1/2 t_p)^{2.5}}{t_n^{2.5} r}$	
Unreinforced fabricated tee (Notes 1, 2)	1	$0.75 i_o + 0.25$	$\frac{0.9}{h^{0.67}}$	$\frac{t_n}{r}$	
Butt welded joint, reducer, or welding neck flange	1	1.0			
Double-welded slip-on flange	1	1.2			
Fillet welded joint (single-welded), or single-welded slip-on flange	1	1.3			
Lapped flange (with ANSI B16.9 lap-joint stub)	1	1.6			
Threaded pipe joint, or threaded flange	1	2.3			

* In-plane.

† Out-of-plane.

NOTES TO TABLE 3.16.2:

- For fittings and mitre bends the flexibility factors, k , and stress intensification factors, i , in the table apply to bending in any plane and shall not be less than unity: factors for torsion shall be equal to unity. Both factors apply over the effective arc length (shown by heavy centre lines in the sketches) for curved and mitre elbows, and to the intersection point for tees.

- The values of k and i can be read directly from Fig. 3.16.2, Chart A by entering with the characteristic h calculated from the equations given where—

R = bend radius of welding elbow or pipe bend, in millimetres

r = mean radius of matching pipe bend, in millimetres

s = mitre spacing at centreline, in millimetres

t_n = nominal wall thickness, in millimetres

(Where the nominal wall thickness of a fabricated tee is greater than that of the adjoining pipes, this thickness shall be maintained, on each side of the branch, for a length not less than the pipe diameter.)

t_p = pad or saddle thickness, in millimetres.

θ = one-half angle between adjacent mitre axes.

- Where flanges are attached to one or both ends, the values of h and i in the table shall be corrected by the factor C , given below, which can be read directly from Fig. 3.16.2 (Chart B), entering with the calculated h :

One end flanged . . . $C = h^{0.17}$

Both ends flanged . . . $C = h^{0.33}$

- Also includes single mitre joint.
- When $t_p \geq 1.5 t_n$, use $h = 4.05 t_n/r$.
- Cast butt welding elbows may have considerably heavier walls than those of the pipe with which they are used. Large errors may be introduced unless the effect of these greater thicknesses is considered.
- In large diameter, thin-wall elbows and bends, pressure can significantly affect the magnitude of the flexibility and stress intensification factors. To correct the values obtained from the table for the pressure effect, divide—

- Flexibility factor k by
 $1 + [6(P/E) (r/t_n)^{2.33} (R/r)^{0.33}]$
- Stress intensification factor i by
 $1 + [3.25(P/E) (r/t_n)^{2.5} (R/r)^{0.67}]$

where E = modulus of elasticity, in megapascals

P = pressure, in megapascals.

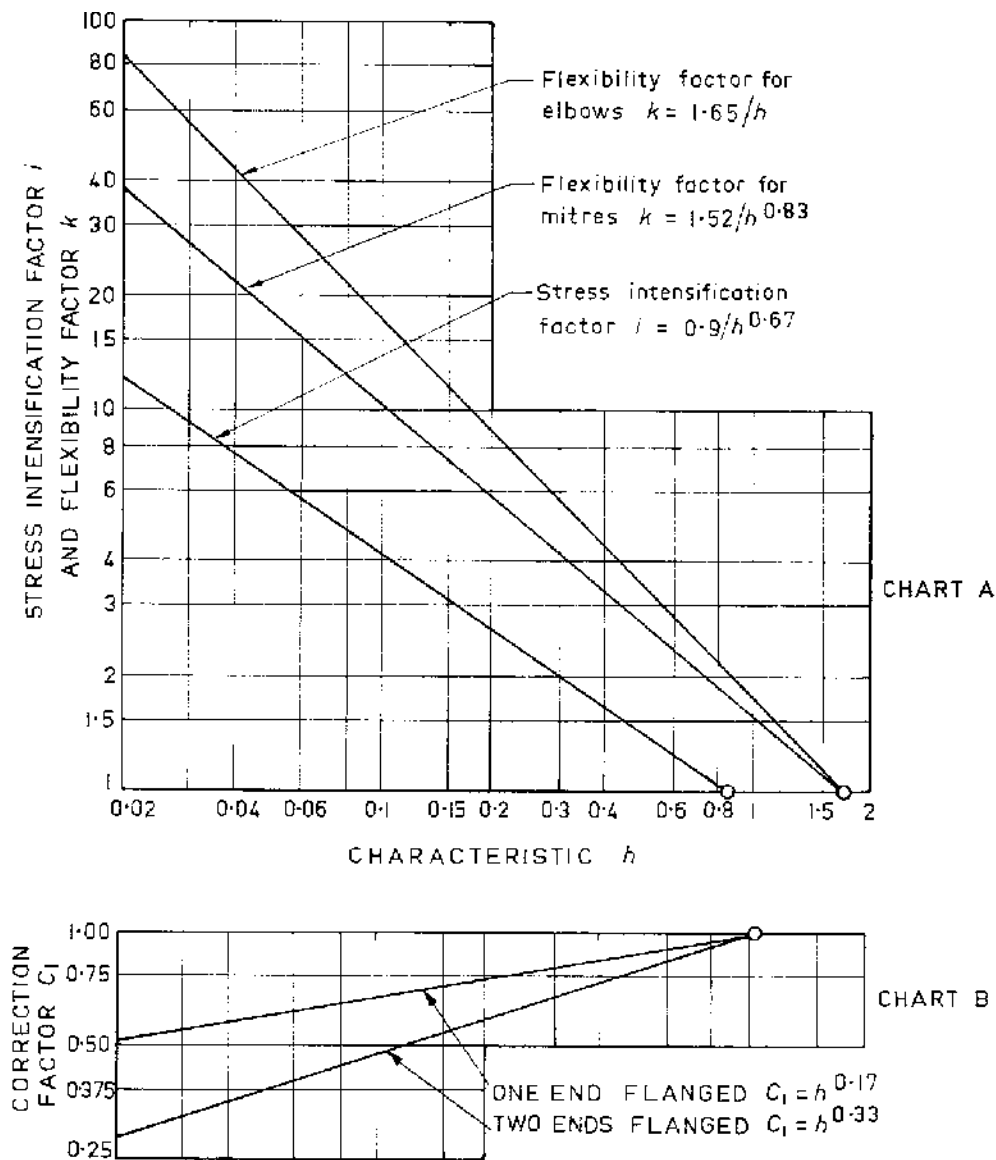


Fig. 3.16.2. FLEXIBILITY AND STRESS INTENSIFICATION FACTORS

3.19 CONTROL OF PIPELINE PRESSURE.

3.19.1 General. A pipeline connected to a source of pressure that is higher than the maximum allowable operating pressure of the pipeline shall be equipped with suitable pressure-regulating or limiting devices of such characteristics and capacity that the maximum allowable operating pressure will not be exceeded during normal operations.

In addition suitable devices shall be installed to protect the pipeline against accidental over-pressure resulting from failure of pressure-regulating or limiting devices and surge pressures resulting from closure of valves or other obstructions to the flow.

Surge calculations shall be made, where applicable, and adequate controls and protective equipment shall be provided so that if the pressure in the pipeline rises because of surges and other variations from normal operation, the increased pressure shall not exceed the maximum allowable operating pressure at any point in the pipeline by more than 10 percent.

3.19.2 Maximum Allowable Operating Pressure.

3.19.2.1 General. Where the points for measuring operating and test pressures are different, the equivalent test pressure at the measuring point for the operating pressure shall be calculated, account being taken of—

- (a) the difference in elevation between the two measuring points; and
- (b) the difference between the densities of the transmitted fluid and the test liquid.

3.19.2.2 Uniform pipelines. For a uniform pipeline in good operating condition, the maximum allowable operating pressure shall not exceed the lesser of—

- (a) the design pressure of the weakest element of the pipeline or any component connected thereto; and
- (b) the pressure obtained by dividing the pressure to which the pipeline was tested after construction by 1.25.

3.19.2.3 Telescoped pipelines. For a telescoped pipeline in good operating condition and which was hydrostatically tested as a whole, the maximum allowable operating pressure shall be—

- (a) in the weakest section, the pressure permitted by Clause 3.19.2.2 for a uniform pipeline; and
- (b) in stronger sections, in which all welds have been radiographically inspected (see Clause 4.13.3(a)), the lesser of—
 - (i) the pressure obtained by dividing the pressure to which the pipeline was tested by 1.10; and
 - (ii) the pressure which will result in a hoop stress obtained by multiplying the specified minimum yield stress of the steel by 0.6;

provided that under normal operating conditions the hydraulic gradient is such that the maximum allowable operating pressure of the weaker sections is not exceeded;

where this proviso is not met, Clause 3.1.9.2.2 for uniform pipelines shall apply.

3.19.3 Requirements for Design of Pressure-relief, Pressure-regulating and Pressure-limiting Stations. All pressure-relief, pressure-regulating, or pressure-limiting devices shall—

- (a) be constructed of such materials that the operation of the device will not normally be impaired by corrosion of external parts by the atmosphere, or the internal parts by fluid carried in the pipeline;
- (b) have valves and valve seats that are designed to minimize the risk of sticking in a position that will make the device inoperative and result in failure of the device to perform in the manner for which it was intended;
- (c) be designed and installed so that they can be readily operated to determine if the valve is free;
- (d) be designed and installed so that they can be tested to determine the pressure at which they will operate; and
- (e) be designed and installed so that they can be tested for leakage when in the closed position.

3.19.4 Basic Requirements for Protection Against Accidental Over-pressure. A pipeline connected to a source where the failure of pressure control or other condition might result in a pressure which would exceed the maximum allowable operating pressure of the pipeline shall be equipped with suitable pressure-relieving or pressure-limiting devices.

All pipelines delivering petroleum to production facilities on a platform shall be equipped with an automatic shut-in valve connected to the automatic and remote shut-in system of the platform.

Any pipelines crossing platforms and not delivering petroleum to these platforms, but which may or may not receive petroleum from those platforms, shall be equipped with high/low pressure sensors to activate an automatic shut-in valve which is to be located in the upstream portion of the pipeline at the platform. This automatic shut-in valve shall be connected to either the automatic and remote shut-in system of the platform or to an independent remote shut-in system.

All pipeline pumps and compressors shall be equipped with protective devices to prevent overpressure in any part of the pipeline.

3.19.5 Prevention of Unauthorized Operation. Precautions shall be taken to prevent unauthorized operation of any valve which will make pressure-limiting devices inoperative.

3.19.6 Protection on Control Piping. Special attention shall be given to control lines to prevent damage from making the over-pressure protection device inoperative.

3.20 RECORDS. Records shall be maintained by the Operating Authority of the design, construction, and testing of the pipeline. These records shall include material specification; route maps and charts; alignment sheets for 'as built' condition; pipe size, grade, SMYS, wall thickness, coatings, and test data. These records shall be amended when necessary, maintained, and kept for the life of the pipeline.