

AS 2885.5:2020



STANDARDS
Australia



Pipelines — Gas and liquid petroleum

Part 5: Field pressure testing



AS 2885.5:2020

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- Department of Primary Industry and Resources (Northern Territory)
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- WorkSafe New Zealand

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Pipelines — Gas and liquid petroleum

Part 5: Field pressure testing

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Preface

This Standard was prepared by the Australian members of the joint Standards Australia/Standards New Zealand Committee ME-038, Petroleum Pipelines, to supersede AS/NZS 2885.5:2012, *Pipelines—Gas and liquid petroleum, Part 5: Field pressure testing*.

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

The objective of this document is to set out methods for the determination of the strength and the LEAK TIGHTNESS of a pipeline test section.

This document forms part of the AS(/NZS) 2885 series and as such refers to other parts in this series. A list of all parts can be found in the Standards Australia online catalogue.

Definitions used in this document and throughout the series are now listed in AS 2885.0.

The major changes in this revision are as follows:

- (a) Alignment with AS/NZS 2885.1.
- (b) Revision of definitions.
- (c) Amplification of STRENGTH TEST Type 2.
- (d) Amendment of the reporting requirements.
- (e) Relocation of Appendix P, Test section analysis using engineering software, to Part 1 of this series (AS/NZS 2885.1).
- (f) Revision of [Appendix N](#), Safety in Pressure Testing, including the method of determining EXCLUSION ZONES.
- (g) Deletion of the supplementary LEAK TEST method.
- (h) Clarification of the requirements for measuring instruments.

The inclusion of roles and responsibilities in this document was approved by the Standards Development and Accreditation Committee on 1 May 2015, as a one-off exemption to the directives of Standardization Guide 009: Preparation of Standards for Legislative Adoption.

SMALL CAPS have been used throughout this document to indicate terms that are defined in [Clause 1.3](#) and in AS 2885.0:2018 (e.g. CALIBRATION). Although “may”, “should” and “shall” are defined terms, they do not appear in small caps. FULL CAPS have been used throughout this document to indicate abbreviations listed in [Clause 1.5](#).

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

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Australian Standard®

Pipelines — Gas and liquid petroleum

Part 5: Field pressure testing

Section 1 Scope and general

1.1 Scope and exclusions

1.1.1 General

This document sets out methods for the pressure testing of petroleum pipelines constructed of steel, designed in accordance with AS/NZS 2885.1, and operated in accordance with AS 2885.3. It may also be used for testing other pipelines, including pipelines designed or operated in accordance with AS/NZS 4645.2.

Pressure testing is used to establish —

- (a) the pressure limit (PL) in accordance with AS/NZS 2885.1 (STRENGTH TEST); and
- (b) the LEAK TIGHTNESS of a test section (LEAK TEST).

Pressure testing with air or gas, while not recommended, is permitted by this document within the limits specified in AS/NZS 2885.1.

NOTE 1 References in this document to liquid or fluid may be generically applied as applicable to air or gas.

This document may also be applicable to high pressure steel pipelines designed and constructed to national Standards of other countries. This document may be applied for PRETESTING of pipe and COMPONENTS and for testing sections of pipe separate from the field test.

NOTE 2 For information on the history and basis of this document, see [Appendix A](#).

1.1.2 Exclusions

This document does not apply to pressure testing of pipe manufactured from plastic or fibreglass materials.

The determination of the pressure-volume-temperature relationship does not apply to plastic or fibreglass pipe. For fibreglass pipe, this relationship shall be established by other means for use in leak test determination.

NOTE The properties of these materials mean that the pipe may be damaged when tested by methods designed for steel pipe. Procedures appropriate to these materials and documented in another Standard should be used, or if required, developed.

1.2 Normative references

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

NOTE Documents for informative purposes are listed in the Bibliography.

AS 1210, *Pressure vessels*

AS 1349, *Bourdon tube pressure and vacuum gauges*

AS 1894, *The storage and handling of non-flammable cryogenic and refrigerated liquids*

AS 2706, *Numerical values — Rounding and interpretation of limiting values*

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

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

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

AS/NZS 4645.2, *Gas distribution networks, Part 2: Steel pipe systems*

API, *Manual of Petroleum Measurement Standards*

MSA Test Method 2, *Calibration of Pressure Gauges*

1.3 Terms and definitions

For the purpose of this document, the definitions given in AS 2885.0 and those below apply.

1.3.1

accuracy tolerance

range or limits relative to the standard, true value of a measured quantity (such as pressure, temperature or volume) which includes effects such as errors or corrections, non-linearity, REPEATABILITY, hysteresis, time drift and MEASUREMENT UNCERTAINTY over a period of time of the order of years

1.3.2

allowable fluid variation

AFV

acceptance criteria (expressed in terms of fluid volume change) by which the test section is declared LEAK TIGHT

1.3.3

calibration

operations that establish, under specified conditions, the relationship between values of quantities indicated by the measuring instrument and the corresponding values realized by reference standards

Note 1 to entry: For the calibrated range, CALIBRATION certificates include statements of the uncertainty of measurement and often any corrections.

Note 2 to entry: CALIBRATION differs from VERIFICATION.

1.3.4

coverage factor

factor or number used to convert a MEASUREMENT UNCERTAINTY to a standard uncertainty or vice versa

1.3.5

end-point

pressure at which the pressurization is to cease

1.3.6

exclusion zone

zone surrounding a test section within which personnel are at risk should the pipeline fail during testing

1.3.7

half-slope end-point

pressure on the PRESSURE-ADDED VOLUME PLOT at which the slope is half that of the obviously elastic portion of the plot after the effects of RESIDUAL AIR are overcome

Note 1 to entry: Information on pipe behaviour during pressurization is given in [Appendix F](#).

Note 2 to entry: The added volume per unit pressure rise at this END-POINT is double that of the obviously elastic portion of the plot after the effects of RESIDUAL AIR are overcome.

1.3.8**hold period****hold time**

period during which the test pressure is maintained in a test

1.3.9**hydrostatic test**

test performed using a liquid test fluid

1.3.10**industrial gauge**

pressure gauge conforming to AS 1349 for an industrial gauge

1.3.11**leak tight****leak tightness**

ability of a test section to be free from visual leaks

Note 1 to entry: The test section should meet the requirements of this document in relation to ALLOWABLE FLUID VARIATION.

1.3.12**may**

indicates the existence of an option

1.3.13**measurement uncertainty**

parameter associated with the result of a measurement, characterising the dispersion of values that could reasonably be attributed to the quantity measured with 95 % confidence

Note 1 to entry: It is commonly used to express the uncertainty determined during a CALIBRATION and is usually less than the range of ACCURACY TOLERANCE.

1.3.14**mill test pressure**

pressure to which each length of pipe is subjected at the pipe manufacturer's works

1.3.15**nominated pressure**

pressure limit at the high point in a test section and, where required, the pressure limit at the low point in a test section

1.3.16**offset volume**

pressure on the PRESSURE-ADDED VOLUME PLOT at which the total added volume equals the sum of the volume required if the test section behaved as predicted (elastic for a Type 2 test or elastic for a Type 3 test) and a percentage of the calculated volume of the test section; the zero pressure being measured at the highest elevation

Note 1 to entry: The OFFSET VOLUME excludes the volume of water added to compress RESIDUAL AIR.

1.3.17**pneumatic test**

test performed using air or gas as the test fluid

1.3.18**pressure-added volume plot****P-V plot**

graph of the pressure of the test liquid against the volume of liquid added to pressurize the test section, and plotted to scales that will enable the pressure to be read to 0.1 % of that equivalent to specified minimum yield strength (SMYS) and the added volume to be read to 0.1 %

1.3.19**repeatability**

ability of repeated measurements of the same property under the same conditions to closely agree

Note 1 to entry: REPEATABILITY can include RESOLUTION or be equivalent to RESOLUTION if the RESOLUTION is greater than the REPEATABILITY.

Note 2 to entry: This term is used for comparison of both pressure- and temperature-based volume equivalent measurement uncertainties with the AFV for LEAK TESTS.

1.3.20**residual air**

volume of air trapped in the test section by the test liquid and referred to as a pressure of 101.325 kPa absolute

1.3.21**resolution**

<analogue> ability to resolve details relative to spacings of smallest markings and pointer width

<digital> smallest difference that can be meaningfully distinguished

EXAMPLE A change of one in the last place of a digital display.

1.3.22**sensitivity**

<general> ability to respond to small inputs

<equivalent volume percentage of the AFV> combination of instrument RESOLUTION and REPEATABILITY

NOTE 1 TO ENTRY: In this document, a combination of instrument RESOLUTION and REPEATABILITY is referred to simply as REPEATABILITY.

1.3.23**shall**

indicates that a statement is mandatory

1.3.24**should**

indicates a recommendation

1.3.25**temperature probe**

instrument designed to measure temperatures below ground and which satisfies the ACCURACY TOLERANCE and REPEATABILITY requirements of this document

1.3.26**test gauge**

pressure gauge conforming to the requirements of AS 1349 for a TEST GAUGE

1.3.27**test plan**

document prepared before the test, detailing the methods and procedures to be used

1.3.28**unaccountable fluid variation****UFV**

volume equivalent of the residual pressure change during a LEAK TEST after adjusting the measured pressure change for measured effects (such as temperature change) and measured fluid loss during the test period

1.3.29**verification**

check against a reference instrument to confirm that the measurement is within the manufacturer's ACCURACY TOLERANCE specification

Note 1 to entry: This may be an in-house or third-party check which requires documentary support and records.

Note 2 to entry: VERIFICATION can be used to determine REPEATABILITY for pipe wall temperature systems used in LEAK TESTS.

1.3.30**yield strength****1.3.30.1****minimum actual yield strength**

lowest yield strength of any pipe in a test section, estimated statistically from the population of pipes with the highest design factor in that test section

1.4 Symbols and units

Unless otherwise noted —

- (a) pressure and calculations involving pressure are based on gauge pressures; and
- (b) pressures are expressed as gauge pressures.

Symbol	Description	Units
A	compressibility of testing medium	kPa ⁻¹
B	temperature coefficient of expansion of testing medium for a restrained test section	
AYS_{MIN}	lowest yield strength of any pipe in a test section, estimated statistically from the population of pipes with the highest design factor in that test section	MPa
$\bar{B}$	temperature coefficient of expansion of testing medium for an unrestrained test section	°C ⁻¹
D	nominal outside diameter	mm
d_H	diameter of equivalent leaking hole	mm
E	Young's modulus	kPa
E_G	girth weld joint efficiency factor	
F	bulk compressibility factor	
F_{TP}	test pressure factor	
f	Darcy-Weisbach friction factor	
L	length of test section	m
P_0	initial pressure in a test section	kPa
P_{ATM}	atmospheric pressure	kPa
P_L	pressure limit	kPa
P_s	start pressure at test point	kPa
P_D	DESIGN PRESSURE	kPa
P_M	measured pressure from STRENGTH TEST	kPa
P_{MIN}	calculated theoretical pressure at which yielding may occur in a test section	kPa
P_{TMAX}	maximum STRENGTH TEST pressure	kPa
P_{TMIN}	minimum STRENGTH TEST pressure	kPa
q_V	flow rate through a leak	m ³ sec ⁻¹
T	average temperature of a test section	°C
T_0	initial temperature of a test section	°C

Symbol	Description	Units
T_r	average LEAK TEST temperature minus 15 °C	°C
t	wall thickness	mm
t_w	wall thickness (required)	mm
U	uncertainty of measurement	
V_0	total initial volume within a test section	L
V_{air}	volume of air within a test section	L
V_{H2O}	volume of water within a test section	L
V_{offset}	OFFSET VOLUME at start pressure	L
V_T	volume of testing medium at temperature (T)	L
VCF	volume correction factor	
W	weighting of TEMPERATURE PROBE	
ΔP	change of pressure within a test section	kPa
ΔT	change in the average temperature in a test section	°C
ΔV	change of volume of testing medium in a test section	L
α	temperature coefficient of expansion of line pipe	10 ⁻⁶ /°C
α_T	temperature coefficient of expansion of testing medium at temperature (T)	10 ⁻⁶ /°C
α_{TP}	temperature coefficient of expansion of testing medium at temperature (T) and pressure (P)	10 ⁻⁶ /°C
ρ	density of testing medium	kg/m ³
ρ_T	density of testing medium at T	kg/m ³
σ_a	allowable design stress	MPa
σ_Y	specified minimum yield strength (SMYS)	MPa
σ_{YA}	lowest yield strength measured for the pipe population	MPa
σ_H	hoop stress	MPa
σ_L	longitudinal stress	MPa
σ_O	uniaxial tensile test yield stress	MPa
σ_R	radial stress	MPa
ν	kinematic viscosity	m ² sec ⁻¹
ν	Poisson's ratio	

1.5 Abbreviations

Abbreviation	Meaning	Units
AFV	ALLOWABLE FLUID VARIATION	L/24 h
EPRG	European Pipeline Research Group	
ERW	Electric resistance welded	
FBE	Fusion-bonded epoxy	
FBT	Flattened bar transverse tensile	
FEA	Finite element analysis	
HFERW	High frequency electric resistance welded	
JSA	Job safety analysis	
JHA	Job hazard analysis	
MAOP	MAXIMUM ALLOWABLE OPERATING PRESSURE	MPa
MSA	Metrology Society of Australasia	
NDT	Non-destructive testing	
RB	Round bar	

Abbreviation	Meaning	Units
RE	Ring expansion	
SAW	Submerged arc welded	
SMS	Safety management study	
SMYS	Specified minimum yield strength	MPa
SRF	Strain rate factor	
TT	Tangential tensile	
UFV	UNACCOUNTABLE FLUID VARIATION	L/24 h
UTS	Ultimate tensile strength	MPa
YS	Yield strength	MPa

1.6 Rounding of numbers

An observed or calculated value shall be rounded to the nearest unit in accordance with AS 2706.

NOTE For examples of interpretation of specified values in accordance with the rounding method, refer to AS 2706.

Section 2 Safety

2.1 Basis of section

The potential for failure during the pressure test presents a significant hazard to personnel and equipment, the public and the environment. Risk associated with this hazard shall be assessed and CONTROLLED.

2.2 Hazard assessment

Prior to conducting a pressure test, a formal hazard assessment shall be undertaken using an appropriate methodology to identify hazards, failure modes, controls, and to assess residual risks.

The TEST PLAN or the test procedure or both shall be included in this assessment.

The hazard assessment shall consider the consequence of pipeline failure at any point along the length of the test section, particularly at locations where the failure may impact on the public, public facilities, or the environment. If necessary, additional controls shall be applied to manage this risk.

The TEST SIGNATORY shall participate in, and endorse, the hazard assessment.

NOTE 1 For the safety management requirements for a new or an existing pipeline, refer to AS/NZS 2885.1, AS/NZS 2885.3 and AS/NZS 2885.6. An SMS does not replace the field pressure testing hazard assessment. The safety management requirements, for example hazard control methods applied to the design and the field-testing procedures, should be considered in the field-testing procedures and provided to the TEST SIGNATORY.

NOTE 2 One method for reducing risk in areas where failure may impact public, facilities or personnel is to apply the concept of PRELIMINARY TESTS in areas such as road or rail crossings and pipeline sections within manned facilities.

The hazard assessment shall be performed prior to commencement of testing operations to consider the sources of potential harm specific to pressure testing. It shall encompass each aspect of the testing operation and consider the safety of testing personnel, other construction personnel, general public, landholders and any other stakeholders.

The hazard assessment and the method used to conduct the hazard assessment shall be documented.

NOTE 3 For further information on safety in pressure testing, see [Appendix N](#).

2.3 Emergency response plan

An emergency response plan shall be prepared for the pressure test. The plan shall address at least the following:

- (a) Risk (or hazard) management in place for the test. This will be different for a new pipeline being tested as part of a construction operation than for an in-service test of an existing pipeline.
- (b) Emergency events identified from the hazard assessment.
- (c) Communication with public authorities and key stakeholders such as landowners.
- (d) Personnel safety and response, including medical evacuation.
- (e) Environmental response.

The emergency response plan shall be APPROVED. Relevant personnel shall be familiarized with the response plan prior to commencement of the test.

For a new pipeline, the emergency response plan may be a subset of the construction safety management plan. For an existing pipeline, the emergency response plan may be a part of the LICENSEE'S PIPELINE MANAGEMENT SYSTEM.

2.4 Communications and transport

Adequate communication and transport systems shall be established and maintained for the duration of the test, having consideration for the operational needs of the test and, if required, to respond to a safety emergency.

2.5 Exclusion zone

2.5.1 General

The EXCLUSION ZONE shall be determined for each test section.

The method by which exclusion is used as a hazard control and the method by which the EXCLUSION ZONE will be communicated with personnel and the public shall be nominated in the TEST PLAN. The effectiveness of these methods shall be assessed in the hazard assessment.

Where the EXCLUSION ZONE is not an effective control (e.g. at crossings and in populated areas), alternative controls shall be identified and applied.

A separate EXCLUSION ZONE shall be prepared for personnel protection against asphyxiation during freeze plugging operations.

NOTE [Appendix N](#) provides guidance on methods for assessing the dimensions of the exclusion zone.

2.5.2 Entry into exclusion zone

Only personnel directly involved in testing operations shall be permitted to enter the EXCLUSION ZONE. Each entry shall be authorized.

Personnel shall not enter the EXCLUSION ZONE during pressurization.

Personnel shall not enter the EXCLUSION ZONE while the test section is at full STRENGTH TEST pressure unless the hazard has been assessed and appropriate controls have been provided to reduce the risk to the testing personnel to as low as reasonably practicable (ALARP).

Where there is a risk of failure when pressure is greater than the MILL TEST PRESSURE, the pressure shall be reduced by not less than 10 % of current test pressure prior to entry being authorized.

2.5.3 Visual leak inspection safety

The safety of personnel conducting a visual inspection during a STRENGTH TEST shall be addressed in the hazard assessment. Controls shall be developed to ensure personnel safety during visual inspection.

NOTE If the test pressure for a visual-type test exceeds the pipe MILL TEST PRESSURE, the STRENGTH TEST pressure should be maintained for 2 h with no access by personnel within the EXCLUSION ZONE. Upon completion of the HOLD PERIOD, the test pressure should be reduced by 10 % and maintained for a sufficient time to facilitate visual inspection for leaks.

2.5.4 Leak repair safety

Leak repair methods shall consider the safety aspects of the repair process.

NOTE 1 Flange bolts and hammer unions should be tightened using the correct tools. Flogging-up methods should not be used.

NOTE 2 Tightening of leaking threaded connections may cause joint failure. Personnel should consider the likely consequence of a thread failure and the impact of such a failure on personnel and equipment in the vicinity of the leak prior to attempting to rectify a leak at a threaded connection. It is recommended that pressure be reduced by at least 50 % of current pressure.

2.6 Environmental safety

The hazard assessment shall address environmental safety and the following:

- (a) Environmental impact, resulting from a pipeline failure or leak at any point along the length of the test section.
- (b) Environmental impact, resulting from supply and disposal of the test fluid.

Additional controls shall be provided to reduce the risk to ALARP.

NOTE 1 Environmental controls should be implemented as part of the design or environmental management plan, but additional controls may be necessary based on knowledge gained through construction or, for an existing pipeline, from changes in land use since the time of construction.

NOTE 2 There may be additional regulatory requirements for the supply and disposal of test liquids. Care should be taken that the general public, operating and testing personnel, operating equipment and the environment are not exposed to any harmful effects. Where additives have been used, extra precautions may be necessary.

NOTE 3 Special requirements apply when the test fluid is a liquid hydrocarbon or other non-aqueous liquid.

2.7 Working with compressed air or gas

Compressed air is frequently used in the testing process to propel pigs used for cleaning and drying. This document also permits tests to be undertaken using compressed air or gas under special circumstances.

CAUTION — COMPRESSED GAS IS HAZARDOUS.

The following measures shall be implemented:

- (a) Whip sock, whip checks, safety locking pins, or lock wire shall be used on all compressed air bayonet fittings.
- (b) Pigs that are driven by compressed air or gas will decelerate and accelerate as they enter and leave pipe sections of differing wall thicknesses. Receivers for pigs used for pipe cleaning or drying shall be designed to arrest the pig safely.
- (c) An **EXCLUSION ZONE** shall be specifically situated around an area where pigs, driven by compressed air, are being launched and received.
- (d) Temporary headers for the launching of pigs, driven by compressed air, shall be designed to contain the air pressures involved.
- (e) Procedures shall be written to ensure that closures are not opened while the launcher contains air pressure.

NOTE 1 A volume of compressed air at a given pressure contains considerably more stored energy than the same volume of liquid at the same pressure.

NOTE 2 All hoses and fittings used with compressed air should be inspected regularly.

NOTE 3 Hoses should be restrained to prevent them flailing around in the event of a fitting failure, refer to AS/NZS 2554 and AS 1180.5.

2.8 Procedures and precautions where test fluid is air or gas

Where the test fluid is air or gas, the **TEST SIGNATORY** shall participate in a hazard assessment. Any action arising from the hazard assessment shall be implemented.

Where the TEST SIGNATORY is not able to participate in the hazard assessment, a hazard assessment workshop shall be convened prior to the PNEUMATIC TEST. The TEST SIGNATORY shall attend the workshop.

Warning signs shall be displayed along the test section.

The LEAK TEST shall be conducted by visual or tracer gas-type inspection.

NOTE The hazard assessment should include an assessment of directional energy dissipation, fragmentation, and protection from secondary projectiles.

2.9 Filling and dewatering

Temporary discharge piping and hoses shall be restrained to safely contain the forces generated during the discharge.

The design should consider the consequences of a failure in the temporary piping. If necessary, an EXCLUSION ZONE should be defined for the safety of personnel and equipment during filling and dewatering.

NOTE 1 Two-phase air-liquid mixtures (slugs) introduce significant loads on temporary discharge piping, hoses, and the associated supports or restraints.

NOTE 2 Slugs may be caused by —

- (a) water or air bypassing the fill pigs;
- (b) compressed air that was trapped in the test fluid being released; and
- (c) breakthrough of compressed air or gas.

2.10 Procedures and precautions where test fluid is petroleum liquid

Where the test fluid is a petroleum liquid, the following procedures and precautions shall apply:

- (a) An emergency procedure shall be established, approved and, in the event of failure, implemented to reflect the specific public and environmental hazard associated with a hydrocarbon fluid release.
- (b) Adequate warning signs shall be displayed along the test section.
- (c) During the period in which the hoop stress is first raised from 50 % SMYS to the maximum test stress and until the pressure is reduced to the MAOP, consideration shall be given to —
 - (i) the evacuation of persons from all neighbouring buildings; and
 - (ii) constant surveillance of the test section.

NOTE Testing with a petroleum fluid should not be carried out for initial testing of a pipeline where the test pressure results in a stress higher than 50 % SMYS.

2.11 Pipe subjected to freeze sectioning

2.11.1 General

Freeze plugging is an acceptable process to section a pipeline to assist in locating a suspected leak when water is used as the test fluid.

Carbon-manganese steel line pipe may be safely exposed to cryogenic temperatures, provided the part of the pipeline that is to be frozen is free of DEFECTS. Dual-phase steels are not inherently safe

at cryogenic temperatures. If used, these materials shall be assessed to establish safe conditions for freeze sectioning. If required, the assessment of these materials shall be included in the TEST PLAN.

NOTE 1 Organic coatings and linings will be affected by cryogenic temperatures. Coatings should be removed prior to freezing to increase the freezing rate and, in any case, should be removed and replaced as part of reinstatement using normal field joint coating techniques. Any damage to internal lining of pipe is deemed to be of no consequence unless the lining is installed for a purpose other than flow enhancement.

NOTE 2 Where practicable, the freeze site should be located at a low point in the pipe section to minimize the time required to freeze the pipe.

The freeze plug shall not be located on, or in close proximity to, a girth weld because a weld may contain DEFECTS that could fail when exposed to cryogenic temperatures.

At each location proposed for a freeze plug, the longitudinal seam of welded pipe manufactured from carbon manganese steel shall be ultrasonically inspected. If the longitudinal seam weld is found to contain flaws, the inspection shall be extended on either side of the proposed location until a length of pipe sufficient for the freeze plug is shown to be free of flaws.

2.11.2 Freeze plugging procedure

A documented procedure for freeze plugging shall be developed. Freeze plugging shall be undertaken in accordance with the procedure that addresses:

- (a) preparation;
- (b) safety and, where necessary, training;
- (c) the freeze plugging process, including testing and freeze maintenance;
- (d) thawing; and
- (e) reinstatement.

2.11.3 Safety

Specific safety requirements shall include —

- (a) organizing the freeze plugging process so that the operator is not required to enter the bell hole when liquid nitrogen (or an asphyxiating substance) is present;
- (b) reviewing the procedure against the recommendations of AS 2865;
NOTE Refer to relevant federal, state and territory regulations to determine any legal requirements.
- (c) conforming to the precautions for safe handling of liquid nitrogen (or an asphyxiating substance) in AS 1894;
- (d) declaring bell holes established for freeze plugging as confined spaces whenever nitrogen (or an asphyxiating substance) is present; and
- (e) protecting the pipe from impact while at low temperatures.

Should it be necessary for an operator to enter a bell hole in the presence of liquid nitrogen (or an asphyxiating substance), then —

- (i) the operator shall be trained in the safety aspects associated with this type of confined space;
- (ii) an adequately sized ventilating fan (usually ducted) shall be operating;
- (iii) the operator shall wear a harness with a trailing rope, monitored by personnel capable of pulling the operator from the bell hole if the need arises;

- (iv) personnel trained in resuscitation techniques and the necessary equipment shall be present; and
- (v) the bell hole shall be immediately evacuated should spill occur.

NOTE To reduce the likelihood of a spill, the integrity of equipment such as Dewars, hoses and containment tanks is vital.

Section 3 Equipment and test liquid

3.1 Basis of section

The validity of the determination of strength and LEAK TIGHTNESS depends on the validity of the measurements made during the pressure test.

This Section defines the minimum requirements for MEASUREMENT UNCERTAINTY of test equipment and the practices to be observed to ensure that readings of test instruments reflect test section parameters and avoid spurious influences.

3.2 Requirements of measurement instruments

3.2.1 General

Only instruments with current VERIFICATION in accordance with this Section shall be used for measuring pressure, volume, and temperature during testing.

VERIFICATION shall be performed in accordance with a documented procedure against a prime reference instrument that is metrologically traceable.

Indicated readings from verified instruments and equipment shall be used without correction.

3.2.2 Pressure-measuring equipment

3.2.2.1 General

Instruments and equipment for the measurement of pressure shall conform to the requirements of this Section.

3.2.2.2 Requirements for pressure-measuring instruments

Pressure-measuring instruments shall conform to the following:

- (a) Type 1 test — Where the test pressure is used to determine the pressure limit, the ACCURACY TOLERANCE of the pressure-measuring device shall be 0.1 % of the pressure reading.

NOTE For a Type 1 test, not used to determine a pressure limit, a TEST GAUGE may be used.
- (b) Type 2 or Type 3 tests — Where a Type 2 or Type 3 test is conducted, the pressure shall be measured by a pressure-measuring device conforming to the following:
 - (i) An ACCURACY TOLERANCE of 0.2 % of the pressure reading.
 - (ii) A RESOLUTION of 0.1 % of the pressure equivalent of SMYS or AYS.
- (c) LEAK TESTS — The REPEATABILITY of pressure-measuring instruments that are used to determine LEAK TIGHTNESS shall not exceed 20 % of the pressure change corresponding to the AFV.

3.2.2.3 Selection of pressure-measuring equipment

The following apply to the selection of pressure-measuring equipment:

- (a) Dead weight testers — are primary reference instruments.
- (b) Pressure transducers/indicators — may be used in place of the primary pressure-measuring equipment specified in this document provided they meet the specified measurement requirements.

- (c) Pressure gauges — (Bourdon tube)
 - (i) TEST GAUGES — Test gauges shall conform to AS 1349. Test gauges shall be selected so that the highest test pressure is between 50 % and 90 % of the scale range.
 - (ii) INDUSTRIAL GAUGES — Industrial gauges as defined by AS 1349 shall not be used for test determination but may be used as local indicators.

3.2.2.4 Verification of pressure-measuring equipment

The maximum period between VERIFICATIONS of equipment for measurement of pressure shall be as follows:

- (a) Dead weight testers — 10 years.
- (b) Pressure transducers/indicators (electronic) — 5 years.
- (c) TEST GAUGES — 2 years.

NOTE Consideration should be given to the temperature coefficient when selecting pressure-measuring equipment.

INDUSTRIAL GAUGES used as indicators shall be verified against a TEST GAUGE or deadweight tester, or equivalent pressure calibrator.

Records of VERIFICATION tests shall be maintained.

3.2.3 Volume-measuring equipment

3.2.3.1 General

Instruments and equipment for the measurement of volume or flow rate shall conform to the following:

- (a) Volume/strain-monitored test — The volume of liquid added or subtracted in this test shall be measured with equipment conforming to the following:
 - (i) ACCURACY TOLERANCE better than 1 % of the pressurising volume.
 - (ii) RESOLUTION better than 0.1 % of the estimated volume of liquid required to produce a pressure equivalent to SMYS after filling has been completed.
- (b) RESIDUAL AIR — Where RESIDUAL AIR is to be determined from the observations of pressure and volume and, where the pressure does not exceed 2 000 kPa, the equipment for measurement of volume shall have an ACCURACY TOLERANCE better than 2 % of that volume which, when added, would produce a change in pressure of 1 000 kPa.
- (c) LEAK TEST — ACCURACY TOLERANCE better than 1 % of the AFV.

3.2.3.2 Verification of volume-measuring equipment

The ACCURACY TOLERANCE and RESOLUTION of equipment for the measurement of volume or flow rate shall be verified at intervals not exceeding 2 years for mechanical equipment and 5 years for electronic equipment.

3.2.4 Temperature-measuring equipment

3.2.4.1 General

Where temperature measurement is required for a test, the following shall apply:

- (a) STRENGTH TEST — Temperature measurement is not required.
- (b) LEAK TEST — Buried pipe wall temperature-measuring devices used for test evaluation shall meet the following requirements:
 - (i) An ACCURACY TOLERANCE of 0.5 °C.
 - (ii) A REPEATABILITY not exceeding 20 % of the temperature change equivalent to the AFV, or 50 % for very large volume test sections, see [Table 6.2](#) LEAK TEST Type E.

NOTE The display or recording resolution of temperature-measuring equipment should be 0.02 °C or better.

The REPEATABILITY of resistance thermometers, thermocouples and electronic temperature-measuring devices shall be determined and documented.

NOTE 2 Pipe wall temperature-measuring devices for LEAK TEST evaluation are used to determine temperature changes of the test fluid. Therefore, differential temperature determination has more importance than overall accuracy. The soil temperatures at pipe depth may show diurnal changes of approximately 0.1 °C, depending on seasonal and soil conditions. The ACCURACY TOLERANCE requirement is sufficient to determine the temperature-pressure response at the prevailing average pipe temperature.

3.2.4.2 Verification of temperature-measuring equipment

The maximum period between VERIFICATIONS of equipment for measurement of temperature shall be as follows:

- (a) Liquid in glass thermometers (ice point) — 2 years.
- (b) Other temperature-measuring devices, including any associated display device or data recorder:
 - (i) Single point check — 2 years.
 - (ii) Span VERIFICATION — 5 years.

Records of each VERIFICATION shall be maintained.

3.3 Installation and location of test equipment

3.3.1 General

Measuring equipment shall be installed and located to ensure that the data obtained is representative of the test section.

Precautions shall be taken to protect the equipment against adverse effects of weather and other hazards.

NOTE Bourdon tube pressure gauges are particularly susceptible to damage from shock loading in transport and in use, and from impurities in the liquid such as sealing tape.

3.3.2 Pressure gauges

Pressure gauges shall be installed in accordance with AS 1349 and MSA Test Method 2. More than one pressure-measuring device shall be used. Any difference of indicated readings between the pressure-measuring devices shall be monitored and investigated.

An indicator pressure gauge shall be installed on the test header at the test location to permit direct reading of the pressure in the event any doubt arises as to the condition of the lines connecting the test instruments to the header.

NOTE A prime pressure reference should be nominated. The use of more than one primary pressure reference instrument is not required.

3.3.3 Temperature measurement

Where temperature measurement is required by the test procedure, the following shall apply:

- (a) The purpose for such measurement shall be clearly stated in the test program.
- (b) Temperature-measuring devices shall be selected to satisfy the requirements of this document.
- (c) Temperature-measurement points shall be carefully selected to ensure that the measurement is relevant to the relationship being measured.
- (d) Sufficient temperature-measuring devices shall be installed to allow the average temperature of the test section to be reliably calculated.
- (e) The sensing element and, where necessary, the instrument shall be protected against the effects of ambient and extraneous temperature sources and electrical interference.

NOTE 1 Pipe temperature-measurement points may be located on the surface of the pipe or the surface of the pipe coating.

NOTE 2 There is evidence that location of the temperature element on the side of the pipe at mid-depth will result in a more reliable measurement of the fluid temperature than placement on the top of the pipe, particularly for pipe diameters greater than 400 mm.

3.4 Test fluid

3.4.1 Type of test fluid

The test fluid shall not be detrimental to the future use of the pipeline. Where there is any doubt, experimental work shall be carried out to determine its suitability.

Where the test fluid is a petroleum liquid, the flashpoint shall be greater than 61 °C.

Compressed air rather than Nitrogen should be used for PNEUMATIC TESTS as Nitrogen runs the risk of asphyxiation when released.

3.4.2 Selection of test liquid

The test fluid should be a liquid with known properties such as water, petroleum liquid or other fluid. Water is the preferred test fluid.

Liquefied petroleum gas or any other similar HIGH VAPOUR PRESSURE LIQUID shall not be used.

NOTE The test liquid may contain corrosion inhibitors or other appropriate additives.

The test liquid shall be selected, after consideration of the consequences of a RUPTURE of the test section or escape of the liquid during the test, with regard to the effects such an incident would have on the general public, personnel, equipment, and the environment.

The method of disposal shall be considered in the selection of the test fluid (including additives). Relevant environment protection requirements shall be established.

3.5 Test headers

Test headers shall conform to the requirements of [Appendix O](#).

Section 4 Preparation for tests

4.1 Basis of section

This document requires that each pressure test be planned and that the plan be documented in a pressure TEST PLAN.

4.2 Test design

The pipeline design shall be capable of being pressure tested at the design conditions, without the pipe being damaged by the test pressure. The pipeline test shall unambiguously demonstrate that the pipeline is LEAK TIGHT.

As part of pipeline design and prior to construction, a detailed pressure test design including parameters and details shall be developed and documented. This pressure test design shall be provided to the construction contractor and to the TEST SIGNATORY.

At the pressure test stage, the TEST SIGNATORY shall review the test design. The TEST SIGNATORY may nominate an alternative design for authorization by the LICENSEE. Any alternative design shall be reviewed for conformance to the requirements of AS/NZS 2885.1 and this document.

The pressure test shall be undertaken in accordance with a test procedure that has been prepared with full consideration of the parameters that affect the validity of the test.

NOTE Where a pressure test is limited to a single test section, the TEST PLAN and test procedure may be combined.

4.3 Test personnel

The TEST SIGNATORY shall be a COMPETENT PERSON in accordance with AS 2885.0.

The preparation of the TEST PLAN, the conduct of the tests, and the assessment of the results of the tests shall be carried out by a TEST SIGNATORY or COMPETENT PERSON under the direct supervision of a TEST SIGNATORY.

4.4 Test plan

A TEST PLAN for each pressure test shall be prepared and APPROVED before any testing takes place. The plan shall include explanatory notes and all data.

NOTE 1 In preparing the TEST PLAN, the TEST SIGNATORY should review —

- (a) the information provided by the pipeline design engineer (refer to AS/NZS 2885.1) and confirm that the data supports the pipeline design engineer's specification for the test; and
- (b) obligations in relation to safety (see [Section 2](#)) recorded in the SMS.

The TEST PLAN shall include an assessment of stresses in the pipe wall of the test section resulting from the mass of the test liquid, end restraints, additional loading from other structures, and other significant loadings associated with the test equipment.

NOTE 2 The TEST SIGNATORY is responsible for confirming that temporary equipment and structures installed for the conduct of the test are safe and conform to the stress limits of AS/NZS 2885.1. The pipeline design engineer is responsible for confirming that the pipeline is safe for the pressure test.

The TEST PLAN shall include details of the following:

- (a) Purpose of the test.
- (b) Location and identification of the test section.

(c) Location and extent of PRETESTED pipe, PIPELINE ASSEMBLIES OR COMPONENTS to be tied into the test section after pressure testing.

(d) Location and extent of PRELIMINARY TESTS to be included in the test section test.

NOTE 3 Consideration should be given to the PRELIMINARY TESTING of crossings of a sensitive nature, where a leak could have significant environmental issues and prove difficult to locate and rectify.

(e) Elevations of the measuring points and the highest and lowest points of the test section.

NOTE 4 For guidance on selecting test sections see [Appendix L](#).

(f) Dimensions of all pipes in the test section (nominal diameter, nominal wall thickness, and total length of each pipe type).

(g) Pipe manufacturing information relevant to the test [specification, grade (SMYS), MILL TEST PRESSURE, yield strength determination, strain rate (where required) and coating].

(h) Test pressure ratings of valves, COMPONENTS, connections, and appurtenances in the test section.

NOTE 5 Ratings may be taken from specifications.

NOTE 6 Consideration should be given to the effect of pressure on all COMPONENTS in the test section (e.g. flanges, fittings, hot bends and valves).

(i) The highest pressure, including any preliminary or pre-test pressure, to which any valve, COMPONENT, connection, or appurtenance in the test section has been previously subjected.

(j) Where not water, the type of test liquid to be used and its variation with expected temperature and pressure of the following properties:

(i) Density.

(ii) Cubic thermal expansion coefficient.

(iii) Compressibility.

(k) Type of additives, if any, in the test liquid.

(l) Minimum STRENGTH TEST pressure and LEAK TEST pressure at the highest and lowest points of the test section, and their relationship to the pressure at the measuring point.

(m) Differentiation between the STRENGTH and LEAK TEST functions of the procedure.

(n) Theoretical slope of the P-V PLOT.

NOTE 7 For guidance on calculating the slope of the P-V PLOT, see [Appendix C](#).

(o) Criteria for evaluating LEAK TIGHTNESS, expressed as an AFV, see [Table 6.3](#). The values in [Table 6.3](#) are appropriate for pipelines carrying gas and stable petroleum fluids. For pipelines carrying other fluids, the values may be reduced by not more than 50 %. The altered values shall be justified and APPROVED.

NOTE 8 For guidance on MEASUREMENT UNCERTAINTY associated with LEAK TEST, see [Appendix H](#).

(p) RESIDUAL AIR limit mitigation action (should it be exceeded) and how it will be addressed in leak assessment.

NOTE 9 For information on air in the test section, see [Appendices B](#) and [G](#).

(q) Test type and END-POINT as nominated by the pipeline design engineer, selected from [Table 6.1](#).

- (r) If applicable, the reason for specifying a pressure higher than that used in any previous pressure test on the pipe or COMPONENT in the test section.
- (s) Procedures for cleaning and filling the test section.
- (t) Procedures for pressurizing the test section.
- (u) Location and elevation of pressurization injection points.
- (v) Method for pressure reduction to allow entry into the EXCLUSION ZONE and the location of pressure-reducing devices.
- (w) Procedures and precautions for the disposal of the test liquid.
- (x) Procedures and precautions for the safety of the general public, operating and testing personnel, and operating and testing equipment, see also [Section 2](#).

NOTE 10 The provisions contained in [Appendix N](#) with respect to hazard assessment and EXCLUSION ZONES should be considered when formulating procedures and precautions. Precautions should include appropriate safety warning signs.

- (y) Procedure for location and repair of leaks, including the procedure to be used for freeze plugging.

NOTE 11 Some jurisdictions require special APPROVAL of a freeze plugging procedure.

NOTE 12 These procedures may not be the responsibility of the TEST SIGNATORY.

- (z) Value of relevant and significant external loads, where required for temporary equipment, and the corresponding value of combined equivalent stresses, as determined in accordance with AS/NZS 2885.1.

The information relating to the physical design of the test section, and the LICENSEE'S requirements for the test shall be provided by the LICENSEE or its authorized representative.

The test procedures and calculations relating to the test shall be developed by the TEST SIGNATORY.

4.5 Test section

The test pressure ratings or previous test pressures of all valves, COMPONENTS, connections, hot bends, and appurtenances in the test section shall be suitable for the intended pipeline test pressure. All valves and equipment that are not suitable shall be isolated or removed. Where necessary, precautions shall be taken to ensure that specified valve seat pressure differentials are not exceeded.

Temporary and permanent connections between the test section and all associated test equipment shall be adequately designed and supported.

Where the test liquid in the test section may experience thermal expansion, provision shall be made for the relief of the resulting increase in pressure.

Where the test liquid will be subjected to temperatures near freezing, precautions shall be taken to protect the equipment and the test section.

4.6 Pressure test procedure

The pressure test procedure shall document the methodology employed in undertaking each pressure test, including all functions, interfaces, and activities required to execute the test and confirm the validity of the methodology.

4.7 Site work

The preparation in the field should include the following:

- (a) Establishment of the EXCLUSION ZONE.
- (b) Placement of pumps.
- (c) Laying of the test liquid supply lines.
- (d) Installation of screens or filters; the line fill meter; temporary pig launchers and scraper traps; manifolds; testing, metering and recording equipment; and all other necessary equipment.
- (e) Preparation and implementation of the JSA/JHA.

NOTE This should be prepared or reviewed in the field with the involvement of all affected parties.

Section 5 Filling

5.1 Basis of section

The process of filling a pipe section for the pressure test shall be undertaken in a manner that —

- (a) displaces trash from the section;
- (b) does not introduce further contaminants that could interfere with the safety or quality of the test; and
- (c) leaves the section substantially free of air or vapour.

NOTE 1 Prior to the introduction of the test fluid into a new pipeline, the pipeline should be cleaned using compressed air and cleaning pigs.

NOTE 2 The cleanliness of an existing pipeline should be assessed prior to the conduct of a test. Where the assessment concludes that it contains contaminants that could affect the validity of the test (including the LEAK TEST), the pipeline should be cleaned by an appropriate means prior to the test.

Where the pipe is internally lined, the process shall be undertaken in a manner that does not damage the lining.

5.2 Filling

Where pigs are used, suitable launching and receiving equipment for the pigs shall be installed. Precautions shall be taken to ensure that pigs are CONTROLLED on slopes.

NOTE 1 A volume (slug) of liquid should be run ahead of the filling pig.

NOTE 2 Filling should be undertaken as a continuous process.

NOTE 3 Where it is necessary to use more than one pig, a slug of liquid of adequate volume should separate the pigs, to ensure that air is not entrained in the test liquid behind the last pig.

The effects of any surge pressure on the safety of the filling operation shall be taken into account.

The volume of air remaining in the test section after filling shall conform to [Clause 6.6.2](#).

NOTE 4 Where pigs are not used for filling, sufficient vents and drains should be provided to fully remove air for the safe conduct of the test and to remove the test fluid after completion of the test.

NOTE 5 Consideration should be given to the dynamic load associated with stopping the pig entering the receiver and the potential for higher than expected velocity resulting from slack flow where the receiver is located at the bottom of a slope, see [Clause 7.2](#) Note 2.

Section 6 Pressure testing

6.1 Basis of section

The field pressure test shall demonstrate the PRESSURE STRENGTH and LEAK TIGHTNESS of a pipeline. The measured PRESSURE STRENGTH is used by the pipeline design engineer to determine the MAXIMUM ALLOWABLE OPERATING PRESSURE in accordance with AS/NZS 2885.1.

For a new pipeline, the pressure test shall comprise a STRENGTH TEST and a LEAK TEST. For an existing pipeline, the test purpose (strength, leak or both) shall be defined prior to commencement of the test.

The pressure test shall not subject any pipe to a strain greater than the limit defined in AS/NZS 2885.1 so that there is no loss of ductility, which is a requirement of a safe design.

The LEAK TEST shall be conducted in a manner that demonstrates that the pipeline does not contain a locatable leak.

The duration of the pressure (strength) test shall be sufficient to verify the integrity of the pipe by allowing sufficient time for near-critical flaws to grow to failure. The duration of the test shall not extend beyond a time where the pipe may be damaged.

The duration of a LEAK TEST shall be appropriate to the dimensions of the pipe section under test. The duration of the test shall be contingent on the test method and SENSITIVITY of the leak detection method.

6.2 Preliminary test

Sections of a pipeline may be subjected to a PRELIMINARY TEST prior to inclusion in a subsequent field test. The purpose of the PRELIMINARY TEST is to remove the risk of failure at locations where failure would present a high risk or would be difficult or impossible to repair if the failure occurred during the field pressure test.

The END-POINT pressure shall be selected in accordance with AS/NZS 2885.1 so as not to limit subsequent field testing.

Test HOLD PERIODS for a PRELIMINARY TEST shall be in accordance with [Clause 6.7.2](#) and [Table 6.2](#).

6.3 Pretested pipe

PRETESTED pipe, PIPELINE ASSEMBLIES, and COMPONENTS may be exempted from a field pressure test as specified in AS/NZS 2885.1 and AS 2885.3.

NOTE A pressure test undertaken during pipe manufacture does not satisfy the requirements of this document for PRETESTED pipe.

6.4 Mechanical interference joints

Where a test section contains mechanical interference fit joints, the maximum pressures/stresses in the field TEST PLAN shall not exceed those qualified in prototype testing and APPROVED.

6.5 Pneumatic test

A PNEUMATIC TEST shall satisfy the requirements of AS/NZS 2885.1 and this clause.

The test may be a combined STRENGTH and LEAK TEST.

The LEAK TEST duration shall be determined by the pipeline design engineer, having regard to the method used to detect a leak and the time required for a leak of the limiting size to reach the level of detection at the measurement point.

A Type F LEAK TEST should follow a PNEUMATIC TEST where leak RESOLUTION is inadequate.

NOTE See [Appendix N](#) for guidance on determining an appropriate EXCLUSION ZONE for the test should a failure occur.

6.6 Pressurization

6.6.1 General

The following shall apply to pressurization:

- (a) The design requirements for the pressurization END-POINT shall be as specified in [Table 6.1](#).
NOTE Yielding will not occur at a pressure below a previous test pressure.
- (b) The END-POINT shall be related to the maximum and minimum test pressures specified in the TEST PLAN and to the maximum stress induced in the pipe in the test section.
- (c) The pressure in any part of the test section shall not exceed the maximum test pressure specified in the TEST PLAN.
- (d) The pressurization procedure shall be designed to stop pressurization in a manner that minimizes the effect of surge pressures on the pipeline when the END-POINT is reached.
- (e) Sufficient controls or valves or both shall be suitably placed so the pressurization process can be conducted without personnel having to enter the EXCLUSION ZONE.
- (f) The procedure shall nominate the method by which leaks that develop during pressurization are identified and rectified or accounted for, given the requirements concerning entry into the EXCLUSION ZONE.
- (g) A PRESSURE-ADDED VOLUME PLOT shall be prepared during pressurization for Type 2 and Type 3 tests for the purpose of monitoring the test section.

6.6.2 Residual air

The air volume in a HYDROSTATIC TEST section at the start of pressurization shall be minimized.

NOTE 1 RESIDUAL AIR in the test section may have an impact on the following issues:

- (a) Assessment of the pipe elastic properties during pressurization.
- (b) Yield assessment during the pressurizing.
- (c) Interference in the determination of pressurizing END POINTS.
- (d) LEAK TEST assessment in the presence of air.
- (e) Possible increased risk of fracture propagation should failure occur.

RESIDUAL AIR shall —

- (a) be reduced to a level where it will not interfere with the assessment of leaks;
- (b) not exceed 5 % of the section volume at atmospheric pressure (in order to limit the risk of fast tearing fracture); and
- (c) be assessed in the pressurizing phase of the test.

NOTE 2 Assessment is not required for a test section being subject to a visual LEAK TEST.

NOTE 3 The RESIDUAL AIR volume should result in the P-V PLOT being linear before the pressure has reached 50 % of the test pressure. [Appendix G](#) provides guidance on the effect and measurement of RESIDUAL AIR.

6.6.3 Pressurization end-point

The method for controlling the pressurization END-POINT shall be in accordance with [Table 6.1](#).

NOTE Refer to AS/NZS 2885.1:2018 [Appendix M](#) for the EPRG minimum hoop failure strain.

6.6.4 Observed leaks during pressurizing

If a leak is observed during pressurization, it shall be remedied or an assessment made of its rate and volume lost and documented in the test report. The leak rate and volume lost shall be used to correct the recorded P-V plot for comparison with the predicted P-V plot.

Should it be necessary to rectify a leak, pressurization shall be halted, and the pressure lowered to a safe level, having regard to the nature of the leak prior to commencing rectification, see [Section 2](#).

If the pressurization is terminated at a pressure less than the nominated value of P_{TMIN} , the reason shall be determined.

NOTE [Appendix F](#) provides guidance on the investigation of a premature END-POINT.

6.7 Strength test

6.7.1 General

For a Type 1 test, the pressure of the test liquid shall be maintained within $\pm 1\%$ of the END-POINT pressure or ± 100 kPa, whichever is the greater.

For a Type 2 or Type 3 test, the pressure shall be maintained within $\pm 1\%$ of the END-POINT pressure for the STRENGTH TEST HOLD PERIOD, unless test pressure at the low point will exceed the maximum allowed; that is, the pressure shall be maintained within 0 % to -2 %.

The pressurization of Type 2 and Type 3 tests shall be monitored, using a plot of pressure increase with added volume (P-V PLOT).

NOTE 1 [Appendix E](#) provides guidance on the P-V method.

NOTE 2 [Appendix L](#) provides guidance on selection and design of test sections.

The design requirements for each test type are given in AS/NZS 2885.1. The requirements for each test type are presented in [Table 6.1](#).

Table 6.1 — Design requirements for STRENGTH TEST pressurization and END-POINT

	Type 1	Type 2	Type 3
Test conditions	No chance of yielding in any pipe $P_{TMAX} \leq$ mill test or a previous STRENGTH TEST, see Note 4.	Small chance of pipe reaching yield strength. σ_H at P_{TMAX} in any pipe $\leq$ AYS_{MIN}	σ_H at P_{TMAX} in any pipe $>$ AYS_{MIN}
Data requirements	MILL TEST PRESSURE or test pressure for a previous STRENGTH TEST, see Note 4.	Mechanical properties determined by ring expansion (see Note 1) or turned tensile methods on uncoated or coated pipe. AYS_{MIN} estimated from mill test data	Mechanical properties determined in accordance with AS/NZS 2885.1 Appendix O on uncoated or coated pipe
Minimum test pressure	P_{TMIN}	P_{TMIN}	P_{TMIN}

Table 6.1 (continued)

	Type 1	Type 2	Type 3
END-POINT limit (Pipe not cold-expanded)	P_{TMAX}	P_{TMAX} A P-V PLOT is used to check data and modelling assumptions	Pressure required to limit individual pipe strain to one-third of the mean hoop failure strain from EPRG testing, see Note 3. A P-V PLOT is used to check data and modelling assumptions
END-POINT limit (Pipe cold-expanded)	P_{TMAX}	The lesser of P_{TMAX} or HALF-SLOPE A P-V PLOT is used to identify HALF-SLOPE and check data and modelling assumptions.	Pressure required to limit individual pipe strain to one-third of the mean hoop failure strain from EPRG testing, see Note 2. A P-V PLOT is used to identify HALF-SLOPE and check data and modelling assumptions.
NOTE 1 Ring expansion method is nominated in AS/NZS 2885.1. NOTE 2 Pipe manufactured by the helical seam process is expected to be covered by the requirements of this table, however, this has not been verified. NOTE 3 The EPRG failure strain is discussed in AS/NZS 2885.1:2018 Appendix M. NOTE 4 Mill test and previous tests apply specifically to line pipe and not to COMPONENTS, i.e. forge fittings, flanges, hot induction bends, valves. NOTE 5 For the determination of AYS_{MIN}, refer to AS/NZS 2885.1:2018 Clause 5.12.7.4.			

6.7.2 Strength test hold period

The STRENGTH TEST HOLD PERIOD for the pipeline shall be not less than 2 h and not more than 8 h, except for PIPELINE ASSEMBLIES.

The STRENGTH TEST HOLD PERIOD for PIPELINE ASSEMBLIES shall be the same as for the pipeline but may be reduced, provided —

- (a) test pressure is CONTROLLED;
- (b) test pressure factor is 1.4; and
- (c) stress induced by the test is not greater than 95 % of SMYS.

The STRENGTH TEST HOLD PERIOD for pipeline assemblies meeting the provisions in Items (a), (b) and (c) above shall not be less than 30 min.

NOTE 1 Added volume required for maintenance of pressure on account of strain in the test section may be distinguished from added volume required because of a leak in the test section by the shape of the pressure decay curve.

NOTE 2 The 30 min STRENGTH TEST HOLD PERIOD is intended to bring pipeline tests that could theoretically be performed under AS 4041 or ASME B31.3 into line with the requirements of these Standards. This criterion will generally apply to above-ground (visual inspection) test sections.

6.7.3 Observed leaks during the strength test hold period

Where actual leaks are visible during the STRENGTH TEST HOLD PERIOD, the quantity of leaked liquid shall be assessed. The HOLD PERIOD may be continued to completion.

NOTE Visible leaks, except leaks in temporary fittings and equipment, should be repaired before the LEAK TEST is conducted.

6.7.4 Strength test assessment

A STRENGTH TEST is acceptable, provided the pressure is maintained within the limits of [Clause 6.7.1](#) for the duration of the HOLD PERIOD. The presence of an identified leak does not invalidate a STRENGTH TEST.

For a buried pipeline, the HOLD PERIOD shall be considered to be completed when the calculated rate of pressure change is less than 1 % per hour after the minimum HOLD PERIOD has elapsed.

NOTE 1 The rate of change may be calculated over any convenient time interval for which reliable values of pressure changes are obtained.

This requirement does not apply to a Type 1 test.

NOTE 2 The 1 % per hour pressure drop is intended to determine whether plastic straining has terminated or is continuing.

If, during the HOLD PERIOD, all pressure-containing COMPONENTS in the test section maintain their integrity at the specified STRENGTH TEST pressure, the STRENGTH TEST performance shall be deemed satisfactory.

If RUPTURE occurs, the damaged pressure-containing COMPONENT shall be replaced, and the STRENGTH TEST repeated. If leakage occurs, the requirements of [Clause 6.7.3](#) shall apply.

The measured pressure (P_M) of a test section shall be the value of the END-POINT pressure measured at, or calculated for, the highest elevation in the test section. It shall not be adjusted for variations in pressure during the STRENGTH TEST HOLD PERIOD. P_M should not be less than P_{TMIN} unless the STRENGTH TEST is terminated early.

NOTE 3 Where a test section is wholly or partly submerged, the PRESSURE STRENGTH may be considered to be that determined in accordance with this clause.

NOTE 4 Where the test section is laid through a water body whose surface elevation may change during the pipeline design life, the test pressure at the low point should be treated as if the water body does not exist.

6.8 Leak test

6.8.1 General

The LEAK TEST shall be concluded only on a section that has previously been subjected to a satisfactory STRENGTH TEST.

The following apply to the design, conduct and acceptance of a LEAK TEST:

- (a) A pipeline shall not contain a locatable leak.

NOTE Where a leak is suspected but not located, the pipeline may be put into service provided —

- (i) all reasonable efforts have been made to locate the suspect leak including test section redesign and retest;
- (ii) it is safe (because the fluid loss is so small that its associated risk is low or negligible when accessed in accordance with AS/NZS 2885.1);

- (iii) it can be inspected by another method (e.g. gas detection) after being put into service if necessary (for an integrity, commercial or environmental reason); and
 - (iv) the fluid transported is not a hydrocarbon liquid or a fluid that, if released, would cause unacceptable environmental damage, a health hazard, or cause erosion or damage to the pipe wall, which would cause leak growth.
- (b) The test section shall be isolated for the LEAK TEST HOLD PERIOD, subject to the provisions of [Clause 6.8.9](#).
- (c) Any volume change shall be accounted for and stated in the test report.

6.8.2 Leak test uncertainty

There is metrological uncertainty associated with measurement of pressure and pipe wall temperature (see [Appendix I](#)). There is also uncertainty relating to whether the average pipe wall temperature change correctly measures the internal water temperature change (see [Appendix J](#)). The combination of these two uncertainties is the LEAK TEST uncertainty.

The LEAK TEST method shall be selected for a test section such that it can discriminate between the pressure change resulting from fluid loss and the pressure change from temperature changes.

This document defines the limit of LEAK TEST uncertainty as the ALLOWABLE FLUID VARIATION (AFV) during the HOLD PERIOD. The UNACCOUNTABLE FLUID VARIATION (UFV) shall be calculated from data determined during the LEAK TEST. The UFV shall be compared with the AFV to determine whether the LEAK TEST satisfies the LEAK TEST uncertainty criteria. The HOLD PERIOD shall be of sufficient time to consider diurnal variations and to establish thermal stability.

NOTE 1 The AFV for a test section in a LOCATION CLASS is set out in [Table 6.3](#).

Where the pipeline is intended to transport a hydrocarbon liquid, the appropriateness of the values in [Table 6.3](#) shall be considered and, if required, revised to reduce the risk of an undetected leak.

NOTE 2 Most pipelines likely to be tested with hydrocarbon liquids have relatively small volume and are installed in industrial location sub-classes where the AFV is stringent.

For the purpose of test assessment, pressure and temperature, changes shall be converted to volume changes using the dV/dP value measured during pressurization and the calculated value of dV/dT .

The following principles apply to the LEAK TEST uncertainty requirements of this document:

- (a) The combination of the AFV, the instrumentation installed on a test section and the test HOLD PERIOD provide the basis for calculating the maximum volume of a test section that can satisfy the LEAK TEST uncertainty limits of this document.
- (b) The combination of test section volume, instrumentation, and test HOLD PERIOD shall allow the required AFV to be detected.

NOTE 3 The AFV values reflect the experience gained in the LEAK TEST of pipelines, using the previous editions of this document, with the experience in testing large volume sections on the Moomba–Wilton pipeline and the experience gained by pressure-testing engineers in the performance of tests of large diameter, large test section volume international pipelines to the principles of previous revisions of this document, see [Appendices B](#) and [I](#).

NOTE 4 A different acceptance criteria may be necessary to satisfy the environmental target for a pipeline transporting hydrocarbon or other liquids

NOTE 5 Significant quantities of exposed pipe within a buried test section make the estimation of the internal water temperature change from pipe wall temperature change measurements more difficult to determine, see AS/NZS 2885.1:2018 Clause 5.12.

- (c) A UFV loss that exceeds the AFV shall be deemed to be a leak.

- (d) A UFV gain that exceeds the AFV shall be deemed to indicate that the test does not satisfy good practice.
- (e) A UFV that is less than the AFV shall be deemed to satisfy the requirements of this document, provided that the TEST SIGNATORY is satisfied that the test data does not show evidence that the pipe contains a leak.

NOTE 6 Because the LEAK TEST uncertainty is reduced for test sections whose volume is less than the maximum limit, the TEST SIGNATORY should nominate a target AFV for each test section that reflects the LEAK TEST uncertainty target expected to be achieved for the test section volume, instrumentation and test duration. The test report should explain the reason for accepting a test at an AFV higher than the nominated value (but not exceeding the value in [Table 6.2](#)).

- (f) In small volume test sections, the pressure change from loss of a nominated volume of fluid is relatively high, allowing a reduction in the LEAK TEST uncertainty. Reduced duration tests and reductions in instrumentation for small volume tests shall be permitted.

NOTE 7 The AFV for each LOCATION CLASS represents the magnitude of a leak which if it remained undetected would not be unsafe, and for which the effort (cost) to find during the construction phase is not justifiable.

NOTE 8 Pipe manufactured by the ERW process may contain fusion line flaws not identified in the factory. Experience has shown that the leakage rate from these flaws is typically in the range of 50 L to 150 L/24 h. Test sections containing ERW pipe should be designed to discriminate between LEAK TEST uncertainty and leaks in this volume range.

Pipe manufactured by the SAW process does not characteristically contain through-wall fusion line flaws. An increased AFV for SAW pipe installed in R1 locations, allowing the test section volume to be increased, shall be permitted.

Table 6.2 — Leak test requirements

LEAK TEST type	Maximum volume recommended	Assessment method	Temperature measurement	HOLD PERIOD h	Comment
A	Not limited	Visual	Not required	0.5	Above-ground pipe — Combined STRENGTH and LEAK TEST permitted. HOLD PERIOD not less than required for STRENGTH TEST. STATION pipe tested to STATION PIPING standard
B	10 000 L	AFV	Not required	3	Applies to sections where the pressure change from the AFV is five times greater than from the expected pipe wall temperature change, see Note 9.
C	250 000 L	AFV	Required	3–24	The temperature-measuring device REPEATABILITY shall be 10 % of the AFV temperature equivalent during that period, see Note 1.
D	10.0 ML	AFV	Required	24 (min.)	See Notes 2, 3, and 4.
E	25.0 ML	AFV (ERW or SAW)	Required	48 (min.) to 120 (max.)	Temperature REPEATABILITY increased to 50 % of the temperature change equivalent to the AFV. Data loggers shall be used for each TEMPERATURE PROBE, see Notes 2, 3, 4, and 5.
E1	25.0 ML	AFV (SAW)	Required	24	Temperature REPEATABILITY in accordance with Clause 3.2.4.1 (20 %). Data loggers shall be used for each TEMPERATURE PROBE, see Notes 2, 3, 4, 5, and 6.

Table 6.2 (continued)

LEAK TEST type	Maximum volume recommended	Assessment method	Temperature measurement	HOLD PERIOD h	Comment
F		Leak detection survey			Survey shall not commence until sufficient time has elapsed for gas leaks to permeate ground level and attain a detectable concentration.
NOTE 1 The test duration may be selected on the basis that there is sufficient discrimination between the effect of the temperature change and the measured change in pressure (that is, short duration tests may be allowed for smaller volume test sections). The test may be extended up to 24 h (i.e. a Type D test). NOTE 2 Where the HOLD PERIOD exceeds 3 h readings of test pressure, ambient temperature should be taken at hourly intervals. NOTE 3 The temperature of the pipeline, ground, or both is taken at least 5 times during a 24 h LEAK TEST period. Pressure is plotted against pipeline or ground temperature and ambient temperature, or both. Account is made for any change in pressure due to change in temperature. NOTE 4 Pipe and soil temperature data should be recorded at regular intervals to allow detailed analysis of temperature trends throughout the test. NOTE 5 For test periods that extend beyond 24 h, the UFV should be calculated for rolling 24 h periods and the value plotted to demonstrate progress to (or divergence from) the AFV. NOTE 6 Leak detection survey during COMMISSIONING is recommended as a validation of LEAK TEST results. NOTE 7 Should a test be proposed beyond the recommended volume limits above, the rationale for this shall be documented and APPROVED. NOTE 8 A LEAK TEST should not extend beyond 120 h. NOTE 9 Larger volumes are permitted provided that it can be demonstrated that the expected pressure change from the AFV is five times greater than from the expected pipe wall temperature change.					

Table 6.3 — Allowable fluid variation

LOCATION CLASS	ALLOWABLE FLUID VARIATION rate (L/24 h period)
R1 (SAW pipe)	400
R1 (ERW pipe)	100
R2	100
T1	40
T2	20

6.8.3 Thermal stability for a leak test

Where correlation of pressure change with temperature change is used to assess LEAK TIGHTNESS, thermal stability shall be achieved prior to commencement of the LEAK TEST, see Note 1.

Sufficient time shall be allowed between pipe filling and the commencement of LEAK TESTING to ensure that thermal stability can be achieved throughout the LEAK TEST period, see Note 2.

NOTE 1 For a list of criteria for demonstrating thermal stability, see [Appendix B](#) and Note 6.

NOTE 2 Assessment of thermal stability is recommended at LEAK TEST pressure to avoid potential disturbances to thermal stability during addition or removal of any test liquid necessary to reach LEAK TEST pressure and may be carried out during the LEAK TEST period. Changes in pressure result in changes in temperature due to the effects of adiabatic compression or decompression.

NOTE 3 For information on adiabatic changes in test sections, see [Appendix M](#).

NOTE 4 Thermal stability is only of concern for LEAK TESTS where the pipe is buried and the section is of sufficient length and volume that test liquid temperature changes affect leak assessment.

NOTE 5 The time taken for stabilization to occur depends on the temperature of the test liquid at the time of filling, specific heat capacity of the test liquid, pipe diameter, burial depth, undisturbed ground temperature, and the thermal conductivity of the backfill and ground which can be affected by groundwater.

NOTE 6 Assessment of thermal stability may be by a number of means, and these are discussed in [Clause A.4.7](#). One method of assessment is to compare the pipe temperature change with the ground temperature change at the same cross-section of the pipeline. Where the difference between the changes during the LEAK TEST period is less than the AFV converted to temperature, this location is considered to be thermally stable. Other methods discussed in [Clause A.4.7](#) are equally acceptable.

NOTE 7 For information on temperature changes, see [Appendix I](#).

6.8.4 Leak test requirements

LEAK TESTS shall conform to the requirements of [Table 6.2](#).

NOTE The table nominates LEAK TEST types based on the test section volume. Simplified requirements are defined for smaller volume test sections, where the pressure change from a leak of the nominated AFV is large. The requirements become more stringent for increasingly large test section volumes.

When the HOLD PERIOD is completed, the pressure shall not be raised above the LEAK TEST pressure.

6.8.5 Temperature data measurement

LEAK TEST Types D, E, and E1 (see [Table 6.2](#)) require temperature recording at regular intervals throughout the test using data loggers. When properly programmed, these devices help reduce the MEASUREMENT UNCERTAINTY by making temperature measurements along the test section at the same time and at pre-set intervals determined by the TEST SIGNATORY.

When used, data loggers should be inspected regularly throughout the tests to confirm that they are functioning correctly. The most recent temperature should be recorded at each inspection to provide the TEST SIGNATORY with data to assess the progress of the test and to confirm the ongoing performance of the data logger.

6.8.6 Leak test pressure

The LEAK TEST pressure shall be not less than 1.1 times the DESIGN PRESSURE.

The LEAK TEST pressure should not exceed 90 % of the STRENGTH TEST pressure calculated at the midpoint elevation, except for a combined STRENGTH and LEAK TEST.

6.8.7 Observed leaks during leak test

During the HOLD PERIOD, visible parts of the test section shall be inspected for leaks.

Where actual leaks are visible in permanent piping, they shall be rectified before a test section is declared LEAK TIGHT, by —

- (a) stopping the test, repairing the leak, and repeating the test;
- (b) eliminating the leak during the HOLD PERIOD and observing the point to be LEAK TIGHT for not less than 3 h; or
- (c) eliminating the leak after the LEAK TEST, provided that the volume of test fluid that leaked is collected and used in assessment of the LEAK TEST, and the leaking element is replaced with a PRETESTED element, refer to AS 2885.3.

NOTE Leaks observed in temporary fittings or temporary test facilities relating only to testing of the test section do not require repair unless failure to do so would negate a successful test. The leaked volume may be collected and used in assessment of the LEAK TEST.

6.8.8 Leak test assessment

6.8.8.1 General

A LEAK TEST is acceptable if the results of measurements (or visual observations of the test section) show that the acceptance criteria nominated in the TEST PLAN have been met.

6.8.8.2 Leak test Type A

LEAK TEST Type A is assessed visually.

If, during the HOLD PERIOD, no leaks are observed or known to be present in permanent pipe or PIPELINE ASSEMBLIES, the test shall be deemed to be satisfactory.

Volume changes during the test need not be recorded.

6.8.8.3 Leak test Type B

LEAK TEST Type B is conducted on buried pipe for which no temperature measurement is necessary.

Where a LEAK TEST Type B is performed and a leak is indicated, the test shall be continued until a representative leak rate can be calculated. The provisions of [Figure 6.1](#) shall then be applied.

6.8.8.4 Leak test Types C, D and E

LEAK TEST Types C, D, and E detect leaks by correlating pressure with temperature.

The test performance shall be deemed to be satisfactory if the volume change during the test period does —

- (a) not exceed the AFV, see [Table 6.3](#); and
- (b) there is no leakage in the permanent pipe work implied by the test results or known to be present.

If either of the above conditions is not met, the procedure outlined in [Figure 6.1](#) shall be applied to determine the acceptability or otherwise of the test.

For test periods exceeding 24 h, the test results shall be assessed over the entire period during which data are gathered. Successive overlapping 24 h periods shall also be analysed. The trend of such analysis shall be included in the assessment and documentation of the test result.

The method of adjusting the measured pressure change for changes in temperature shall be in accordance with [Appendix B](#).

6.8.8.5 Leak test Type F

LEAK TEST Type F is by direct measurement of loss using a detectable tracer gas and an instrument of appropriate SENSITIVITY.

A Type F LEAK TEST may be conducted as an alternative to a hydrostatic LEAK TEST or where required by [Figure 6.1](#).

A test procedure shall be developed and qualified to demonstrate its SENSITIVITY. The test procedure shall nominate the following:

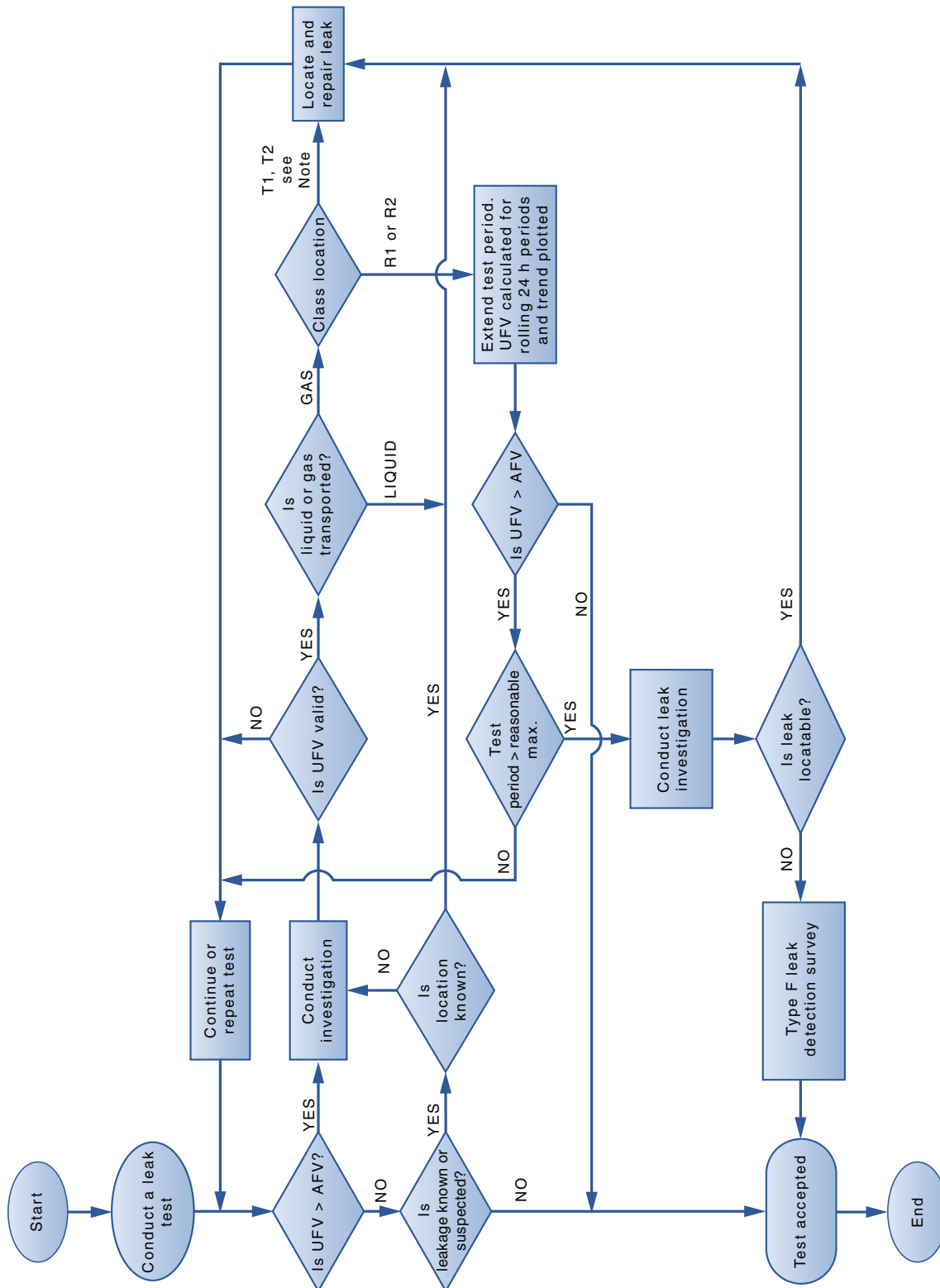
- (a) Tracer gas, its concentration, and the method by which it is to be blended into the carrier fluid.
- (b) Detection instrument and the spatial limits for the sensor, relative to the pipe centre-line and ground surface, and the travel speed.
- (c) Minimum pipeline pressure during the test.
- (d) Qualified detection SENSITIVITY.

Where it is proposed to use a remote-sensing method for leak detection (e.g. from an aircraft), the method and its SENSITIVITY shall be APPROVED.

6.8.9 Combined strength and leak test

The minimum test pressure for a combined STRENGTH and LEAK TEST shall be nominated by the pipeline design engineer. The test pressure shall satisfy the requirements of both the STRENGTH TEST and the LEAK TEST.

NOTE A Type A LEAK TEST could be considered if a leak is not locatable in the hydrostatic LEAK TEST.



NOTE A Type F LEAK TEST could be considered if a leak is not locatable in the HYDROSTATIC TEST.

Figure 6.1 — Procedure to determine the acceptability of LEAK TEST

Section 7 Reinstatement of the test section

7.1 Basis of section

This Section sets out requirements for the safe and orderly transition from test section to pipeline before COMMISSIONING of the pipeline. Requirements relevant to COMMISSIONING are given in AS/NZS 2885.1.

7.2 Reinstatement

AS/NZS 2885.1 specifies requirements for reinstatement following construction. In addition to those requirements, the following shall be observed:

- (a) Disposal of the test fluid shall conform to the requirements of the relevant authorities and ensure that the general public, operating and testing personnel, operating equipment and the environment are not exposed to any harmful effects. Where additives have been used, extra precautions may be necessary.
- (b) At the end of the test and before COMMISSIONING or RECOMMISSIONING the pipeline, the test section and all associated equipment shall be put into a safe condition.

NOTE 1 Where a pipeline is placed in operation sometime after it has been pressure tested, AS/NZS 2885.1 provides for corrosion mitigation.

NOTE 2 In steeply sloping test sections, the elevation gradient may exceed the hydraulic gradient, causing the flow to change from 'packed' to 'slack' (flow with a free surface). If this should occur, the velocity in the slack section will be significantly higher than in the packed section, and significant surge pressures may be caused when the vapour cavity collapses.

NOTE 3 Consideration should be given to potential for significant increase in the pressure required to displace the test liquid if air enters the test section, as a result of the compounding of 'U' tube effects (i.e. air locks) between successive high and low points. To avoid this, it is recommended that the procedure used to fill the pipe be applied in reverse.

Section 8 Reports and records

8.1 Basis of section

This Section sets out the requirements for reports which are essential records of the integrity of the pipeline i.e. records that have to be retained for the life of the pipeline.

The full record of the pressure testing of the pipeline shall be retained by the operating authority for the life of the pipeline.

8.2 Reporting requirements

A detailed report shall be prepared for each test section. The reports for all test sections shall be collated to form a full record of the pressure testing of the pipeline.

The report shall include at least the following:

- (a) A conformance section, being a statement that the test section has been tested and does or does not conform to the requirements of the pipeline design. The conformance section shall include the following:
 - (i) Name of the organization responsible for the test and the TEST SIGNATORY.
 - (ii) Methodology as to how this conformance was determined.
 - (iii) Results of any investigations conducted arising out of the test.
 - (iv) Date(s) on which the testing was conducted.
 - (v) Instrumentation used and its validation, CALIBRATION or VERIFICATION as applicable.
 - (vi) Test certificate signed by the TEST SIGNATORY.

NOTE 1 A typical test certificate is given in [Appendix K](#).

- (b) A descriptive section stating the following:
 - (i) Name of the pipeline and a general description and location.
 - (ii) Test section number.
 - (iii) Test section specific description or location. This may include marked up alignment sheets, maps, isometric drawings or plot plans.
 - (iv) Test section length and chainages, where applicable.
 - (v) Accurate location and elevation of the test point.
 - (vi) Test section's pipe information, including each pipe diameter, wall thickness, grade combination, and cumulative length for each pipe section where relevant.
 - (vii) Prior test pressure of the pipe or, where the test section has been tested previously, the maximum pressures achieved.

NOTE 2 For a newly constructed test section, the prior test pressure will be the pipe mill nominal minimum test pressure, which may be obtained from either the mill test certificate of the Pressure Test Design.

- (viii) Where a Type 2 or Type 3 STRENGTH TEST has been undertaken, AYS_{MIN} for the highest design factor section.

NOTE 3 AYS_{MIN} may be obtained from the Pressure Test Design.