

Australian Standard[®]

Serially produced pressure vessels



This Australian Standard® was prepared by Committee ME-001, Pressure Equipment. It was approved on behalf of the Council of Standards Australia on 26 April 2007. This Standard was published on 12 July 2007.

The following are represented on Committee ME-001:

- ACT WorkCover
 - Australasian Institute of Engineer Surveyors
 - Australian Aluminium Council
 - Australian Building Codes Board
 - Australian Chamber of Commerce and Industry
 - Australian Industry Group
 - Australian Institute for the Certification of Inspection Personnel
 - Australian Institute of Energy
 - Australian Institute of Petroleum
 - Bureau of Steel Manufacturers of Australia
 - Department of Consumer and Employment Protection, WorkSafe Division, WA
 - Department of Industrial Relations, Queensland
 - Department of Justice, Workplace Standards Tasmania
 - Department of the Premier and Cabinet, SafeWork SA
 - Energy Networks Association
 - Engineers Australia
 - Insurance Council of Australia
 - LPG Australia
 - Materials Australia
 - National Association of Testing Authorities, Australia
 - Pressure Equipment Association
 - Victorian WorkCover Authority
 - Welding Technology Institute of Australia
 - WorkCover NSW
-

This Standard was issued in draft form for comment as DR 06252.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

Serially produced pressure vessels

Originated as AS 2971—1987.
Previous edition 2002.
Third edition 2007.

COPYRIGHT

© Standards Australia

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher.

Published by Standards Australia GPO Box 476, Sydney, NSW 2001, Australia
ISBN 0 7337 8273 6

PREFACE

This Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee ME-001, Pressure Equipment to supersede AS 2971—2002, *Serially produced pressure vessels*. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

This Standard covers a wide range of small, usually low-hazard, pressure vessels whose design and construction are based on satisfactory burst and other performance tests of a significant number of representative samples. The main types of vessels falling into this group are small, serially produced refrigeration type vessels, air brake reservoirs, drink dispensers, and consumer items such as pressurized fire extinguisher bodies not covered by other Australian Standards, and beer kegs.

Almost invariably these types of vessels do not comply with AS 1210, *Pressure vessels*, which has been prepared primarily for one-off vessels where the design is based on proven formulas, and construction is based on proven materials, fabrication procedures, personnel, and tests which are predominantly non-destructive. AS 1210 does permit burst testing as a basis for acceptance of design of parts or vessels, but only when they cannot be calculated. Thus, there is a need to cover this alternative method of producing safe vessels where it is frequently equally sound and more economic to use burst and other performance tests to validate design, materials, and fabrication, all simultaneously.

The main changes in this revision include the following:

- (a) Clause 1.1, Scope—The lower limit for the temperature range has been changed from -20°C to -30°C , to better meet the needs of the refrigeration industry.
- (b) Clause 1.5.1, Batch—The time period considered to constitute a ‘batch’ has been widened from 5 days to 3 months, as the previous test regime was thought to be unnecessarily onerous.
- (c) Clause 1.5.14, Unfired pressure vessel—The definition of the pressure envelope has been clarified in line with AS 1210—1997.
- (d) Section 3, Performance requirements—The test requirements for designs using ‘suitably ductile’ materials have been substantially altered.
- (e) Clause 5.2, Type testing—Allowance for testing of a ‘representative’ vessel or design where there is a family of designs which varies only in length and connections.
- (f) Table 5.1, Schedule for assessment of performance characteristics—The number of vessels between tests for burst and fragmentation requirements has been increased from 500 to 1000.
- (g) Appendix D, Burst and fragmentation test—The known performance of materials operating outside the range of 0 to 50°C is now taken into account in tests and design strengths.
- (h) Appendix I, Corrosion tests—The brass cracking test method has been replaced to avoid the safety risks involved with the use of mercurous nitrate.

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

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

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	5
1.2 OBJECTIVE	5
1.3 APPLICATION	5
1.4 REFERENCED DOCUMENTS	6
1.5 DEFINITIONS	6
1.6 CLASSIFICATION OF VESSELS	7
1.7 DESIGNATION	8
1.8 APPLICATION OF CLASSES AND TIERS OF VESSELS	8
SECTION 2 MATERIALS, DESIGN AND MANUFACTURE	
2.1 MATERIALS	10
2.2 DESIGN	10
2.3 MANUFACTURE	12
2.4 PROTECTIVE DEVICES AND FITTINGS	12
2.5 CORROSION PROTECTION	12
SECTION 3 PERFORMANCE REQUIREMENTS	
3.1 GENERAL	13
3.2 RESISTANCE TO INTERNAL PRESSURE	13
3.3 RESISTANCE TO BURSTING AND FRAGMENTATION	13
3.4 RESISTANCE TO FATIGUE	13
3.5 RESISTANCE TO DROPPING	13
3.6 RESISTANCE TO PENETRATION	13
3.7 RESISTANCE TO IMPACT	13
3.8 RESISTANCE TO TORQUE	14
3.9 CLOSURE	14
3.10 RESISTANCE TO CORROSION	14
3.11 PRESSURE RELIEF	14
3.12 MARKING PLATE ADHESION	15
3.13 SURFACE QUALITY AND CONFORMANCE	15
3.14 OTHER PERFORMANCE CHARACTERISTICS	15
3.15 RETESTS AFTER FAILURE OF A PRODUCTION TEST	16
SECTION 4 MARKING AND INSTRUCTIONS	
4.1 MARKING	17
4.2 INSTRUCTIONS	17
SECTION 5 ASSESSMENT OF DESIGN COMPLIANCE WITH THE REQUIREMENTS OF THIS STANDARD	
5.1 GENERAL	18
5.2 TESTING	18
5.3 WITNESSING OF TYPE TESTS	18
5.4 REPORT OF TYPE TESTING	18
5.5 MANUFACTURER'S DATA REPORT	18
5.6 AUDITING OF MANUFACTURER'S FACILITIES	19
5.7 RETESTS	19

APPENDICES

A	INTEGRATED PRESSURE EQUIPMENT TEST STATIONS	23
B	INFORMATION TO BE SUPPLIED BY THE CUSTOMER AND THE MANUFACTURER	25
C	PROOF PRESSURE TESTS	27
D	BURST AND FRAGMENTATION TEST	28
E	FATIGUE TEST.....	30
F	DROP TEST	31
G	PENETRATION TEST.....	33
H	IMPACT TEST.....	35
I	CORROSION TESTS.....	37
J	PRESSURE-RELIEF DEVICE TESTS	39
K	MARKING PLATE ADHESION TEST	41
L	REFERENCED DOCUMENTS	42
COMMENTARY		43

STANDARDS AUSTRALIA

Australian Standard

Serially produced pressure vessels

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for the materials, design, manufacture, inspection and testing of serially produced metallic or non-metallic or combination unfired pressure vessels comprising:

- (a) A maximum volume of 500 L.
- (b) A design pressure exceeding 0.05 MPa.
- (c) A product of the design pressure (in megapascals) and the total vapour space (in litres) that is greater than 1 but less than 3000 MPa.L. Where the vessel contents are classified as harmful or very harmful to AS 4343, the upper limit is 1500 MPa.L. This Standard excludes contents classified as lethal.

NOTE: The vapour space is the maximum volume which will contain compressed gas or vapour or liquefied gas or liquid above its atmospheric boiling point.

- (d) A temperature range of -30°C to 150°C . Vessels designated outside the range of 0°C to 50°C require special tests. Refer to Appendices D, F and G where applicable.

Such vessels may be refillable or non-refillable.

NOTE: Users of this Standard are reminded that it has no legal authority in its own right, but may acquire legal standing if adopted by government or any other authority having jurisdiction, or if specified as part of a commercial contract.

1.2 OBJECTIVE

This Standard is intended to —

- (a) establish minimum requirements for the materials, design, manufacture, inspection and testing for pressure vessels within the range of Clause 1.1; and
- (b) provide a method of design based on destructive type testing and monitoring of manufacture by performance testing of representative samples from production. This method is an alternative to that given in AS 1210 to vessels within the range of Clause 1.1.

1.3 APPLICATION

This Standard is not intended to apply to —

- (a) pressure vessels covered by other Australian Standards, e.g. portable fire extinguishers, LP Gas fuel vessels for automotive use and sterilizers;
- (b) compressed gas cylinders covered by AS 2030 (series);
- (c) glass and plastics bottles; or
- (d) vacuum vessels (i.e. vessels that operate only below atmospheric pressure).

1.4 REFERENCED DOCUMENTS

A list with titles of documents referred to in this Standard is given in Appendix L.

1.5 DEFINITIONS

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

1.5.1 Batch

A group of serially produced vessels made with the same set-up in the same plant over a period not exceeding 3 months and subject to the same quality control measures.

NOTE: The 'same set-up' refers to the same diameter, nominal thickness, heat treatment process and welding control settings.

1.5.2 Certification body

A nationally recognized body that provides certification.

1.5.3 Customer

Person or organization that receives a product or service.

NOTES:

- 1 A customer may be internal or external to the organization.
- 2 A customer can be the 'purchaser'.

1.5.4 Design minimum temperature

The lowest temperature at which the vessel part under consideration is intended to be operated. It is used to select material with suitable low temperature properties and as the basis for type and production tests.

1.5.5 Design pressure

The maximum gauge pressure, at a designated temperature, which is allowed at the top of the pressure vessel in its operating position.

1.5.6 Design temperature

The maximum temperature at the design pressure, used to determine the dimensions of the vessel part under consideration, and used as the basis for type and production tests.

1.5.7 Design verifier

A person who verifies the design of pressure equipment.

NOTE: In this Standard, the design verifier may also witness tests or interpret test results or a combination of these.

1.5.8 Integrated pressure equipment test station (IPETS)

A test station integral with the manufacturing process and operating as specified in Appendix A. It is responsible for the quality of all pressure equipment sold from the manufacturing plant from which it operates.

1.5.9 Production testing

An ongoing evaluation procedure for the purpose of manufacturing verification, carried out on production vessels.

1.5.10 Serially produced vessels

Vessels of the same diameter, configuration, nominal thickness, materials, openings, attachments and manufacture which are produced in series in such manner and numbers as will permit the use of statistical methods to control quality.

NOTE: Such vessels are sometimes referred to as 'multiple duplicate' vessels.

1.5.11 Shall

Indicates that a statement is mandatory.

1.5.12 Should

Indicates a recommendation.

1.5.13 Type testing

An evaluation procedure for the purpose of design verification on a representative sample of production which ascertains that the product will fulfil the performance requirements of the design specification and the application Standard.

1.5.14 Unfired pressure vessel

A vessel subject to internal pressure or external pressure including inter-connecting parts and components up to the first point of connection to connected piping and fittings by bolting, screwing, welding, or by other means, but not including those vessels wherein steam or other vapour is or is intended to be generated, or water or other liquid is or is intended to be heated, by the application of fire or the products of combustion or by electrical means.

The attachment of a pressure system component to the pressure envelope of a serially produced pressure vessel is not considered a part of the vessel, unless the component and the joint attaching it to the vessel are capable of meeting the performance requirements of this Standard.

NOTE: For example, in refrigerating systems where copper pipeways are connected to steel vessels by expanding, brazing or other means, and the copper component will not pass some of the specified tests, these are not considered part of the vessel.

1.5.15 Verification

Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled (by the IPETS or an independent third party design verifier and independent third party inspector).

1.5.16 Verifying organization

An organization accredited by a recognized body to grant certificates to the integrated pressure equipment test stations.

1.6 CLASSIFICATION OF VESSELS

Vessels shall be classified according to their design, material, manufacture, and pressure performance as shown in Tables 1.1 and 1.2.

TABLE 1.1
CLASSES OF VESSELS

Class	Minimum burst pressure (times design pressure)	Minimum proof pressure (times design pressure)	Performance fatigue test	Other performance test
1H	2.35	1.25	Required if $N > 10$	see Section 5
1	3.5	1.5	Required if $N > 200$	
2	4.4	1.5 (Note 3)	Not required	
3	9	2	Not required	

NOTES:

- 1 N = the expected number of significant pressurizing cycles (i.e. cycles having a range of pressure greater than 20 percent of the design pressure) over the design life.
- 2 The manufacturer shall state in the data report the design life in cycles for Class 1H and Class 1 vessels or vessel parts.
- 3 Vessels less than 155 mm inside diameter and with harmful and non-harmful contents may be tested at design pressure.

TABLE 1.2
TYPICAL APPLICATIONS OF CLASSES OF VESSELS

Class	Material	Service (see Note)	Example of application
1H	Ductile	Static	Sparklet cylinders
1	Ductile	Static	Refrigeration vessels
2	Ductile	Static or dynamic	Air brake reservoir, refrigeration vessels, or components, including ductile plastics vessels or components
3	Non-ductile	Static or dynamic	Cast iron, glass, or plastics vessels or components

NOTE: Dynamic service is service where the vessel will normally be subject to extra stresses due to external shock loads or due to pressure shocks, e.g. air brake reservoirs.

1.7 DESIGNATION

Vessels shall be designated by the number of this Standard and the class of vessel (e.g. for a Class 1 vessel: AS 2971.1).

1.8 APPLICATION OF CLASSES AND TIERS OF VESSELS

Vessels are divided into two 'tiers' (see Table 1.3) to allow for appropriate levels of production testing. The class and tier applicable to each vessel shall be nominated by the manufacturer and be in accordance with Table 1.1, Table 1.2 and Table 1.3 as appropriate. The class and tier nominated shall be reviewed by the person or body witnessing the type tests in accordance with Clause 5.2, applicable to the pressure envelope which is usually governed by the cylindrical shell.

Where non-ductile components are attached to ductile vessels, the non-ductile components shall be tested in accordance with Class 3 requirements. This may require different testing for the non-ductile components.

TABLE 1.3
TIERS OF VESSELS

Property	Tier 1 vessels	Tier 2 vessels
Shape	Simple (see Note 1)	All shapes
Class of vessel	1, 2 or 3	1, 2, 3, or 1H
Materials	Suitably ductile (see Note 2)	All acceptable materials
Service conditions	Fatigue tests not required except where required by Table 1.1 for Class 1	All conditions
Contents	Harmful and non-harmful (see Note 3)	All contents classifications except lethal (see Note 3)

NOTES:

- 1 Simple shape: Vessel which is cylindrical or spherical in shape and has ends of conventional shape.
- 2 Suitably ductile: Those materials having a yield or 0.2% proof strength of less than 300 MPa and an elongation of more than 20%. Where the yield or 0.2% proof strength is >320 MPa but ≤360 MPa, the elongation may be reduced by 1% for each 10 MPa over 320 MPa but in no case be <16%.
- 3 Refer to AS 4343 for the classification of contents and hazard levels of pressure equipment.

SECTION 2 MATERIALS, DESIGN AND MANUFACTURE

2.1 MATERIALS

The material used in pressure parts of a vessel shall not be deleteriously affected by, nor have a deleterious effect on, the intended contents of the vessel or the intended service environment, and shall be such that each vessel would be able to pass the relevant tests specified in this Standard.

For the purpose of establishing the classification applicable to each vessel in accordance with Clause 1.6, ductile materials may be considered to be those materials which when tested by approved methods after manufacture of the vessel have not less than 8 percent elongation at rupture on a gauge length of $5.65\sqrt{S_0}$, where S_0 is the original cross-section within the gauge length, or equivalent elongation when measured on other gauge lengths or in a bend test or burst test, and which do not fragment during burst tests (see Clause 3.3). The ductility shall be measured in the area or areas of the vessel, and at conditions, such as temperature, that represent the lowest ductility in the material of the vessel as manufactured. Where the manufacturing process does not significantly alter the properties of the material, test certificates for, or tests on, the original material may be accepted by the manufacturer.

Vessels are divided onto two tiers to allow for appropriate levels of production testing. The class and tier applicable to each vessel shall be nominated by the manufacturer and be in accordance with Table 1.1 and Table 1.3 as appropriate. The class and tier nominated shall be reviewed by the person or body witnessing the type tests in accordance with Class 3 requirements. This may require different testing for the non-ductile components

2.2 DESIGN

2.2.1 General

The design shall be such that each vessel will consistently be able to pass the type tests specified in this Standard.

2.2.2 Design pressure

The design pressure shall not be less than one or more of the following:

- (a) The maximum operating pressure specified in the appropriate application Standard, e.g. AS/NZS 1677(series).
- (b) The maximum pressure likely to be experienced in normal operation.
- (c) The maximum developed pressure at 65°C where the vessel is likely to be exposed to the sun without insulation unless satisfactory evidence can be provided demonstrating that a lower temperature can be assumed.
- (d) The start to discharge pressure of any pressure-relief device(s) in the system with which the vessel is to be used (see Note).

NOTE: To avoid premature operation of pressure-relief device(s), it is necessary for the design pressure to be higher than the normal operating pressure.

2.2.3 Crevices

Reverse curvature ends, joggled joints, joints with retained backing strips, and incomplete penetration welds are not permitted where serious crevice or local corrosion could occur.

2.2.4 Cleaning access

Suitable provision shall be made for cleaning purposes where cleaning is required in service. Access openings may be required for this purpose.

2.2.5 Inspection openings

Each vessel subject to corrosion and exceeding 155 mm inside diameter shall have at least two openings of at least 11 mm clear bore, or one opening of at least 20 mm clear bore, to permit inspection of representative areas of the vessel's inside surface. For a vessel 155 mm or less inside diameter, the size, number, and location of openings shall be appropriate for the principal dimensions of the vessel. Such openings may be provided by openings for piping, fittings, or drainage.

2.2.6 Closures

Closures shall comply with following requirements as appropriate:

(a) *Screwed cap or plug*

A screw-threaded cap or plug closure shall have provision to leak while there are still sufficient threads engaged to withstand the design pressure. Adequate allowance shall be provided for reduction of effective threads due to expected wear in operating the closure, and due to corrosion. It shall not be possible to release the closure at any dangerous pressure without a clear indication of leakage.

(b) *Studded connection*

The length of studs on a studded connection shall be such that the closure can leak while there are sufficient threads engaged to withstand the design pressure.

(c) *Bayonet closure*

For a quick-acting bayonet closure, it shall not be possible to dangerously pressurize the vessel unless the closure is fully or safely engaged (see Note 2).

(d) *Internally fitted bridge closure*

The forces on a bridge type internally fitted closure at any dangerous pressure shall be such that the closure cannot be opened by unassisted handpower (see Note 2).

(e) *Externally fitted bridge closure*

For a bridge type external closure, it shall not be possible to dangerously pressurize the vessel unless the bridge is fully or safely engaged (see Notes 1 and 2).

NOTES:

- 1 In Item (e), the operation of a screw on a bridge-type externally fitted closure should lift the lid slowly and cause obvious leakage before the bridge can be moved to an open position.
- 2 In Items (c), (d), and (e), dangerous pressure is any pressure sufficient to eject the vessel contents or any part of the closure in a manner that could result in injury to personnel.

2.2.7 Drains

Where waste liquid or deposits can accumulate in the vessel, drainage of the vessel in the operating position shall be possible. Openings provided for other purposes may be utilized for drainage.

2.3 MANUFACTURE

The manufacturing procedures shall be such that each vessel will be able to pass the relevant type tests specified in this Standard.

NOTES:

- 1 See Appendix B for information to be supplied by the customer and manufacturer.
- 2 Appendix A describes the function of the manufacturer's IPETS or equivalent to verify each production set up, the weld performance, and the materials or components used, to ensure similar vessel performance to the originally type tested products.

This may include testing of an appropriate weld coupon where settings have changed or after any time gap that may effect weld performance, as in the case of Submerged Arc Welding.

2.4 PROTECTIVE DEVICES AND FITTINGS

2.4.1 Fittings

Provision shall be made for each vessel to be equipped with valves or other pressure-retaining fittings including safety fittings necessary to ensure that, in service, the vessel will—

- (a) be able to be used as intended;
- (b) be protected against overpressure; and
- (c) comply with the requirements of the appropriate application Standard.

2.4.2 Pressure-relief devices

Each vessel shall be fitted with a suitable pressure-relief device where either of the following conditions prevail:

- (a) Where it is possible for the vessel to be pressurized in normal service from a source having a pressure greater than the design pressure of the vessel.
NOTE: Excessive pressure may be prevented by a suitable pressure-relief device in the filling system. A pressure-reducing valve or regulator is not adequate alone.
- (b) Where the pressurized vessel may be subject to fire while not attached to a system having a suitable pressure-relief device, except that a pressure-relief device is not required where the gas or vapour space is not greater than 2 L and the contents are non-harmful.

Pressure-relief devices shall comply with the performance requirements of Clause 3.11.

2.5 CORROSION PROTECTION

Each vessel shall be suitably protected against corrosion, and where specified in Table 5.1 shall be capable of passing the appropriate corrosion test in Clause 3.10.

Air brake reservoirs shall be protectively treated against corrosion as follows:

- (a) After satisfactory completion of hydrostatic testing, all reservoirs shall be suitably treated to remove scale and rust, dried internally, and protectively treated internally against corrosion, particular attention being paid to the open joint in the inserted end.
- (b) The material used for protective treatment shall be resistant to oil, grease, water, and crankcase gases, and to temperatures up to 150°C, and when tested with an equivalent coating thickness as provided in the air reservoir, shall comply with Clause 3.10(b).
- (c) An exterior paint finish providing the same salt spray protection as for the interior shall be applied to all reservoirs on completion.

For vessels subject to corrosion by moisture, a corrosion allowance of 0.7mm shall be added to the vessel thickness where no corrosion protection is applied.

SECTION 3 PERFORMANCE REQUIREMENTS

3.1 GENERAL

Each vessel shall be capable of complying with the relevant requirements specified in this Section (3) for the performance characteristics applicable to the type of vessel, as given in Table 5.1.

NOTES:

- 1 Other methods of test at least equivalent to the method described in this Standard may be used subject to approval by the design verifier.
- 2 Vessels subjected to type or production testing should not enter service unless the vessel is not required for test records, and it can be demonstrated that the integrity and remaining life of the vessel has not been affected.

3.2 RESISTANCE TO INTERNAL PRESSURE

When proof tested in accordance with Appendix C, the vessel shall not leak nor show signs of weakness (i.e. cracking or excessive distortion).

3.3 RESISTANCE TO BURSTING AND FRAGMENTATION

When tested in accordance with Appendix D, the vessel shall not leak nor burst at, or below, the minimum burst pressure given in Table 1.1, and when the test is continued until the vessel bursts, any Class 1H, Class 1, or Class 2 vessel shall fracture in a ductile manner and shall not fragment.

3.4 RESISTANCE TO FATIGUE

When tested in accordance with Appendix E, the vessel shall not leak or show any sign of bulging, cracking, or other defects indicative of the onset of failure.

3.5 RESISTANCE TO DROPPING

When tested in accordance with Appendix F, the vessel shall not leak nor show signs of cracking except that for vessels which have non-harmful contents, leakage or penetration is permitted provided that the vessel complies with Clause 3.6(b).

3.6 RESISTANCE TO PENETRATION

When tested in accordance with Appendix G, the vessel—

- (a) shall not be penetrated; or
- (b) if penetrated—
 - (i) shall fracture in a ductile manner;
 - (ii) shall remain in one piece;
 - (iii) shall not be projected in a dangerous manner (i.e. not more than 1 m in height); and
 - (iv) shall not dangerously expel fluid through the penetration.

3.7 RESISTANCE TO IMPACT

When tested in accordance with Appendix H, the vessel shall not leak, and parts shall not be damaged to an extent that the vessel will not function safely. Small dents, chipping of paint work, and similar superficial damage shall be ignored.

3.8 RESISTANCE TO TORQUE

Connections for the attachment of pipe and fittings, bushings, terminal studs, and similar strength attachments to pressure parts which are subjected to torque when connections are made or removed shall not turn nor shall the vessel part be damaged when subjected to a torque of the lesser of 100 N.m and $D^2/4.5$ N.m, where D is the minimum outside diameter of the connection or the root diameter of the threaded part (in millimetres), whichever is the lesser.

There shall be no visible sign of damage to any pressure part.

3.9 CLOSURE

The closure of a vessel shall comply with the following requirements:

- (a) When the closure is not completely fitted in the final operating position, the vessel shall obviously leak when pressurized and the maximum pressure which can be developed with normal filling shall not exceed a safe value for the closure.
- (b) When the closure is fully shut, sealed, and at any pressure up to the design pressure, it shall not be possible by normal means (without tools) to remove the closure in a manner which could be dangerous to the operator.
- (c) When the vessel is raised to the design temperature, parts of the closure to be handled shall not exceed 50°C, and when the vessel is reduced to the design minimum temperature, parts of the closure to be handled shall be not less than –20°C.

3.10 RESISTANCE TO CORROSION

Where corrosion tests of the vessel or vessel parts are required, the vessel shall comply with the following requirements as appropriate:

- (a) *Welded stainless steel pressure parts* When three test pieces from representative welds of each type of weld in a stainless steel vessel are tested in accordance with AS 2038, all test pieces shall pass the test.
- (b) *Vessels subject to corrosion due to moisture* When tested in accordance with Paragraph I3 of Appendix I, test pieces from the vessel shall not exhibit corrosion, except for the following:
 - (i) Minor or scattered corrosion spots are permitted.
 - (ii) Corrosion is to be disregarded if it is in areas exposed in preparation for testing, or on purposely uncoated areas such as threads.
- (c) *Parts of copper alloy containing more than 15 percent zinc* When parts of copper alloy containing more than 15 percent zinc are tested in accordance with Paragraph I4 of Appendix I or with ISO 6957, the parts shall pass the tests.
- (d) *Vessels subject to other types of corrosion* Where vessels are subject to types of corrosion other than those covered in Items (a) to (c), approved test methods and acceptance criteria agreed by the parties nominated in Section 5 shall be used to assess the vessels.

3.11 PRESSURE RELIEF

3.11.1 Pressure-relief valves or similar devices

When a pressure-relief valve or similar device is tested in accordance with Paragraph J4.1 of Appendix J—

- (a) the pressure at which the device commences to discharge shall not exceed the design pressure;