

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

TECHNICAL SPECIFICATION

PRESSURE VESSELS (BASED ON ASME SECTION VIII)

PTS 31.22.20.31

September 2011



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This revision of PTS 31.22.20.31 - **Pressure Vessels (Based on ASME Section VIII) (September 2011)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The previous version of this PTS 31.22.20.31 (**February 2010**) will be removed from PTS binder / e-repository from herein onwards.

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Documents

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PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

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PART I INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the construction of metallic pressure vessels designed for an internal gauge pressure of 0.1 MPa (15 psi) or greater, or designed for full vacuum, or if specified by the Principal. This PTS also applies to pressure vessels that are components of packaged equipment units.

This PTS, accompanied by a completed data sheet (and, where necessary, additional technical notes), shall be used for purchasing pressure vessels in accordance with ASME Section VIII. All or parts of this PTS may also form part of the construction specification.

PART II of this PTS specifies requirements for all ASME Section VIII pressure vessels, except where modified by Annexes I, II, III, IV or VI for the particular category or type of vessel.

The following are excluded from the scope of this PTS:

- Pressure vessels fabricated by brazing
- Pressure vessels or pressure vessel parts fabricated by casting
- Pressure vessels constructed in accordance with other codes such as EN 13445 and PD 5500.

This PTS is an amendment and supplement to the PTS with the same number dated February 2010.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by Group of company, and to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/distribution installations.

When PTSs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies materials, equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicate a requirement.

The word **should** indicate a recommendation.

1.3.2 Specific definitions

Construction	all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief
Hydrogen charging service	service in which atomic hydrogen exists in the pressure containing steels. Services include Wet H ₂ S or sour, hydrofluoric acid, hydrogen service
Hydrogen service (H₂ service)	service in which the hydrogen partial pressure is greater than 700 kPa absolute (100 psia) at any temperature. See also API RP 941, Figure 1.
Manufacturer's Standard Pressure Vessel	type of pressure vessel that are used for low service risk. These vessels are generally pre-engineered and included in a Manufacturer's or vendor's catalog of standard vessels for purchase.
Maximum Allowable Pressure (MAP)	the calculated allowable pressure, using the entire new (non-corroded) thickness at ambient temperature, including the full corrosion allowance.
Maximum Allowable Working Pressure (MAWP)	the maximum internal gage pressure permissible at the top of the completed vessel in its normal operating position at the designated coincident temperature for that pressure using the entire new (non-corroded) thickness minus the full corrosion allowance.
Maximum Allowable External Working Pressure (MAEWP)	the maximum external gage pressure permissible acting on the completed vessel in its normal operating position at the designated coincident temperature for that pressure using the entire new (non-corroded) thickness minus the full corrosion allowance.
Very toxic (substances)	substances that are very hazardous for the environment or human health, as specified in PTS 01.00.01.30. (which also references databases of "toxic" substances)

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (Part III).

1.5 SUMMARY OF MAIN CHANGES

This PTS is a revision of the PTS of the same number dated February 2010. The following are the main, non-editorial changes.

Old section	New section	Change
NA	Part I 1.3.2	Added definition for Hydrogen Charging Service
Part I 1.3.2	Part I 1.3.2	Deleted Note under Very toxic definition
Part I 1.3.2	Part I 1.3.2	Revised definition for MAWP and MAEWP

Old section	New section	Change
Part II 1.3	Part II 1.3	Added requirement to use PTS 31.38.01.11.
Part II 2.1	Part II 2.1	Revised to avoid confusion during selection of code division to refer.
Part II 2.2	Part II 2.2	Added vessel category number for classification to reduce error during designing
NA	Part II 2.3	Added requirement for marine system pressure vessels.
Part II 2.3.2	Part II 2.4.2	Revised requirement for ITP submission
Part II 2.4.2	Part II 2.5.2	Added additional information required on vendor drawings. Revised to highlight that this is a minimum requirement
Part II 2.4.3	Part II 2.5.3	Revised to highlight that this is a minimum requirement
Part II 3.1.2	Part II 3.1.2	Revised requirement pertaining equivalent material in accordance with EN standards
Part II 3.1.7	Part II 3.1.7	Added requirement to meet PTS 39.01.10.11.
Part II 3.2.3	Part II 3.2.3	Revised to meet Code
Part II 3.3 Table 1	Part II 3.3 Table 1	Revised bolting materials requirement
Part II 3.6.1.1	Part II 3.6.1.1	Deleted requirement for 1.0 mm (1/32 in.) corrosion allowance on non-carbon steel materials.
Part II 3.6.3	Part II 3.6.3	Revised clad vessel requirement
Part II 4.1.1	Part II 4.1.1	Corrected equation (c)
Part II 4.1.3	Part II 4.1.3	Revised minimum thickness of cladding
Part II 4.2.1	Part II 4.2.1	Revised design temperature requirement
Part II 4.2.7.2	Part II 4.2.7	Revised design temperature requirements to meet PTS 01.00.01.30. Added requirement to meet PTS 30.10.02.31.
NA	Part II 4.3.3	Added requirement to use specified design pressure and to calculate MAWP
Part II 4.4	Part II 4.4	Added transportation load during shipment (L9) and operating load onboard for FPSO type of vessel (L10)
Part II 4.4 b)	Part II 4.4 b)	Added requirement to include loadings resulting from topsides acceleration when applicable
Part II 4.4 i)	Part II 4.4 i)	Added requirement to include loadings resulting from wave action and/or sloshing when applicable.

Old section	New section	Change
Part II 4.5.1	Part II 4.5.1	Revised table 3 to include L9 and L10
Part II 4.6.4	Part II 4.6.4	Wind loads determination requirement deleted
Part II 4.8.1	Part II 4.8.1	Rephrase requirement and revised temperature for creep analysis for stainless steel in table 4
NA	Part II 4.9	Added requirements for shell seam spacing.
NA	Part II 4.12.5 d)	Added requirement for flanges to be raised face
Part II 4.12.9	Part II 4.12.9	Added requirement
NA	Part II 4.12.11 f)	Added examination requirements for set-on nozzles
Part II 4.12.13 a)	Part II 4.12.13 a)	Rephrased for clarity
Part II 4.12.13 d)	NA	Requirement deleted. Rules have been incorporated in ASME Section VIII, Division 1, 2010 edition.
Part II 4.12.14 e)	Part II 4.12.14 e)	Revised location of drain and vents
NA	Part II 4.12.18	Added requirement for nozzles in clad vessels
Part II 4.13.1 c)	Part II 4.13.1 d)	Revised to state skirt vents are only excluded when approved by Principal.
NA	Part II 4.13.1 c)	Added requirement for skirt material for low temperature carbon steel vessels
Part II 4.13.1 f)	Part II 4.13.1 g)	Revised template requirements
Part II 4.13.5	Part II 4.13.5	Revised requirement for saddle supports prohibiting use as stiffening ring
Part II 4.15.2	Part II 4.15.2	Added requirement for vent holes
Part II 4.15.3	Part II 4.15.3	Added requirement for vent holes
Part II 4.15.5	Part II 4.15.5	Added additional safety factor
Part II 4.15.7	Part II 4.15.7	Added requirement for continuous full penetration welds for hydrogen charging service vessels
Part II 4.15.10	Part II 4.15.10	Deleted c)

Old section	New section	Change
NA	Part II 4.15.15	Added requirement for anodes to be installed when specified by the Principal.
NA	Part II 4.15.16	Added requirement for use of manway davits in accordance with Standard Drawing S 10.070.
NA	Part II 4.15.17	Added requirement for earthing bosses
NA	Part II 4.16.12	Added prohibition on dissimilar metal welds in category A, B, C, D
NA	Part II 4.16.13	Added requirement for full penetration welds in hydrogen charging services.
Part II 5.1.1	Part II 5.1.1	Added requirement prior to commencement of fabrication
Part II 5.1.4	Part II 5.1.4	Revised PWHT requirements
NA	Part II 5.1.4.1	Clarified requirement on carbon and low-alloy steels
NA	Part II 5.1.4.2	Added requirement for materials in hydrogen charging processes
NA	Part II 5.1.4.3	Modified requirement to permit ASME Code elongation percentage for all other materials.
NA	Part II 5.2.2	Added requirements based on chemistry
Part II 5.3.3	Part II 5.3.3	Added sagging analysis requirement
Part II 6.3.1.4	Part II 6.3.1.4	Revised RT/ UT requirement
Part II 6.4.1.2	Part II 6.4.1.2	Revised UT requirement for welds
Part II 6.4.1.6	Part II 6.4.1.6	Revised UT requirements
Part II 6.5.1.1	Part II 6.5.1.1	Revised extent of PT examination
NA	Part II 6.9.1.1	Revised reference PTS
Part II 6.9.1.3	Part II 6.9.1.3	Revised duration for pressure testing
Part II 6.9.1.5	Part II 6.9.1.5	Revised usage of gasket during pressure testing
Part II 7.2.4	Part II 7.2.4	Additional requirement for telltale weep holes in reinforcing pads
Part II 7.2.5	Part II 7.2.5	Revised acceptable shipping covers for nozzles

Old section	New section	Change
NA	Part II 7.2.7.2	Added marking for glass-lined vessels
NA	Part II 7.2.9	Added insulation set shall be furnished for connection between dissimilar materials
NA	Part II 7.3.9	Added default lateral and vertical accelerations for open water shipment
Part III	Part III	References updated
I.4.15.12	NA	Deleted
VIII.2.3.4	NA	Deleted
VIII.2.3.5	VIII.2.3.4	Revised to meet Code
IX.1	IX.1	Deleted informative paragraphs
X3.6	X3.6	Revised test block requirement to vanadium enhanced steels only.
Annex XII	NA	Deleted Informative annex
NA	Annex XIII	Added additional requirements for marine service vessels.

PART II REQUIREMENTS FOR ALL ASME SECTION VIII PRESSURE VESSELS

1. INTRODUCTION

1.1 CODE STAMP

Pressure vessels shall be designed and fabricated in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Division 1 or Division 2. The ASME Code Symbol Stamp shall be applied if required by the applicable regulations or if specified by the Principal.

1.2 GEOMETRIC BOUNDARY

Unless otherwise specified by the Principal, the geometric boundary of the pressure vessel designed and fabricated in accordance with this PTS shall include the following:

- The face of the first flange for bolted, flanged connections.
- The pressure retaining cover and bolts for vessel openings such as manways or handholes.
- Non-pressure parts that are welded to the pressure retaining envelope of the pressure vessel.

1.3 OVERPRESSURE PROTECTION

Pressure vessels shall be protected from overpressure in accordance with PTS 80.45.10.11. Unless otherwise specified by the Principal, piping between the pressure relief device and the vessel connection shall be in accordance with PTS 31.38.01.11.

1.4 UNITS OF MEASUREMENT

This PTS uses SI units followed by US Customary units in brackets. If any further unit conversions are required they shall be made in accordance with ASME Section VIII Division 1, Appendix GG or ASME Section VIII Division 2, Part 1, Annex 1C.

1.5 SPHERICAL PRESSURE VESSELS

Spherical pressure vessels shall be constructed in accordance with PART II of this PTS and Annex VI.

1.6 UNFIRED STEAM BOILERS

Pressure vessels for use as unfired steam boilers shall be constructed in accordance with Part II of this PTS and Annex V.

1.7 REGISTRATION

Pressure vessels shall be registered in accordance with the applicable regulations. Where the applicable regulations have no requirements for pressure vessel registration, the Principal shall specify if registration in accordance with the US National Board of Pressure Vessel Inspectors is required.

NOTE: Registration with the US National Board of Pressure Vessel Inspectors ensures continuous access to an accurate copy of the Manufacturer's Data Report.

2. GENERAL REQUIREMENTS

2.1 SELECTION OF DIVISION 1 OR DIVISION 2

2.1.1 The selection of Division 1 or Division 2 shall be based on both design and economic considerations.

If one or more of the following conditions apply, the vessels shall be constructed in accordance with Division 2, unless otherwise approved by the Principal:

- Pressure vessels with a nominal wall thickness greater than 38 mm (1½ in) using Division 1.
- Pressure vessels with a design pressure of 10 MPa (1500 psi) or higher
- Pressure vessels operating in cyclic service, pressure- or temperature-induced
- Pressure vessels which operate in the creep range of the materials of construction

2.1.2 Division 1 may be selected if:

- All other additional requirements as specified by the Principal and/or as indicated on the data sheet or User's Design Specification are met. Additional requirements may include, but are not limited to the following:
 - Additional calculations required for all or certain construction details
 - Application of hydraulic bolt tensioning with specified values
 - PMI of materials, additional testing of the materials, and/or limitations on origin of material
 - Additional welding procedure requirements
 - Additional Third party inspection requirements

2.2 VESSEL CATEGORIES

2.2.1 General

Pressure vessels constructed in accordance with this PTS shall be classified by the Principal into one of four categories:

- Manufacturer's Standard Pressure Vessels (Category 4)
- Pressure vessels for Minimum Service (Category 3)
- Pressure vessels for General Service (Category 2)
- Engineered pressure vessels (Category 1)

Requirements of this PTS shall be met; however, they may be superseded by the applicable annex.

2.2.2 Manufacturer's Standard Pressure Vessels (Category 4)

Pressure vessels in this category shall:

- be fabricated from carbon steel, 304/304L austenitic stainless steel or 316/316L austenitic stainless steel;
- have a design temperature not exceeding 260 °C (500 °F) for carbon steel
- have a design temperature not exceeding 400 °C (750 °F) for austenitic stainless steel
- be selected only for non-corrosive services or a services for which the corrosion allowances shown in Table 2 are not exceeded;
- not be selected for cyclic service (see 4.7.1);

- not be selected if they will be subjected to wind-induced vibration as specified in (4.6);
- not be selected if they require PWHT
- not be selected if they are to be of clad or weld-overlay construction

Manufacturer's Standard Pressure Vessels shall be constructed in accordance with Division 1, and the requirements of Annex I of this PTS.

Pressure vessels classified in this category may be exposed to hydrogen provided the hydrogen partial pressure and temperature does not exceed 700 kPa (100 psi) and 230 °C (445 °F).

2.2.3 Pressure Vessels for Minimum Service (Category 3)

Pressure vessels in this category shall:

- be fabricated from carbon steel or solid 300 series austenitic stainless steel
- have a design pressure not exceeding 3.5 MPa (500 psi)
- have a design temperature not exceeding 260 °C (500 °F) for carbon steel
- have a design temperature not exceeding 400 °C (750 °F) for austenitic stainless steel
- have a Minimum Design Metal Temperature (MDMT) not below –29 °C (–20 °F) if made from non-impact-tested carbon steel;
- not be selected if they require PWHT for either code or process requirements

Pressure Vessels for Minimum Service shall be constructed in accordance with Division 1, and the requirements of Annex II of this PTS.

NOTE: Pressure vessels with a limited service life may be constructed as a Pressure Vessel for Minimum Service.

Pressure vessels in this category may be exposed to hydrogen provided the hydrogen partial pressure and temperature does not exceed 700 kPa (100 psi) and 230 °C (445 °F).

2.2.4 Pressure Vessels for General Service (Category 2)

Pressure vessels in this category:

- shall be fabricated from carbon steel, low alloy material, solid 300 series austenitic stainless steel, or clad with any material
- may be in a service with a corrosion rate exceeding the limits for Minimum Service pressure vessels
- have a nominal wall thickness not exceeding 75 mm (3 in)

Pressure vessels for General Service may be constructed in accordance with Division 1 or Division 2 (see 2.1), and the requirements of Annex III of this PTS.

Pressure vessels in this category may be placed in Hydrogen Service if the hydrogen partial pressure does not exceed 700 kPa (100 psi).

2.2.5 Engineered Pressure Vessels (Category 1)

Pressure vessels in this category meet the general characteristics provided in (2.1.1) and the requirements of Annex IV. Division 2 shall be the first choice for code of construction. Division 1 may be used if:

- The requirements of (2.1.2) are met; and
- The use of Division 1 provides a clear advantage in terms of cost or schedule.

2.3 MARINE SYSTEM VESSELS

Designated marine system pressure vessels shall be in accordance with applicable regulations. See Annex XIII for additional information.

2.4 QUALITY ASSURANCE

2.4.1 General

Pressure vessels shall be purchased only from Manufacturers accepted by the Principal.

2.4.2 Surveillance

Surveillance requirements shall be established for each pressure vessel constructed in accordance with this PTS. The requirements shall be established by the Principal, or by the Contractor with the approval of the Principal.

The minimum surveillance requirements for each pressure vessel category shall be as specified in Annexes II, III or IV, as applicable for the particular vessel category. These are summarised in the following:

- Annex II, Exhibit II-1 – Pressure Vessels for Minimum Service
- Annex III, Exhibit III-1 – Pressure Vessels for General Service
- Annex IV, Exhibit IV-1 – Engineered Pressure Vessels

The Manufacturer shall submit the Inspection and Test Plan (ITP) to the Principal/Contractor for review and approval prior to commencement of engineering and procurement. Surveillance requirements identified by the Principal or the Contractor shall be incorporated into the Manufacturer's ITP.

ITPs for Engineered Pressure Vessels shall be reviewed and approved by Principal.

2.5 DRAWINGS AND FINAL DATA

2.5.1 Data sheets and design specification

The Principal's Design Specification or data sheet shall be completed for each pressure vessel. See Annex XI for additional information.

The Manufacturer's documentation for each pressure vessel shall include the Code Data Report and shall also be in accordance with PTS 31.22.10.35.

2.5.2 General drawings

The general arrangement, assembly or outline drawing(s) shall contain the following information as minimum:

- Code of Construction Division, edition year, addenda year and applicable Code Cases
- References to supplementary drawings, standards and specifications
- Equipment tag number
- Vessel Category
- Operating and design pressures and temperatures of all services for which the vessel is designed including number of cycles if designed for fatigue
- Environmental data
 - Wind speed
 - Earthquake data
- Corrosion allowances for shell, heads, nozzles, manways, and all supports and other accessories
- Nozzle schedule with allowable loads

- Weld joint efficiencies
- Maximum Allowable Pressure (MAP); New and Cold
- Maximum Allowable Working Pressure (MAWP) with coincident Temperature
- Minimum Design Metal Temperature(s) (MDMT) with coincident Pressure(s)
- Field pressure test pressure at top of vessel
- Shop pressure test pressure and orientation of vessel
- Test fluid properties
 - Product and its composition
 - Temperature
 - Density
- Weights; shipping, operating, water full with all internals
- Center of gravity location
- Lifting arrangements

2.5.3 Fabrication drawing(s)

The detailed fabrication drawing(s) shall contain the following information as minimum:

- Full dimensions of all parts and sub-assemblies shown including necessary tolerances and any finishing requirements
- Complete identification of materials, including gaskets
- Complete identification of internal materials supplied by fabricator, including gaskets.
- Location of all circumferential and longitudinal joints
- Details of weld preparations and welding procedure numbers
- Impact test requirements
- Heat treatment details, including temperature of PWHT, time at temperature, heatup and cooldown rates
- General remarks on fabrication, assembly and testing as appropriate
- Bolt torque for body flanges
- Extent and location of all nondestructive examination (NDE)
- Cleaning, surface preparation, painting and marking requirements
- Nozzle schedule including the mark number, quantity, size, rating, facing, and type. Nozzle orientation and elevation shall be provided. The mark number shall match that shown on equipment data sheet.

3. MATERIALS AND CORROSION ALLOWANCE

3.1 MATERIALS SELECTION

3.1.1 Materials shall be selected in accordance with ASME Section II, Part A or Part B, as follows:

- a) pressure-containing parts
- b) attachments subject to stress not induced by pressure (e.g. supporting skirts, lugs, baffles, reinforcement pads, etc.).

3.1.2 As an exception to (3.1.1), equivalent material in accordance with acceptable international standards for non-pressure and non-load bearing parts, may be selected subjected to Principal approval.

3.1.3 Materials with tensile properties enhanced through quench and tempering shall not be used without approval of the Principal.

3.1.4 Cr-Mo materials shall also meet the requirements of Annex X of this PTS.

3.1.5 Micro-alloyed steels shall not be used without the approval of the Principal.

3.1.6 Materials for use other than that specified in (3.1.1) shall be of established identity and shall be compatible with the material to which they are welded.

3.1.7 Materials selection shall also comply with PTS 30.10.02.11 and PTS 39.01.10.11.

3.1.8 If approved by the Principal, carbon steel (P1, Gr. 1, 2 or 3) with a tensile strength greater than 485 MPa (70,300 psi) may be used for Division 1 construction if:

- a) the vessel will not operate in cyclic service;
- b) the vessel will not operate in the creep range of the material specified.

3.1.9 Electric Resistance Welded (ERW) pipe or tube shall not be used for pressure retaining parts such as shells or nozzle necks.

3.2 SERVICE-SPECIFIC REQUIREMENTS

3.2.1 Material selection for pressure vessels in low temperature applications shall be in accordance with PTS 30.10.02.31.

3.2.2 Material selection for pressure vessels in wet H₂S service shall be in accordance with Annex IX.

3.2.3 Carbon steel, clad carbon steel and low alloy steels for use in hydrogen service shall be in accordance with API RP 941. The maximum hydrogen partial pressure and maximum operating temperature shall be used as the basis for materials selection. These temperatures and hydrogen partial pressures shall be at least 28 °C (50 °F) below and 170 kPa (25 psi) to the left of the applicable material curve of API RP 941, Figure 1.

The base metals of alloy clad or weld overlay pressure equipment for hydrogen service shall also be selected in accordance with the applicable curve of API RP 941. No credit shall be taken for the presence of the alloy cladding or weld overlay with regard to hydrogen attack limits.

3.2.4 Non-metallic sheet type gaskets shall not be permitted for body flanges on pressure vessels that are in wet H₂S service or services that are considered very toxic.

3.3 BOLTING

Bolts used externally for pressure vessel flanges, including nozzle flanges on manways and with installed blind flanges, shall be selected in accordance with the Table 1.

Table 1 Bolting materials

DESIGN TEMPERATURE	BOLT MATERIAL	NUT MATERIAL
–195 °C to –102 °C (–320 °F to –151 °F)	SA-320 Gr. B8 – Class 2 ⁽²⁾	SA-194 Gr. 8N
–101 °C to –30 °C (–150 °F to –21 °F) General Service	SA-320 Gr. L7 ⁽²⁾	SA-194 Gr. 4
–101 °C to –30 °C (–150 °F to –21 °F) Sour Service	SA-320 Gr. L7M ⁽²⁾	SA-194 Gr. 7M
–40 °C to 427 °C (–40 °F to 800 °F) General Service	SA-193 Gr. B7	SA-194 Gr. 2H
–29 °C to 427 °C (–20 °F to 800 °F) Sour Service	SA-193 Gr. B7M	SA-194 Gr. 2HM
428 °C to 538 °C (801 °F to 1000 °F) Carbon steel and low alloy flanges	SA-193 Gr. B16	SA-194 Gr. 2H
428 °C to 538 °C (801 °F to 1000 °F) Austenitic and non-ferrous flanges	SA-453 Gr. 660 – Class C ⁽³⁾	SA-453 Gr. 660 – Class C
593 °C to 815 °C (1101 °F to 1500 °F) Carbon steel and low alloy flanges	SA-193 Gr. B8 – Class 1 ⁽¹⁾⁽³⁾	SA-194 Gr. 8T
538 °C to 815 °C (1000 °F to 1500 °F) Austenitic and non-ferrous flanges	SA-193 Gr. B8 – Class 1 ⁽¹⁾⁽³⁾	SA-194 Gr. 8T
⁽¹⁾ Controlled bolting techniques may be required to maintain tightness. ⁽²⁾ This material is selected primarily for low temperature applications. The upper limit has been set for standardization purposes but it may be used up to the limits given in ASME Section II. ⁽³⁾ This material is selected primarily for high temperature applications. The lower limit has been set for standardization purposes but it may be used down to the limits given in ASME Section VIII.		

Bolts used to attach piping to nozzle flanges shall be in accordance with the piping class of the attached piping. For other applications, see PTS 30.10.02.11.

3.4 APPROVAL OF MATERIALS SUPPLIERS

The Principal reserves the right to approve material suppliers. Included with this approval process shall be the right to perform on-site audit of manufacturing facilities.

3.5 POSITIVE MATERIAL IDENTIFICATION (PMI)

The Manufacturer shall perform PMI in accordance with PTS 31.10.00.10 as follows:

- a) On all alloy material upon receipt at the fabrication facility. Vessel category requirements are indicated in the applicable Annexes.
- b) On vessels prior to shipment.

- c) PMI on welding consumables shall be performed in accordance with PTS 31.10.00.10.

3.6 CORROSION ALLOWANCE

3.6.1 Pressure-containing components

- 3.6.1.1 The minimum corrosion allowance for pressure-containing components shall be in accordance with Table 2.

Table 2 Minimum corrosion allowances

Component and Material	mm	in
Carbon Steel and Low Alloy Pressure Vessel Shell / Heads	1.5	1/16
Carbon Steel and Low Alloy Nozzles	3	1/8

- 3.6.1.2 Corrosion allowance shall be in accordance with the Material's Selection Report or selected after consultation with Materials Specialist of Principal.

- 3.6.1.3 Corrosion allowance shall be listed on the Data Sheet for each component.

3.6.2 Internal parts

The minimum corrosion allowance for internal parts, excluding processing trays and other processing parts, shall be in accordance with the following:

- 50 % of the value listed on the Data Sheet for parts which may be removed from the pressure vessel.
- Equal to the value listed on the Data Sheet for parts that are welded to the pressure-retaining portion of the pressure vessel.

3.6.3 Clad vessels

Unless otherwise specified, the entire thickness of any applied cladding shall not be considered as pressure retaining material, but used for corrosion control or product purity.

A chemical analysis of the clad material shall be made at one of the following depths:

- 2.5 mm (0.10 in) for cladding applied as corrosion protection, or
- 1.5 mm (0.050 in) for cladding applied only for product purity.

The chemical analysis shall comply with the specification for the material alloy of the cladding.

Loose lining is not permitted.

Ultrasonic examination (UT) of the material is required. Method and acceptance of results shall be in accordance with (6.).

3.6.4 Flange faces

No corrosion allowance shall be provided on flange faces.

3.7 MATERIAL EXAMINATION

Additional material examination requirements are specified in (6).

4. DESIGN

4.1 GENERAL

4.1.1 The minimum thickness of carbon steel and low alloy pressure vessels (including corrosion allowance but excluding the thickness of cladding) shall be the greater of the following:

a) 6 mm (1/4 in)

$$\frac{D}{650} + 1.8$$

b) mm

$$\frac{D}{650} + 0.071$$

c) (in)

where

D is the mean vessel diameter, expressed in millimetres (inches)

4.1.2 The minimum thickness of all high alloy pressure vessels shall be no less than the greater of 3 mm (1/8 in) or the value as calculated in accordance with section (4.1.1).

4.1.3 Minimum thickness of alloy cladding or lining is 2.75 mm (7/64 in) for corrosive service and 1.5 mm (1/16 in) for product purity. See also Division 1, UCL-23(c) or Division 2, Part 6.5.6 for information if base material is removed to ensure material chemistry at weld location.

4.1.4 Allowable stresses used in design calculations for non-pressure containing parts shall be in accordance with ASME BPV Section II, Part D at Design Temperature.

4.1.5 When two sets of allowable stresses are provided for materials, use of lower value is required for flanges designed in accordance with either Division of ASME BPV Section VIII. See note G5 in ASME BPV Section II, Part D.

4.2 DESIGN TEMPERATURE

4.2.1 The design temperature specified for the pressure vessel shall be 10 °C (18 °F) above the MOT.

In exceptional cases (e.g. where a higher alloy material would otherwise be required because of oxidation or creep) a DT of 5 °C (9 °F) above the MOT may be selected.

For pressurised LPG storage facilities the DT shall be equal to the corresponding boiling temperature at the derived design pressure and the assessed LPG composition.

4.2.2 Limiting appurtenances shall also be considered when determining the design temperature.

4.2.3 Design temperatures for uninsulated flanges and bolts may be specified at a reduced temperature as follows:

a) Lap-joint flanges: 85 % of Design Temperature

b) All other flanges: 90 % of Design Temperature

c) Bolts (if listed on Data Report): 80 % of Design Temperature

4.2.4 The need to specify multiple design temperatures coincident with various operating pressure conditions, such as steaming-out conditions and operational upset, shall be considered.

4.2.5 When a single design temperature is selected, it shall be applied to internal pressure and external pressure conditions.

4.2.6 When multiple design temperatures are selected (see 4.2.4), the design temperature for external pressure shall be selected in accordance with (4.2.1).

4.2.7 The minimum design metal temperature (MDMT) shall be specified as the minimum metal temperature (MMT) as defined by PTS 01.00.01.30:

NOTE: Repressurization requirements shall be considered when specifying this temperature as MDMT. A temperature warmer than the minimum temperature reached during depressurization may be specified if approved by the Principal. .

In addition, consideration for the prevention of brittle fracture shall be made in accordance with the requirement of PTS 30.10.02.31.

4.3 DESIGN PRESSURE

4.3.1 The design pressure shall be selected in accordance with PTS 01.00.01.30.

4.3.2 The responsible Process Engineer shall be consulted if Design Pressures are not provided.

4.3.3 Pressure vessels shall be designed using the specified design pressure given, and the MAWP shall be calculated for all pressure vessels. Pressure vessels shall not have their MAWP limited by nozzles or flanges.

4.3.4 Vacuum

4.3.4.1 The pressure vessel shall be designed for Full Vacuum if any of the following conditions apply:

- a) If the process is such that vacuum conditions can routinely occur.
- b) If the vessel normally operates under vacuum. Vessels that operate at less than full vacuum [i.e. absolute pressure between 0 kPa and 100 kPa (0 psi and 14.7 psi)] shall be evaluated for design at full vacuum.
- c) Vessels in steam or condensate systems those are not open to the atmosphere.

4.3.4.2 Jacketed or compartmented vessels that are designed for vacuum in the compartment under consideration shall have the common components designed for an external pressure equal to the sum of internal design pressure of the adjacent compartment plus the vacuum design pressure of the compartment under consideration.

4.3.4.3 If the pressure may drop below atmospheric pressure due to utility failure, instrument failure, low-load conditions, maloperation, blocked-in situations or any other cause, the minimum possible absolute pressure shall be stated in the documents for mechanical design.

4.3.4.4 For large diameter and/or thin wall vessels, it shall be considered to design for actual vacuum rather than full vacuum. The value selected for vacuum shall be subject to the approval of the Principal.

4.4 DESIGN LOADS

Design loads are classified as follows:

- a) **Dead Load (L1)** is the weight of the vessel including internals, platforms, insulation, fireproofing, refractory, piping, and other permanent attachments.
- b) **Operating Load (L2)** is the weight of the liquid at the maximum operating level or catalyst content. When applicable, loadings resulting from topsides acceleration shall be included.
- c) **Pressure Load (L3₁)** is the pressure, internal or external, hot and corroded condition, to which the vessel is certified considering the pressure variations through the vessel, if any. This is typically the stamped MAWP or MAEWP.
- d) **Pressure Load (L3₂)** is the pressure in the new and cold condition. This is considered the maximum allowable pressure, and is designated as MAP. It may be higher than MAWP.
- e) **Thermal Load (L4)** are those caused by the restraint of thermal expansion / interaction of the vessel and its supports.
- f) **Test Load (L5)** is the hydrostatic test conditions including the weight of the test fluid, usually water.
- g) **Wind Load (L6)** shall be determined in accordance with PTS 34.00.01.30. Alternatively, ASCE 7 Method 2 or the ASCE report "Wind Loads on Petrochemical Facilities" may be used. When using ASCE 7, the following shall be used:
 - Classification Category II shall be used unless approval for other category is obtained from Principal.
 - Basic wind speed shall be in accordance with ASCE 7, Figure 6.1, or the applicable climate data, for the point of installation of the equipment.
 - Exposure Category shall be in accordance with ASCE 7 unless otherwise directed by the Principal.
 - Topographic factor shall be in accordance with ASCE 7.
 - Force coefficients shall be in accordance with ASCE 7. Vertical vessels provided with spoilers to prevent wind induced vibration shall be considered with a surface type of very rough.
- h) **Seismic Load (L7)** shall be determined in accordance with PTS 34.00.01.30. Alternatively, ASCE 7 may be used unless otherwise specified by the jurisdiction having authority.
- i) **Piping and Superimposed Equipment Loads (L8)** are those caused by piping other than Dead Load (L1) and superimposed equipment and such loads shall be considered as applicable. When applicable, loadings resulting from wave action and/or sloshing shall be considered.
- j) **Transportation load during shipment (L9)** is caused by transportation arrangement.
- k) **Operating load onboard for FPSO type of vessel (L10)** to cater movement of the FPSO type of vessel.

4.5 LOAD COMBINATIONS

4.5.1 General

Vessels and their supports shall be designed to meet the most severe of the load combinations in Table 3.

Table 3 Load combinations

Load combination	Description
L1 + L6	Erected condition with full wind load
L1 + L2 + L4 + L6 + L8 + L10	Operating condition, no pressure, with full wind load
L1 + L2 + L3 ₁ + L4 + L6 + L8 + L10	Operating condition with full pressure and full wind loads
L1 + L2 + L4 + L7 + L8 + L10	Operating condition, no pressure, with full seismic load
L1 + L2 + L3 ₁ + L4 + L7 + L8 + L10	Operating condition with full pressure and full seismic loads
L1 + (F)L3 ₂ + L5 + (0.25)L6 (Note 1)	Initial hydrostatic test condition when specified by the Principal.
L1 + (F)L3 ₁ + L5 + (0.25)L6 (Note 1)	Future hydrostatic test condition when specified by the Principal. Also, use this load combination when consideration for flooded tower is required.
L9	Transportation arrangement
Lift condition	See 4.15
NOTE 1: (F) = 1.5 for pressure vessels built in accordance with Division 1, 1998 edition and earlier. (F) = 1.3 for pressure vessels built in accordance with Division 1, 1999 addenda and later. (F) = 1.43 or 1.25 for pressure vessels built in accordance with Division 2, Part 8, para. 8.2.	

4.5.2 Horizontal vessels

In addition to (4.5.1), horizontal vessels shall also be evaluated for buckling, local circumferential bending and shear stresses. The saddle horn tip and shell bending stresses shall be checked for the "filled but no pressure" condition, (L2). The preferred method of evaluation shall be finite element analysis; however, the method described in Section VIII, Division 2, Part 4.15 or the method described as the Zick Analysis may be used.

4.6 WIND INDUCED LOADINGS

4.6.1 Vessel design shall include analysis for the following

- Tower deflection
- Moments and forces at foundation due to wind loads
- Vortex shedding effects on the vessel under erection, on standby and in operating conditions.

- 4.6.2 The fabricator shall provide a proposal for mitigation against vortex shedding effects for towers that meet the following conditions:
- a) H/D ratio of 15 or greater, and
 - b) Mass damping parameter (MDP) less than 0.8 under operating conditions, or MDP less than 1.1 when the vessel is under erection or on standby.

Where

$$\text{MDP} = \frac{m \cdot \beta}{\phi \cdot d^2}$$

m = mass per unit length of the top third of the tower, in the condition considered

β = structural damping ratio, 0.004 for empty, unlined steel vessel

ϕ = density of air

d = mean diameter over the top third of the tower

D = nominal diameter of tower

H = height of tower

NOTE: The term MDP is dimensionless. Consistent units shall be used for the above equation to be valid.

- 4.6.3 Mitigation measures shall include vortex destruction devices such as spoilers, tuned mass dampers or positioning of platforms to reduce vortex formation. Mitigation proposal shall be submitted for review and shall be approved by the Principal.

- 4.6.4 Tower deflection at the top of the equipment shall be no greater than

- a) H/500 for brick lined equipment
- b) H/200 for all other equipment

The calculation of the deflection during operational conditions shall take into account insulation, steel structures and piping that are guided or supported by the equipment. Calculations shall be submitted for review and shall be approved by the Principal when the tower has a natural frequency of less than 1.1 Hz.

Wind loads shall be determined in accordance with Appendix 1 of PTS 34.00.01.30, unless deviation is necessary to comply with national and/or local regulations.

4.7 FATIGUE EVALUATION

- 4.7.1 Vessels that are subject to the following types of cyclic service shall be analyzed in accordance with ASME Section VIII, Division 2, Part 5:

- a) Application or fluctuation of pressure including testing
- b) Temperature transients
- c) Temperature fluctuations, especially when expansion or contraction is restricted
- d) Vibrations
- e) Variations in external loadings

- 4.7.2 The Principal, subject to the approval of the owner, shall specify on the data sheet or User's Design Specification whether a detailed fatigue analysis is required to be performed by the Manufacturer. Fatigue assessment of welds using the structural stress method of ASME Section VIII, Division 2, Part 5 shall only be performed with approval of owner.

- 4.7.3 The determination of requirements for vessels constructed to Division 1 shall be made according to the rules of Division 2, Part 5; however, the allowable stresses for Division 1 shall be used in the analysis.

4.8 CREEP ANALYSIS

- 4.8.1 If a vessel is operating above the temperatures given in Table 4, where time dependent properties are a consideration, a creep analysis shall be performed in accordance with ASME Section VIII, Division 2. Alternatively, API RP 579-1 / ASME FFS-1 may be used.

Table 4 Temperatures above which creep analysis is required

Material	Temperature
Carbon steel	400 °C (750 °F)
Nickel steel	400 °C (750 °F)
1 Cr–0.5 Mo	470 °C (875 °F)
1¼ Cr–0.5 Mo	440 °C (825 °F)
2¼ Cr–1 Mo1	440 °C (825 °F)
AISI Type 304 & 304H	510°C (950°F)
AISI Type 316 & 316H, AISI Type 321 & 321H, AISI Type 347 & AISI Type 347H	538°C (1000°F)

- 4.8.2 The temperatures in (4.8.1) are not valid if the vessel is also subject to fatigue. If cyclic service is a consideration along with operation in the time dependent temperature range, API RP 579-1 / ASME FFS-1 shall be used for analysis method.

- 4.8.3 The Principal shall specify the required service lifetime and all operating data, necessary to perform the analysis. If a vessel is intended to be used in a service where more than one set of operating parameters (pressure and temperature) is expected, the data shall include this information and shall state the duration of each anticipated operating mode.

4.9 SHELLS

If shell courses have different thicknesses, the inside diameter shall be constant unless otherwise specified by the Principal.

The minimum distance between two longitudinal seams in one course shall be 200 mm (8 in) or five times the wall thickness, whichever is the larger, as measured between the toe of each weld. The minimum distance between the staggered longitudinal seams of two adjacent courses shall be 200 mm (8 in) or five times the wall thickness, whichever is the greater. However, where this cannot be achieved, the last 300 mm (12 in) of the adjacent longitudinal seams shall be subjected to 100% examination in accordance with (section 6.3) or (6.4) as applicable.

4.10 FORMED HEADS

- 4.10.1 Unless otherwise specified by the Principal, heads shall be ellipsoidal.

- 4.10.2 Torispherical heads shall not be used in the following situations for pressure vessels constructed to Division 1:

- Design pressure of 525 kPa (75 psi) or greater
- Operating temperatures of 345 °C (650 °F) or greater
- Bottom heads of vertical vessels supported by a skirt
- Vessel diameters greater than 2.4 m (8 ft)
- Vessels in cyclic service
- Top heads with mounted agitators

- 4.10.3 ASME Code Case 2260 may be used only if specified or approved by the Principal.

- 4.10.4 Hemispherical heads, if specified, are typically thinner than the shell. Unless otherwise specified by the Principal, the mean diameter of the shell and the head shall match.