

DEP SPECIFICATION

PRESSURE VESSELS (BASED ON ASME SECTION VIII)

DEP 31.22.20.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

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

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PART I INTRODUCTION

1.1 SCOPE

This DEP 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 DEP also applies to pressure vessels that are components of packaged equipment units.

This DEP, 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 DEP may also form part of the construction specification.

PART II of this DEP 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 DEP:

- 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, PD 5500 and GB150.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (Part I, 1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall 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 could be more stringent than in this DEP, 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 DEP 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 DEP 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 equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
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.
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 gauge 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 gauge 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 DEP 01.00.01.30-Gen. (which also references databases of "toxic" substances)

1.4 CROSS-REFERENCES

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

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2011. The following are the main, non-editorial changes.

Old section	New section	Change
Part II	Part II	
1.3	1.3	Revised SHALL [PS] to shall
1.3	1.3	Revised SHALL [PS] to shall
1.5	1.5	Revised SHALL [PS] to shall

Old section	New section	Change
1.6	1.6	Revised SHALL [PS] to shall
2.2.4	2.2.4	Revised SHALL [PS] to shall
3.1.9	3.1.9	Revised SHALL [PS] to shall
3.2.2	3.2.2	Revised SHALL [PS] to shall
3.2.2	3.2.2	Revised SHALL [PS] to shall
3.2.3	3.2.3	Revised shall to SHALL [PS] in last sentence. Revised temperature location from 28°C to 15°C as compared to Nelson curve (to align with DEP 31.22.10.32-Gen)
3.2.4	3.2.4	Eliminated prohibition on non-metallic sheet type gaskets on pressure vessels that are in wet H ₂ S services.
3.5 a)		Deleted
3.5 b)		Deleted
3.5 c)		Deleted
4.2.7	4.2.7	Revised SHALL [PS] to shall
4.2.7		Deleted Note.
4.2.7	4.2.7	Revised SHALL [PS] to shall
4.3.1	4.3.1.1	Revised SHALL [PS] to shall
4.4 h)	4.4 h)	Revised SHALL [PS] to shall Revised reference DEP to DEP 34.00.01.10-Gen.
4.5.2	4.5.2	Revised SHALL [PS] to shall
4.6.2	4.6.2	Revised shall to SHALL [PS]
4.12.3 a)	4.12.3 a)	Modified requirement for Sch. 160 CS nozzles only when externally insulated and may be standard wall when under-insulation TSA coating applied. Added reference to DEP 30.48.40.31-Gen.
4.12.6	4.12.6	Revised SHALL [PS] to shall
4.12.13 d)	4.12.13 d)	Revised SHALL [PS] to shall
4.13.1 e)	4.13.1 e)	Revised shall to SHALL [PS]
4.16.7	4.16.7	Revised SHALL [PS] to shall
6.9.1.5	6.9.1.5	Revised SHALL [PS] to shall
Appendices		
		Aligned retrictions to better meet UN GHS and DEP 01.00.01.30-Gen.
I.1.1	I.1.1	Revised SHALL [PS] to shall
II.1.1	II.1.1	Revised SHALL [PS] to shall
II.4.12.6	II.4.12.6	Revised SHALL [PS] to shall
III.4.12.6	III.4.12.6	Revised SHALL [PS] to shall

Old section	New section	Change
III.4.12.10	III.4.12.10	Revised SHALL [PS] to shall
IV.3.5		Deleted
IV.4.12.6	IV.4.12.6	Revised SHALL [PS] to shall
IV.4.12.10	IV.4.12.10	Revised SHALL [PS] to shall
VI.4.12.6	VI.4.12.6	Revised SHALL [PS] to shall
	X.2.2	Added SHALL [PS] requirement for experienced Manufacturers/Suppliers

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II REQUIREMENTS FOR ALL ASME SECTION VIII PRESSURE VESSELS**1. INTRODUCTION****1.1 CERTIFICATION MARK**

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 Certification Mark shall be applied if required by the applicable regulations or if specified by the Principal. A U or U2 Designator shall be applied as applicable.

1.2 GEOMETRIC BOUNDARY

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

- The face of the first flange for bolted, flanged connections.
- The first piping weld for unflanged piping.
- 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 DEP 80.45.10.11-Gen. Unless otherwise specified by the Principal, piping between the pressure relief device and the vessel connection shall be in accordance with DEP 31.38.01.11-Gen.

1.4 UNITS OF MEASUREMENT

This DEP 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 DEP 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 DEP and (Annex V).

1.7 REGISTRATION

Pressure vessels shall be registered in accordance with the applicable local regulations.

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 any of the following conditions apply, the vessels should be constructed in accordance with Division 2, unless otherwise specified by the Principal, see also (2.1.2):

- Pressure vessels operating in cyclic service, pressure- or temperature-induced
- Pressure vessels which operate in the creep range of the materials of construction
- Pressure vessels where weight savings are a critical factor such as offshore or marine applications.

If either 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)
- Pressure vessels with a design pressure of 10 MPa (1500 psi) or higher

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:

- a) Additional calculations required for all or certain construction details
- b) Application of hydraulic bolt tensioning with specified values
- c) PMI of materials, additional testing of the materials, and/or limitations on origin of material
- d) Additional welding procedure requirements
- e) Additional Third party inspection requirements

2.2 VESSEL CATEGORIES

2.2.1 General

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

- Manufacturer/Supplier's Standard Pressure Vessels
- Pressure vessels for Minimum Service
- Pressure vessels for General Service
- Engineered pressure vessels

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

2.2.2 Manufacturer/Supplier's standard pressure vessels

Pressure vessels in this category shall:

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

- e) not be selected for cyclic service, see (4.7.1);
- f) not be selected if they require mitigation of wind-induced vibration as specified in (4.6.2);
- g) not be selected if they require PWHT
- h) not be selected if they are to be of clad or weld-overlay construction

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

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). Vessels in wet H₂S service (see DEP 30.10.02.17-Gen.) shall not use Manufacturer/Supplier's Standard pressure vessels.

2.2.3 Pressure vessels for minimum service

Pressure vessels in this category shall:

- a) be fabricated from carbon steel or solid 300 series austenitic stainless steel
- b) have a design pressure not exceeding 3.5 MPa (500 psi)
- c) have a design temperature not exceeding 260°C (500°F) for carbon steel
- d) have a design temperature not exceeding 400°C (750°F) for austenitic stainless steel
- e) have a Minimum Design Metal Temperature (MDMT) not below -29°C (-20°F)
- f) 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 DEP.

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

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 DEP.

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

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 installed 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/Suppliers accepted by the Principal.

2.4.2 Surveillance

Surveillance requirements shall be established for each pressure vessel constructed in accordance with this DEP. 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/Supplier shall submit the Inspection and Test Plan (ITP) to the Contractor for review and approval. Surveillance requirements identified by the Principal or the Contractor shall be incorporated into the Manufacturer/Supplier's ITP.

ITPs for Engineered Pressure Vessels shall be reviewed and approved by the 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/Supplier's documentation for each pressure vessel shall include the Code Data Report and shall also be in accordance with DEP 31.22.10.35-Gen.

2.5.2 General drawings

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

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

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

2.5.3 Fabrication drawing(s)

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

- a) Full dimensions of all parts and sub-assemblies shown including necessary tolerances and any finishing requirements
- b) Complete identification of materials, including gaskets
- c) Complete identification of internal materials supplied by fabricator, including gaskets.
- d) Location of all circumferential and longitudinal joints
- e) Details of weld preparations and welding procedure numbers
- f) Impact test requirements
- g) Heat treatment details, including temperature of PWHT, time at temperature, heatup and cooldown rates
- h) General remarks on fabrication, assembly and testing as appropriate
- i) Installed bolt torque and bolt stress for body flanges
- j) Extent and location of all nondestructive examination (NDE)
- k) Cleaning, surface preparation, painting and marking requirements
- l) 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 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 EN standards may be selected if approved by the Principal and in compliance with the requirements of ASME Section VIII.

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 [PS] also meet the requirements of (Annex X) of this DEP.

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 DEP 30.10.02.11-Gen.

3.1.8 If approved by the Principal, carbon steel (P1, Gr. 1, 2 or 3) with a minimum specified 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 [PS] be in accordance with DEP 30.10.02.31-Gen.

3.2.2 Material selection for pressure vessels in H₂S containing environments (sour service) in Upstream applications shall be in accordance with DEP 30.10.02.15-Gen.

Material selection and fabrication requirements for pressure vessels in wet H₂S service in Downstream applications shall be in accordance with DEP 30.10.02.17-Gen.

3.2.3 Carbon steel, clad carbon steel and low alloy steels for use in hydrogen service SHALL [PS] be in accordance with API RP 941. No credit shall be taken for the presence of the alloy cladding or weld overlay with regard to hydrogen attack limits. 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 [PS] be at least 15°C (27°F) below and 170 kPa (25 psi) to the left of the applicable material curve of API RP 941, Figure 1.

3.2.4 Non-metallic sheet type gaskets SHALL [PS] not be permitted for flanges on pressure vessels that are in services that are considered very toxic in accordance with DEP 01.00.01.30-Gen.

3.3 BOLTING

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

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

Table 1 Bolting materials

DESIGN TEMPERATURE	BOLT MATERIAL ⁽¹⁾	NUT MATERIAL ⁽¹⁾
–195°C to –102°C (–320°F to –151°F)	SA-320 Gr. B8 – Class 2 ⁽³⁾	SA-194 Gr. 8N
–101°C to –30°C (–150°F to –21°F) General Service	SA-320 Gr. L7 ⁽³⁾	SA-194 Gr. 4
–101°C to –30°C (–150°F to –21°F) Sour Service	SA-320 Gr. L7M ⁽³⁾	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. 4
428°C to 538°C (801°F to 1000°F) Austenitic flanges	SA-453 Gr. 660 – Class C ⁽⁴⁾	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 ^{(2) (4)}	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 ^{(2) (4)}	SA-194 Gr. 8T
(1) Other bolting materials may be permitted in this temperature range. Consult with materials engineer for final selection. (2) Controlled bolting techniques may be required to maintain tightness. (3) 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. (4) 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.		

3.4 APPROVAL OF MATERIALS MANUFACTURERS/SUPPLIERS

The Principal reserves the right to approve material Manufacturers/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/Supplier shall perform PMI in accordance with DEP 31.10.00.10-Gen.

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.
- No corrosion allowance for Stainless Steel Components.

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/strip cladding shall not be 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.

All flange faces shall be raised face type unless otherwise specified by the Principal.

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)
- b) $\frac{D}{650} + 1.8$ mm
- c) $\frac{D}{650} + 0.71$ (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 (4.1.1 (b) or (c)).

4.1.3 Minimum thickness of alloy cladding is 2.5 mm (0.10 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 and flanged extension of a tubesheet 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) or more above the Maximum Operating Temperature, (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.

The maximum temperature at which a reduction in the allowable stress is not required should be considered for use as design temperature if doing so would not adversely affect the services of the vessel or the design of any appurtenances.

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 the highest temperature considered.

4.2.7 The minimum design metal temperature (MDMT) shall be specified as the minimum metal temperature (MMT) as defined by DEP 01.00.01.30-Gen.

In addition, consideration for the prevention of brittle fracture shall be made in accordance with the requirements of DEP 30.10.02.31-Gen.

4.3 DESIGN PRESSURE

4.3.1 General

4.3.1.1 Pressure vessels shall be designed using the specified design pressure selected in accordance with DEP 01.00.01.30-Gen.

4.3.1.2 The MAWP shall be calculated for all pressure vessels and the MAWP shall be included along with the Design Pressure on the vessel nameplate

4.3.1.3 Pressure vessels shall not have their MAWP limited by nozzles or flanges.

4.3.2 External pressure

4.3.2.1 The pressure vessel SHALL [PS] be designed for Full Vacuum if any of the following conditions apply:

- a) If the process is such that vacuum conditions can 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 steam condensate systems that are not open to the atmosphere.

4.3.2.2 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.

4.3.2.3 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 and the mechanical design shall be for Full Vacuum

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 DEP 34.00.01.30-Gen. and local requirements. Alternatively, ASCE 7 Method 2 or the ASCE report "Wind Loads on Petrochemical Facilities" may be used unless otherwise specified by the local jurisdiction. When using ASCE 7, the following shall be used:

- o Classification Category II shall be used unless approval for other category is obtained from Principal.
 - o 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.
 - o Exposure Category shall be in accordance with ASCE 7 unless otherwise directed by the Principal.
 - o Topographic factor shall be in accordance with ASCE 7.
 - o 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 DEP 34.00.01.10-Gen. 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.

4.5 LOAD COMBINATIONS

4.5.1 General

Vessels and their supports SHALL [PS] 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 (Note 2)	Operating condition, no pressure, with full wind load
L1 + L2 + L3 ₁ + L4 + L6 + L8 (Note 2)	Operating condition with full pressure and full wind loads
L1 + L2 + L4 + L7 + L8 (Note 2)	Operating condition, no pressure, with full seismic load
L1 + L2 + L3 ₁ + L4 + L7 + L8 (Note 2)	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.
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. NOTE 2: Actual resonant sloshing forces parallel to the longitudinal axis of the vessel, but shall not be less than 2 times the specified deck accelerations as specified in (Annex XIII).	

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:**

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

4.6.2 The fabricator SHALL [PS] 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

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

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, and MKS (meter, kilogram, second) units are preferred.

4.6.3 Mitigation measures against vortex shedding effects 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.

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 Fatigue assessment of welds using the structural stress method of ASME Section VIII, Division 2, Part 5 shall only be performed with approval of the Principal, and shall be documented on the User's Design Specification.
- 4.7.3 The fatigue evaluation 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 Mo	440°C (825°F)
Austenitic stainless steels	540°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 (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:

- a) Design pressure of 525 kPa (75 psi) or greater
 - b) Operating temperatures of 345°C (650°F) or greater
 - c) Bottom heads of vertical vessels supported by a skirt
 - d) Vessel diameters greater than 2.4 m (8 ft)
 - e) Vessels in cyclic service
 - f) Top heads with mounted agitators
- 4.10.3 ASME BPV Code Case 2260 may be used only if specified or approved by the Principal.
- 4.11 FLAT HEADS
- 4.11.1 Unless otherwise specified by the Principal, flat heads shall be attached by full penetration welds, or by bolting.
- 4.11.2 Flat heads secured by retaining rings or similar methods shall not be used.
- 4.12 NOZZLES, CONNECTIONS AND OPENINGS
- 4.12.1 Unless otherwise specified by the Principal, all connections shall be flanged with through studs, or specified with a butt weld end connection.
- 4.12.2 Nozzle necks shall be a minimum of DN 40 (NPS 1½). Reducers may be installed in accordance with Standard Drawing S 10.101.
- 4.12.3 Nozzle necks SHALL [PS] be a minimum thickness of Schedule Standard Pipe plus corrosion allowance with the following exceptions:
- a) Carbon steel or low alloy nozzles DN 80 (NPS 3) or less SHALL [PS] be minimum schedule 160 when the operating temperature of the vessel is between 0°C (32°F) and 175°C (350°F) and when the vessel and nozzle are externally insulated. However, this requirement may be waived to use Schedule Standard Pipe plus corrosion allowance when the vessel and nozzle have Thermal Spray Aluminium (TSA) under-insulation coating applied in accordance with DEP 30.48.40.31-Gen.
 - b) Austenitic stainless steel or other high alloy nozzles DN 80 (NPS 3) or less shall be minimum schedule 80S.
- 4.12.4 Nozzle sizes of DN 32 (NPS 1¼), DN 65 (NPS 2½), DN 90 (NPS 3½) and DN 125 (NPS 5) shall not be used.
- 4.12.5 Flanges used for nozzles shall be in accordance with the following:
- a) ASME B16.5 for nozzle sizes through DN 600 (through NPS 24)
 - b) ASME B16.47 Series B or ASME Section VIII design for nozzle sizes DN 650 through DN 1500 (NPS 26 through NPS 60), as specified by the Principal. Series A is permitted when required to flange to equipment supplied with a Series A flange, or when analysis shows rotation is acceptable with a Rigidity Index < 1.0 in accordance with ASME Section VIII.
 - c) ASME Section VIII design for nozzles larger than DN 1500 (NPS 60)
 - d) Flange facing shall be in accordance with ASME B16.5. Flanges shall have raised face unless otherwise specified by the Principal.
- 4.12.6 Flange selection shall be in accordance with (Annexes I, II, III or IV), as applicable. Custom-designed lap joint flanges may be appropriate for the service of the pressure vessel and may be used if approved or specified by the Principal. To aid in the bolt-up of custom-designed lap joint flanges, retainer clips shall be installed to the external surface of the nozzle neck, not less than 13 mm (½ in) below the flange when the nozzle is vertical.
- 4.12.7 Flange boltholes shall straddle the normal centrelines of the vessel.

4.12.8 Openings in vessels shall be the following minimum distances from any major structural discontinuity, where D is the nozzle outside diameter and $t_{\min}$ is the minimum required thickness of the shell or head being analyzed.

- a) The greater of $1.8(D \times t_{\min})^{0.5}$ or 50 mm (2 in) for vessels in either cyclic or creep service.
- b) The lesser of $1.8(D \times t_{\min})^{0.5}$ or 50 mm (2 in) for all other vessels

4.12.9 Where a nozzle cannot avoid a circumferential or longitudinal weld seam, the following requirements shall be met:

- a) The nozzle shall straddle the weld seam by a length of at least 50 mm (2 in) or $2 \times t_{\min}$, whichever is greater. This distance shall be measured on the I.D. of the nozzle along the circumferential axis and the longitudinal axis.
- b) The weld seam shall receive 100 % RT for a distance of $[1.8(D \times t_{\min})^{0.5} + D/2]$, measured from the centre of the nozzle, where D is the nozzle outside diameter. Automated UT may be substituted for RT.

Distances are measured from the toe of the welds.

4.12.10 If using integrally reinforced nozzle necks, the integral thickness shall not be more than 2 times the vessel wall thickness at the connection location unless otherwise approved or specified by the Principal.

4.12.11 Nozzles shall be attached with through-wall (set-in), full penetration welded connections, except that set-on connections may be used if:

- a) The vessel shell or head thickness is not less than 50 mm (2 in); and
- b) The nozzle thickness is less than $\frac{1}{2}$ of the shell thickness; and
- c) The plate material meets the requirements of ASTM A 770 S3 with a minimum area reduction of 35 % or EN 10164 (Quality Class Z35); and
- d) 100 % UT examination shall be performed on a 100 mm (4 in) wide band around the nozzle opening before the attachment of the nozzle meeting the requirements of SA-578 Acceptance Level B; and
- e) The vessel is not in hydrogen service above 230°C (445°F) or the nozzle is attached to the header box of an air-cooled heat exchanger in any service; and
- f) The edge of the opening in the vessel wall or head shall be receive MT examination for ferro—magnetic materials and PT examination for nonferro-magnetic materials.

All inside edges of nozzles and connections, whether flush or extended, shall be rounded off to a radius of at least 3 mm (1/8 in).

4.12.12 Nozzle reinforcement shall not limit the MAWP of the vessel.

4.12.13 When reinforcing elements are required, the following requirements shall be met:

- a) The reinforcing element thickness shall not exceed the lesser of 50 mm (2 in) or the nominal thickness of the shell at the location of the opening.
- b) The reinforcing element shall be installed parallel to the shell and normal to the nozzle.
- c) Reinforcing elements shall have a 6 mm ($\frac{1}{4}$ in) telltale hole packed with grease suitable for operating temperature following the hydrotest. When multi-segmental reinforcing elements are used, each piece shall have a telltale hole.
- d) Reinforcing elements shall not be used above 400°C (750°F) with P1, P3, P4 or P5 materials, or above 480°C (900°F) with P8 material.
- e) If vessels are in cyclic service, an analysis shall be made to determine whether to use reinforcing elements or integrally reinforced nozzles.