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1 SCOPE

This Specification establishes the technical requirements for the execution of the mechanical design and fabrication design of pressure vessels to be supplied to PETROBRAS' FPSOs.

Pressure vessels are understood any equipment (such as vessels, filters, towers and heat exchangers) containing process fluids under pressure or fully/partial vacuum and according defined in the ASME BPVC Section VIII scope.

This technical specification is based on ASME BPVC Section VIII Divisions 1 and 2 and establishes complementary requirements to be met on mechanical and fabrication design of pressure vessels to be supplied to PETROBRAS.

Pressure vessels design shall be according ASME BPVC Section VIII Divisions 1 and 2. Other internationally recognized standards or code can be used only with the prior PETROBRAS approval.

When design is based on a standard or code other than ASME BPVC Section VIII, design shall be in full compliance with the standard or code adopted, and this Technical Specification shall be used only when applicable.

When the vessel is a component part of steam generation equipment, it shall be designed according to ASME BPVC Section I.

2 NORMATIVE REFERENCES

The pressure vessels designed and fabricated in accordance with this Technical Specification shall attend, when applicable, the following documents. Rules and regulations of the Classification Society applied to the unit.

2.1 CLASSIFICATION SOCIETY

2.1.1 MANUFACTURER shall perform the work in accordance with the requirements of Classification Society.

2.1.2 MANUFACTURER is responsible for submitting to the Classification Society all documentation in compliance with stated Rules.

2.2 CODES AND STANDARDS

2.2.1 The following codes and standards include provisions for this specification. The latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced below:

ASME BPVC Section I - Rules for Constructions of Power Boilers
ASME BPVC Section II - Materials - Part D: Properties
Part D
ASME BPVC Section VIII - Rules for Constructions of Pressure Vessels
ASME Code Cases - Pressure Vessels
ABNT NBR 6123 - Forças devidas ao Vento em Edificações
ASME B 16.5 - Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B 16.11 - Forged Fittings, Socket-Welding and Threaded
ASME B16.47 - Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard
BSI PD 5500:2009 - Specification for Unfired Fusion Welded Pressure Vessels
ISO 15156 - Petroleum and natural gas industries - Materials for use in H2S-containing environments in oil and gas production
ISO 27509 - Compact flanged connections with IX seal ring
WRC Bulletin 107 - Local Stresses in Spherical and Cylindrical Shells Due to External Loadings
WRC Bulletin 297 - Local Stresses in Cylindrical Shells Due to External Loadings on Nozzles
WRC Bulletin 443 - External Pressure: Effect of Initial Imperfections and Temperature Limits
WRC Bulletin 537 - Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loadings for Implementation of WRC Bulletin 107

2.3 GOVERNMENTAL REGULATION

Ministério do Trabalho e Emprego (Brazilian Labor Ministry) – Norma Regulamentadora Nº 13 (NR-13) - "CALDEIRAS, VASOS DE PRESSÃO, TUBULAÇÕES E TANQUES METÁLICOS DE ARMazenamento"

*Note: Government codes, regulations, ordinances or rules applicable to the equipment in Brazil shall prevail over the requirements of this specification, including reference codes and standards, only if more stringent.

2.4 REFERENCE DOCUMENTS

DR-ENGP-I-1.15 - COLOR CODING
I-ET-3000.00-1200-940-P4X-001 - TAGGING PROCEDURE FOR PRODUCTION UNITS DESIGN.
I-ET-3010.00-1200-251-P4X-001 - BOLT MATERIALS
I-ET-3010.00-1200-540-P4X-002 - REQUIREMENTS FOR PRESSURE VESSELS FABRICATION
I-ET-3010.00-1200-955-P4X-001 - WELDING
I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING
I-ET-3010.00-1200-956-P4X-003 - THERMAL SPRAY COATING APPLICATION ALUMINUM

Specific Documents to be supplied by PETROBRAS:
2.5 CONFLICTING REQUIREMENTS

In any case of conflicts or ambiguities related this specification and other cited document (Classification Society rules, Governmental regulations, referenced codes, rules, standards and other PETROBRAS document), MANUFACTURER shall revert to PETROBRAS for clarification prior to start fabrication activities.

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

3.1.1 CAN: Can requirements are conditional and indicate a possibility open to the user of the standard.

3.1.2 Clad steels: steels produced by hot roll cladding, explosive welding, surfacing by welding, or combined weld/hot roll cladding.

3.1.3 Document supplied by PETROBRAS: Project’s document to be furnished by PETROBRAS to MANUFACTURER, this document contain information to be used during equipment design and fabrication. It is indicated by the expression: [document supplied by PETROBRAS]

3.1.4 Lining: coating or layer of sheet material adhered to or in intimate contact with the interior surface of a vessel used to protect the vessel against corrosion or contamination.

3.1.5 Major components: shell, heads, nozzles, flanges, support.

3.1.6 MANUFACTURER: The supplier, vendor or Contractor. Company responsible for the fabrication of equipment and internal components.

3.1.7 MAY: May indicates a course of action that is permissible within the limits of the standard (a permission).

3.1.8 SHALL: Shall is an absolute requirement which must be followed strictly in order to conform with the standard.

3.1.9 Recommended practice: a provision that may be adopted under the conditions of this Technical Specification, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Technical Specification) to the particular application. It is characterized by the verbal form “should” and equivalent expressions such as “it is recommended that...” and “ought to...” (verbs of a non-mandatory nature). It is indicated by the expression: [Recommended Practice].
3.2 ABBREVIATIONS

API - American Petroleum Institute
ASME BPVC - American Society of Mechanical Engineers – Boiler and Pressure Vessel Code.
ASTM - American Society for Testing and Materials
P&ID: - Piping & Instrumentation Diagram
FPSO - Floating Production Storage and Offloading
LPG - Liquefied Petroleum Gas
MAWP - Maximum Allowable Working Pressure
PWHT - Postweld Heat Treatment
SSC - Sulphide Stress Corrosion
TSA - Thermal Spray Aluminum

4 DESIGN CRITERIA

4.1 OPERATION ENVIRONMENT

The equipment shall be suitable for the environment and range of ambient conditions, including, atmospheric pressure, relative humidity, rainfall, dry-bulb air temperature, characteristic monthly values and wind motions defined in METOCEAN DATA specification [document supplied by PETROBRAS].

4.2 MOTION REQUIREMENTS

The necessary design data and information on motion requirements of the floating unit are given in the latest revision of MOTION ANALYSIS report [document supplied by PETROBRAS].

4.3 EQUIPMENT LOCATION

Equipment location is according to the floating unit GENERAL ARRANGEMENT drawing [document supplied by PETROBRAS].

4.4 BASIC ALLOWABLE STRESSES

4.4.1 For pressure parts, basic allowable stresses values are those listed in ASME BPVC Section II Part D prescribed in ASME BPVC Section VIII.

*NOTE: When stress analysis is required for any component of a pressure vessel designed according to ASME BPVC Section VIII Division 1, the analysis shall be made according to Part 5 of ASME BPVC Section VIII Division 2 using the basic allowable stress corresponding to ASME BPVC Section VIII Division 1.
4.4.2 Welds attaching nonpressure parts to pressure parts, such as supports of main internal components, shall be designed considering the allowable stress for pressure parts.

4.4.3 Carbon steel anchor bolts shall be calculated with a basic allowable stress of 98 MPa (1000 kgf/cm²), based on the root area. For the assembly condition, a maximum allowable stress of 118 MPa (1200 kgf/cm²) may be considered.

4.4.4 For flanges, tubesheets and other parts of the vessel, made of austenitic stainless steel, which may be subject to leaks or malfunction due to slight amount of distortion, the lowest value of allowable stress available on tables of ASME BPVC Section II Part D shall be adopted.

4.4.5 For flanged joints connecting two equipment parts or flanged joints designed according ASME BPVC sec. VIII (e.g.: heat exchanger flanged joints) the PACKAGER/MANUFACTURER shall submit to PETROBRAS approval the completely tightening report containing at least the following information: lubricant, bolt/stud torque, gasket type and flange calculation report. In these cases, MANUFACTURER shall design the flange to be able to a bolt tightening loads at least equal to a 60% of the bolt yield stress.

4.5 DESIGN CONDITIONS

4.5.1 MANUFACTURER shall design the equipment in accordance with the design conditions and dimensions as specified in the PROCESS DATASHEET [document supplied by PETROBRAS].

4.5.2 If design conditions are not defined in the PROCESS DATASHEET document, MANUFACTURER shall consult PETROBRAS for clarification.

4.6 DESIGN LOADS

4.6.1 All pressure vessels, including its supports, shall be checked for the following conditions at least: I – Assembly; II – Manufacturer Hydrostatic Test; III – Eventual Hydrostatic Test (after field assembly); IV – Normal Operation; V – Shutdown; VI - eventual short term, and emergency loads.

4.6.2 The applied loads, allowable stress values and thicknesses which shall be considered for conditions listed in item 4.6.1 (for items: I to V) are given in Table 4.1. For each condition loads are considered to act simultaneously.
Table 4.1 - Combination of Loads for Pressure Vessels Designed According to ASME BPVC Section VIII Division 1

<table>
<thead>
<tr>
<th>Condition</th>
<th>Loads</th>
<th>Allowable tensile membrane stress (Note 7)</th>
<th>Thicknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - ASSEMBLY</td>
<td>a) vessel dead weight (Note 1); b) loads due to wind (Note 2).</td>
<td>Allowable stress values increased by 20%, at room temperature.</td>
<td>Nominal plate thicknesses. (Note 6)</td>
</tr>
<tr>
<td>II - MANUFACTURER HYDROTATIC TEST</td>
<td>a) internal pressure of hydrostatic test; b) vessel weight completely full of water (Note 1); c) weight of all permanent loads supported by the vessel during the test (Note 3).</td>
<td>The maximum stress may not exceed 90% of the yield strength at room temperature. For non pressure parts the basic allowable stress may be considered increased by 33.3%.</td>
<td>Nominal thicknesses. (Note 6)</td>
</tr>
<tr>
<td>III - EVENTUAL TEST (after field assembly)</td>
<td>a) internal pressure of hydrostatic test; b) vessel weight completely full of water (Note 1); c) weight of all permanent loads supported by the vessel during the test (Note 3). d) loads due to ship motion, when applicable. e) loads due to wind (Note 2).</td>
<td>The maximum stress may not exceed 90% of the yield strength at room temperature. For non pressure parts the basic allowable stress may be considered increased by 33.3%.</td>
<td>Nominal and corroded thicknesses. (Note 6)</td>
</tr>
<tr>
<td>IV - NORMAL OPERATION (Note 5)</td>
<td>a) internal or external design pressure at design temperature; b) weight of fluid at operating level; c) vessel dead weight; d) weight of all permanent loads supported by the vessel (Note 4); e) loads due to wind (Note 2); f) loads due to ship motion, when applicable; g) piping loads.</td>
<td>Allowable stress values at design temperature.</td>
<td>Corroded thicknesses, i.e. nominal thicknesses minus corrosion allowance. (Note 6)</td>
</tr>
<tr>
<td>V - SHUTDOWN</td>
<td>a) vessel dead weight; b) weight of all permanent loads supported by the vessel (Note 4); c) loads due to wind (Note 2). d) loads due to ship motion, when applicable.</td>
<td>Allowable stress values increased by 20%, at room temperature.</td>
<td>Corroded thicknesses (Note 6)</td>
</tr>
</tbody>
</table>

Notes: 1) It includes the shell and welded accessories; it excludes external accessories and removable internals.
2) Loads due to wind need not be considered for the horizontal pressure vessels design, but shall be considered in the foundation and structure design of such vessels.
3) It excludes internal and external insulation.
4) It includes removable internals, internal and external insulation, external accessories and piping.
5) In special cases, at the designer criterion, it may be necessary to consider under condition III the simultaneous effect of other active loads, such as thermal expansion of the vessel itself, thermal expansion of piping systems and other structures connected to the vessel, pressure fluctuation, dynamic loads caused by internal fluid movement and vibrations.
6) For parts whose thickness is reduced during the fabrication process, the minimum thicknesses expected after forming shall be considered instead of nominal thickness.
7) The allowable longitudinal compressive stress, for all loading conditions, for the vessel and support skirts shall be determined in accordance with paragraph UG-23 of ASME BPVC Section VIII Division 1.
4.6.3 Wind Loading Effects

4.6.3.1 Wind loads shall be calculated according to ABNT NBR 6123 with wind basic velocity of 45 m/s. Other standard may be used with previous PETROBRAS approval.

4.6.3.2 In vertical pressure vessels the effects of vibration induced by wind shall be verified in wind direction and perpendicular to wind direction.

4.6.3.3 For vertical vessels the maximum deflection due to wind shall not exceed 1/200 of the vessel height.

4.6.3.4 Loads due to wind on platforms, ladders, piping, and other accessories attached to the shell of the vessel shall be included in the total wind load.

4.6.4 Eventual Short Term, and Emergency Loads

4.6.4.1 Equipment design shall comply with eventual short term loads foreseen by Process Design. When applicable, emergency conditions shall also be considered, such as:

a) Temperature drop due to depressurization of low molecular weight gases;
b) Loads due to deflagration of gases inside the pressure vessel (see Appendix H of ASME BPVC Section VIII).

4.6.4.2 Neither eventual short term nor emergency loads need to be considered simultaneously with wind loads.

4.6.4.3 For non-pressure parts allowable stress may be increased by 33.3%.

4.7 CYCLIC LOADINGS

For pressure vessels subjected to cyclic loadings a fatigue evaluation according to Part 5.5.2 of ASME BPVC Section VIII Division 2 shall be performed if any component is subject to cyclic loading, even for that pressure vessels designed according to ASME BPVC Section VIII Division 1.

4.8 DESIGN LIFETIME

4.8.1 Unless otherwise specified, MANUFACTURER shall design and fabricate the complete equipment for a minimum service life of 25 years, unless otherwise mentioned in a specific PETROBRAS document.

4.8.2 For a removable or replacement parts (e.g. tube bundles, towers internals, etc.) a minimum service life shall be 8 years.

4.8.3 The service life of Pressure Vessel shall be used as a basis for the selection of materials, determination of corrosion and erosion thickness allowances, calculation of fatigue and creeping deformation and any other criterion based on the time factor.

4.8.4 When compliance with service life is not technically or economically feasible, PETROBRAS shall decide on a case by case basis.
4.9 MAXIMUM ALLOWABLE WORKING PRESSURE

4.9.1 The MAWP is the maximum allowable working pressure at design temperature with corroded thicknesses.

4.9.2 The MAWP shall be calculated and the vessel part that limits this pressure shall be indicated.

4.9.3 Nozzle reinforcements shall not in any case limit the hydrostatic test pressure or the MAWP of the vessel, except for vessels of small dimensions whose thickness shall be defined by the minimum structural value.

4.9.4 Pressure vessel's MAWP shall be limited by the components: shell or heads.

4.9.5 If MANUFACTURER have designed a pressure vessel with other component (instead of shell or head) limiting equipment MAWP, the MANUFACTURER shall request PETROBRAS approval prior fabrication.

4.10 WELDED JOINT EFFICIENCY

4.10.1 For any component designed according to ASME BPVC Section VIII Division 1 radiographic examination shall be at least spot radiography, as specified in paragraphs UW-11 and UW-12 and described in paragraph UW-52.

4.10.2 For any component designed according to ASME BPVC Section VIII Division 2 radiographic examination shall be fully radiography, as specified in paragraphs UW-11 and UW-12 and described in paragraph UW-52.

4.10.3 Equipment classified by PETROBRAS as “Service with H2S”, and equipment that requires SSC-resistant steels according to methodology of ISO 15157 shall comply with requirements of paragraph UW-2(a) of ASME BPVC Section VIII Division 1.

4.10.4 Pressure vessels made of material P-number 10H shall be fully radiographed.

5 MATERIALS

5.1 MATERIAL SELECTION

5.1.1 Pressure vessels material selection shall be according to MATERIAL SPECIFICATION FOR PRESSURE VESSELS [document supplied by PETROBRAS].

5.1.2 Only if the material selection is not specified by PETROBRAS, the MANUFACTURER shall define the complete pressure vessel's material considering the minimum design lifetime stated item 4.8. For these cases, the material selected by MANUFACTURER will be only accepted with PETROBRAS prior approval.

5.2 MATERIAL REQUIREMENTS

5.2.1 For shells, heads and all other pressure parts only qualified materials shall be specified. Qualified materials shall be recognized by ASME BPVC Section II and ASME BPVC Section VIII. ASTM materials will be allowed, provided that the deviations are described and submitted to PETROBRAS for previous approval.
5.2.2 The acceptance of materials equivalent to ASME BPVC materials or in accordance with other standards is subject to the previous approval of PETROBRAS. These materials shall be included in specifications of internationally recognized standardization societies (Ex.: BS, DIN, JIS etc.). In such cases, the bidder shall present the full text of the proposed specification either in portuguese or in english including necessary tests for material requalification, according to ASME BPVC.

5.2.3 Materials listed in current ASME Code Cases may be used with PETROBRAS previous approval.

5.2.4 Carbon steels for pressure parts shall present a carbon content not exceeding 0.30%, and for shell and head plates the carbon content shall not exceed 0.26 %. Steels having a carbon content exceeding the above limits may be used only in the following circumstances:

a) Unwelded parts, such as blind flanges and manhole covers;
b) Plates more than 50 mm in thickness.

5.2.5 The use of carbon steels containing other alloy elements besides manganese and silicon and/or with tensile stress exceeding 485 MPa (70 ksi), nominal stress value given in the material specification, as well as the use of quenched and tempered steels shall be subject to PETROBRAS previous approval.

5.2.6 Regardless of the temperature limits established in code ASME BPVC Section II Part D for use in ASME BPVC Section VIII, the materials indicated in Table 5.1 shall only be used in continuous service for temperatures up to the limits given in this table. Materials may be used at higher temperatures for occasional or short-time conditions or in those cases where there is no other alternative deemed to be technically or economically viable. In any case, PETROBRAS approval is required. Limits for pressure parts are mainly based on the mechanical strength (creep resistance) of the material. The limits for nonpressure parts are based on the scaling temperature of the material.

5.2.7

5.2.8 Table 5.2 shows the basic criteria for the specification of materials for the various parts of pressure vessels. These criteria shall be followed, except as otherwise specified for a particular vessel. The classes of parts of vessels mentioned on the first column of

5.2.9 Table 5.2 are described in items 5.2.9.1 to 5.2.9.6.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Maximum Operating Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pressure Parts</td>
</tr>
<tr>
<td>Structural carbon-steel.</td>
<td>150</td>
</tr>
<tr>
<td>Rimmed carbon-steel (qualified materials).</td>
<td>400</td>
</tr>
<tr>
<td>Carbon steel killed with Si.</td>
<td>450</td>
</tr>
<tr>
<td>1 ¼ Cr – 1/2 Mo alloy steels.</td>
<td>530</td>
</tr>
<tr>
<td>2 ¼ Cr – 1 Mo alloy steels.</td>
<td>530</td>
</tr>
<tr>
<td>2 ¼ Cr – 1 Mo – V alloy steels.</td>
<td>482</td>
</tr>
<tr>
<td>5 Cr – 1/2 Mo alloy steels.</td>
<td>480</td>
</tr>
<tr>
<td>Stainless steel 405, 410, 410S.</td>
<td>480</td>
</tr>
</tbody>
</table>
Table 5.2 - Criteria for Specification of Materials of Vessel Components

<table>
<thead>
<tr>
<th>Class of the Vessel Part under Consideration</th>
<th>Vessel's Base Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>I</td>
<td>Same material as for shell.</td>
</tr>
<tr>
<td>II</td>
<td>Same material as for shell.</td>
</tr>
<tr>
<td>III</td>
<td>Structural carbon-steel.</td>
</tr>
<tr>
<td>IV</td>
<td>Materials specified for each case.</td>
</tr>
<tr>
<td>VI</td>
<td>Structural carbon-steel.</td>
</tr>
</tbody>
</table>

Note: The same material used for the shell shall be adopted whenever it is required for corrosion-resistance reasons

5.2.9.1 Class I

Parts of the pressure wall of the vessel in contact with the process fluid (e.g.: shells, heads, nozzle necks, flanges, blind flanges and others) and other pressure parts in contact with the process fluid (e.g.: tubesheets). This class also includes internal parts welded to vessels and subject to primary stress (e.g.: rings, plates and other elements for supporting trays, gratings, internal heads and others). This class also includes reinforcements (any type) of openings on the vessel pressure wall.

5.2.9.2 Class II

Parts of the vessel pressure wall not in contact with the process fluid such as external reinforcements, vacuum reinforcements and others, except reinforcements of openings (included in Class I).

5.2.9.3 Class III

Internal parts welded to the vessel but not subject to primary stress (e.g.: baffles, vortex breakers, weir plates and others). External parts welded to the vessel subject to stress during operation, such as any type of support (e.g.: skirts, columns, saddles etc.), supporting elements for ladders, platforms, external piping and others. For supports, this class only includes the parts of supports directly welded to the vessel or very close to it.
Note: The supports shall have a section 1000 mm long from the attachment to the vessel, with the same shell material in the following cases:

a) design temperature lower than or equal to 15 °C;
b) design temperature over 340 °C;
c) service with hydrogen;
d) vessels made of alloy steel, stainless steels and nonferrous materials.

5.2.9.4 Class IV

Internal removable parts (not welded to the vessel), such as trays, bubble caps, gratings, supporting beams, distributors, tube bundles and others.

5.2.9.5 Class V

Parts of supports of any type not included in Classes III and IV. For all parts of this class, the design temperature is always the ambient temperature.

5.2.9.6 Class VI

External parts welded directly to the vessel but subject to loads only during assembly, maintenance, disassembly and others, such as lifting eyes, davits and others. For all parts of this class, the design temperature is always the ambient temperature.

5.2.10 The specification of materials, the definition of the need, if any, for impact tests and heat treatment, as well as temperature and energy of impact test shall be made by the mechanical design based on basic design data.

5.2.11 Materials for vessels intended for low-temperature services shall comply with requirements of ASME BPVC, not only in the shell and heads but also in all other parts subject to pressure, such as flanges, necks, couplings, bolts, nuts and others.

5.2.12 When the sensitization of austenitic stainless steels is deleterious to their corrosion resistance, materials that are not susceptible to sensitization shall be used (low carbon steels, types L and ELC or stabilized steels). Attention is drawn to the fact that sensitization may occur as a result of welding, heat treatments or operating temperature of the vessel.

5.2.13 Castings are not allowed.

5.2.14 For vessels with internal diameter to shell thickness ratio less than 15, the fabrication by forging, instead of formed plates, shall be evaluated. [RECOMMENDED PRACTICE]

5.3 ADDITIONAL REQUIREMENTS FOR “\(\text{H}_2\text{S}\) SERVICE”

5.3.1 All materials that are exposed to hydrocarbons containing hydrogen sulphide must follow the requirements of ISO 15156 for sour service. This requirement also must be applied in systems that are located downstream of Dehydration Unit.

5.3.2 When using carbon steel materials in wet \(\text{H}_2\text{S}\) environment requirements below must be met:
5.3.2.1 Carbon steel plates shall conform to SA-516, with additional supplementary requirements S54.1, S54.2 and S54.3. Plates shall be examined according to ASME SA-578, acceptance standard – level C, supplementary requirement S1.

5.3.2.2 Forgings shall have the following limitations in the chemical analysis:

a) \( C \leq 0.30 \% \),
b) \( CE \leq 0.45 \% \), where: \( CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15} \)

5.4 WELD METAL OVERLAY VESSELS

5.4.1 Plates shall be either of integral or weld metal overlay clad material and shall conform to applicable requirements of SA-263, SA-264 or SA-265.

5.4.2 Strip lining is not allowed.

5.4.3 Design calculations shall be based on the base material thickness, exclusive of the thickness of the clad material.

5.4.4 Cladding material shall be according to MATERIAL SPECIFICATION FOR PRESSURE VESSELS [document supplied by PETROBRAS].

5.4.5 Construction details of integrally clad or welded metal overlay cladded vessels shall comply with Figure 5.1 to Figure 5.3.

5.5 BOLTS AND NUTS

5.5.1 Bolt material shall comply with I-ET-3010.00-1200-251-P4X-001 - BOLT MATERIALS.

5.6 ORGANIC INTERNAL COATING

If internal coating is required, it shall be in accordance with I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING.

*NOTE: For surfaces in which an organic internal coating is required, a weld overlay may be required in the sealing areas, e.g.: RTJ flanges faces.

5.7 THERMAL SPRAY ALUMINUM (TSA)

If internal TSA is required, it shall be in accordance with I-ET-3010.00-1200-956-P4X-003 - THERMAL SPRAY COATING APPLICATION ALUMINUM.

5.8 PAINTING AND COLOR

5.8.1 Internal and external painting shall be according the latest revision I-ET-3010.00-1200-956-P4X-002 - GENERAL PAINTING.

5.8.2 Pressure vessels color shall be according the latest revision of DR-ENGP-I-1.15 – COLOR CODING.
Figure 5.1 - Construction details of integrally or weld metal overlay
Figure 5.2 - Construction details of integrally or weld metal overlay cladded vessels – 2” to 10” nominal diameter

Figure 5.3 - Construction details of integrally or weld metal overlay cladded vessels – 12” and greater nominal diameter
6 THICKNESSES

6.1 GENERAL REQUIREMENTS

6.1.1 The thicknesses indicated on drawings are the minimum plate thicknesses which are to be adopted for vessel fabrication.

6.1.2 For dished heads and other pressed or formed parts, provision shall be made for a minimum increase in the plate thickness to compensate the thickness loss in pressing or forming, so that the final thickness of the finished part be at least equal to the calculated value or the value shown on the drawings.

6.1.3 For vessels in which various different shell course thicknesses are specified, the MANUFACTURER may increase some of these thicknesses in order to match the length of commercial plate dimensions.

6.1.4 An adequate corrosion allowance shall always be added except:

a) when an anticorrosive internal coating/Clad is available, or;

b) when, for service and material of the vessel, corrosion is recognized by PETROBRAS as to be absent or negligible.

6.1.5 Corrosion allowances shall be based on the service life, as specified in this Technical Specification. As a general rule, when the expected corrosion rate exceeds 0.24 mm/year, or when the corrosion allowance exceeds 6 mm, other materials with a higher corrosion resistance should be used. [RECOMMENDED PRACTICE]

6.1.6 For carbon-steel or low alloy steel parts, a minimum corrosion allowance of 1.5 mm shall be adopted, even if the estimated corrosion is lesser than this value.

6.1.7 Unless otherwise specified, the following minimum values shall be adopted for corrosion allowance, for parts made of carbon-steel or low alloy steels:

a) Towers, vessels and heat exchangers for hydrocarbon service: 3 mm;

b) Sumps for the above vessels: 6 mm;

c) Vessels and filters containing fresh water: 3 mm;

d) General pressure vessels for either vapor or air: 1.5 mm;

e) LPG storage vessels: 1.5 mm.

6.1.8 The criteria given in Table 6.1 shall be adopted for corrosion allowance application.

### Table 6.1 - Corrosion Allowance Application Criteria

<table>
<thead>
<tr>
<th>Vessel Part</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts of the pressure wall in contact with the process fluid:</td>
<td></td>
</tr>
<tr>
<td>shells, heads, nozzle necks, tubesheets, flanges, blind flanges and others.</td>
<td>Add the total corrosion allowance value to each surface of the part in contact with the fluid.</td>
</tr>
<tr>
<td>Non-removable internal parts subject to primary loads: tray supports,</td>
<td></td>
</tr>
<tr>
<td>packing supports, lifting lugs, welded trays, others.</td>
<td></td>
</tr>
<tr>
<td>Non-removable internal parts not subject to loads: weir plates, vortex</td>
<td></td>
</tr>
<tr>
<td>breaker, baffles, others.</td>
<td>Add one-half of the corrosion allowance value to each surface in contact with the fluid.</td>
</tr>
<tr>
<td>Removable internal parts subject to loads (excluding trays and their</td>
<td></td>
</tr>
<tr>
<td>accessories): beams, rods, other supporting parts.</td>
<td></td>
</tr>
</tbody>
</table>
6.1.9 Regardless of the value calculated for the thickness, in carbon-steel and low alloy steel vessels, shells and heads shall have a minimum thickness equal to the higher of the 2 values given below:

a) \( t_{\text{min}} = 4.8 \text{ mm} \);

b) \( t_{\text{min}} = 2.5 + 0.001 \text{ ID} + \text{C.} \);

Where: \( t_{\text{min}} \) = minimum thickness, mm; ID = internal diameter, mm; C = corrosion allowance, mm.

6.1.10 In vessels made of stainless steels and nonferrous metals the minimum design thickness shall not be less than 2 mm.

6.1.11 Unless otherwise specified, the alignment of plates having different thicknesses, in the vessel shell or head, shall be done from the inner surface.

7 HEADS AND TRANSITION SECTIONS

7.1 GENERAL REQUIREMENTS

7.1.1 The head shape shall be one of those permitted by ASME BPVC Section VIII.

7.1.2 For pressure vessels designed according to ASME BPVC Section VIII Division 1, only welded flat heads as shown in Figures UW-13.2 (a), (b), (c), (e) and (f) are allowed.

7.1.3 Ellipsoidal or torispherical heads shall have a semi-axis ratio of 2:1. Torispherical heads known as false ellipse may be calculated as ellipsoidal.

Note: Torispherical head known as false ellipse: it is the torispherical head which has an inside knuckle radius of 0.173 D and an internal spherical radius of 0.904 D, where D the internal vessel diameter.

7.1.4 Ellipsoidal or torispherical carbon-steel and low-alloy steel heads having an inside diameter up to 1800 mm shall be constructed as a single unit without welds. For torispherical heads with an inside diameter larger than 1800 mm and for clad heads or made of other materials not than carbon-steel or low alloy steel of any diameter, \textbf{Figure 7.1} shows acceptable weld details and \textbf{Figure 7.2} shows unacceptable weld details. Welds fully contained in the toroidal area of the head are not allowed except for welds in the radial position. For construction in radial sections, the central crown shall not have a radius less than 20% of the head radius.

Note: Heads as shown in \textbf{Figure 4.3.3} of ASME BPVC Section VIII Division 2 are acceptable for any diameter, for pressure vessels designed according to this division.

7.1.5 The thickness required for the cylindrical part (head skirt) of the ellipsoidal and torispherical heads shall not be less than the thickness required for the shell to which it is connected.

7.1.6 Vessel support shall not be welded to conical section of the vessel.
Figure 7.1 – Examples of Acceptable Weld Details

Figure 7.2 – Examples of Non Acceptable Weld Details
8 NOZZLES AND OTHER OPENINGS

8.1 GENERAL REQUIREMENTS

8.1.1 For all pressure vessels, or for each vessel part, which are not completely drainable through piping, a drain nozzle is necessary for complete internal drainage.

8.1.2 The vessels shall have, as a minimum, manholes or inspection holes in each pressure compartment, as shown in Table 8.1.

Table 8.1 - Vessel Manholes and Inspection Holes

<table>
<thead>
<tr>
<th>Vessel Internal Diameter, mm</th>
<th>Vessels with Internals or with Internal coating</th>
<th>Vessels without Internals</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID ≤ 250 mm</td>
<td>Upper flanged cover</td>
<td>2 inspection holes 2&quot; diameter.</td>
</tr>
<tr>
<td>250 mm &lt; ID ≤ 815 mm</td>
<td>Upper flanged cover (see Note)</td>
<td>2 inspection holes 4&quot; diameter.</td>
</tr>
<tr>
<td>ID &gt; 815 mm</td>
<td>Manhole(s).</td>
<td>Manhole(s).</td>
</tr>
</tbody>
</table>

Note: It shall be evaluated the convenience of using conical reduction in order to allow smaller flanged cover, as well the use of dished heads instead of blind flanged cover. [Recommended Practice]

8.1.3 The minimum nominal diameter of manholes shall be as indicated in Table 8.2.

Table 8.2 – Minimum Nominal Diameter of Manholes

<table>
<thead>
<tr>
<th>Inside Diameter of Vessel, mm</th>
<th>Vessel with or without Internals</th>
</tr>
</thead>
<tbody>
<tr>
<td>815 ≤ ID ≤ 1220</td>
<td>20&quot;</td>
</tr>
<tr>
<td>1220 ≤ ID</td>
<td>24&quot;</td>
</tr>
</tbody>
</table>

8.1.4 For vessels with trays, gratings or other similar parts, which are dismountable and for vessels which have a hatch, the minimum number of manholes for clean services shall be as specified in Table 8.3. Additional manholes shall be considered at the fluid inlet where internal piping and baffles may need frequent cleaning.
Table 8.3 - Minimum Number of Manholes

<table>
<thead>
<tr>
<th>Number of Trays or Gratings</th>
<th>Minimum Number of Manholes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 25</td>
<td>2</td>
</tr>
<tr>
<td>26 - 41</td>
<td>3</td>
</tr>
<tr>
<td>42 - 60</td>
<td>4</td>
</tr>
<tr>
<td>61 and higher</td>
<td>5 + 1 (plus one) per each 20 trays added over 60.</td>
</tr>
</tbody>
</table>

8.1.5 For services requiring frequent cleaning or for safety reasons, the number of manholes indicated in Table 8.3 may be increased, according to the severity of the service, up to a maximum of one manhole for every 6 trays.

8.1.6 For vertical vessels with a single manhole, it shall be located in the cylindrical shell at the lowest possible position. When the vertical vessel has 2 manholes, the second manhole shall be located above the upper tray or at the highest possible position. For vertical vessels with 3 or more manholes, additional manholes shall be equally spaced wherever possible along the length of the vessel and preferably located next to inlet nozzles and internal piping systems.

8.1.7 For horizontal vessels, the manhole shall be preferably located on one of the heads; the second manhole, if any, shall be located on the top part of the shell, near the opposite end. Horizontal vessels more than 10 m long shall have 2 manholes.

8.1.8 Inlet nozzles shall be sufficiently far away from the level gauge instrument to avoid level disturbances that may affect the instrument reading.

8.1.9 Inlet and outlet nozzles shall be located away from each other to avoid short circuits in the vessel. For horizontal vessels, it is recommended that these nozzles be located near each of the vessel ends. [Recommended Practice]

8.1.10 For towers and vertical vessels nozzle orientation, when not determined due to process reasons, shall meet the needs of the piping route. The orientation of the manholes shall meet the arrangement requirements of platforms and ladders.

8.1.11 Manholes shall be located on the same vertical line or on 2 vertical lines diametrically opposite. [Recommended Practice]

8.1.12 Nozzles shall be oriented in such a manner that the vertical piping is concentrated in one or 2 restricted sectors of the vessel circumference. [Recommended Practice]

8.1.13 Valves, flanges, threaded connections or beveled ends for weld shall not be placed inside the skirt. If the bottom nozzles require valves connected directly to the vessel, the arrangement shall conform to Figure 8.1 to avoid valves inside the skirt.

8.1.14 All nozzles connected to piping systems shall be provided with spectacle blind flange, exception for instrument nozzles.

8.1.15 All vessels shall have nozzles for vent, drain and pressure inlet connections. They shall be used for hydrostatic test, cleaning or maintenance. These connections shall have easy access.
8.2 NOZZLES AND MANHOLES CONSTRUCTION

8.2.1 All nozzles NPS 2 or over shall be flanged, except when specified for butt weld in the piping. Butt-weld nozzles shall be avoided, however they may be adopted for large diameter nozzles or for high pressures, in any case PETROBRAS previous approval is required. For nozzles smaller than NPS 2 threaded connection are acceptable only in following conditions:

a) Service with following fluids: water, compressed air or inert gases;

b) Nozzle without impact test requirement.

8.2.2 The minimum nominal diameter of nozzles shall be 3/4". Exceptionally ½" threaded nozzles are allowed for thermowells or other instruments in following conditions:

a) Service with following fluids: water, compressed air or inert gases;

b) Nozzle without impact test requirement.

8.2.3 Nozzles having NPS 1 ¼, 2 ½, 3 ½, 5 and 7 shall not be used.

8.2.4 Nozzles up to 12" NPS shall be made of seamless pipe, unless they are made of long welding neck flanges (LWN) or forged steel. Nozzles NPS 14 and greater may be of following types:

a) Welded or seamless pipe;

b) Forged steel;

c) Rolled plate with a single longitudinal weld.

Note: In cases in which rolling is impracticable due to high thickness, pressing with 2 longitudinal welds is allowed, since previously approved by PETROBRAS.

8.2.5 The minimum thicknesses for carbon or low alloy steel nozzles shall be as following:
a) Sch. 80 for nozzles up to NPS 2;
b) Sch. 40 for nozzles from NPS 3 through NPS 10;

8.2.6 The external projection of nozzles shall be the smallest possible, but sufficient to:

a) Provide an adequate distance between the flange weld and the shell weld (see item 12.2.12 of this Technical Specification);
b) allow the disassembly of flange bolts without damaging thermal insulation;
c) prevent the bolts or nuts from becoming embedded in thermal insulation;
d) allow access for welding of the nozzle neck to the shell.

Note: Figure 8.2 and Table 8.4 shows external projections for nozzles and manholes based on requirements above. [Recommended Practice]

Figure 8.2 - Minimum External Projection of Nozzles and Manholes [Recommended Practice]
Table 8.4 – Nozzle Minimum External Projection Dimensions

<table>
<thead>
<tr>
<th>NPS</th>
<th>150</th>
<th>300</th>
<th>600</th>
<th>900</th>
<th>1500</th>
<th>2500</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ½</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ½</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>350</td>
<td></td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>400</td>
<td></td>
<td>550</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td>350</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>250</td>
<td></td>
<td></td>
<td>400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>300</td>
<td></td>
<td></td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>400</td>
<td></td>
<td></td>
<td>500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) Dimensions in millimeters, unless otherwise specified;
2) For pressure vessels with thermal insulation thicker than 75 mm, add insulation thickness to minimum external projection indicated in table above;
3) See item 8.2.6;
4) If davit support is attached to nozzle, add 50 mm to minimum external projection indicated in table above.
8.2.7 Except for process reasons, nozzles with internal projection require PETROBRAS previous approval.

Note: Drains and vents shall have no internal projection

8.2.8 The inner edge of any nozzle without internal projection shall be rounded.

8.2.9 Pad type nozzles, as shown in Figure UG-40 (a-1) and (a-2), and in Figure UW-16.1 (p) of ASME BPVC Section VIII Division 1, or other similar construction details, shall not be used, except in exceptional cases to be subjected to PETROBRAS approval.

8.2.10 Nozzle neck to shell attachment shall be a full-penetration weld, as well as the attachment of reinforcing pad to nozzle neck.

Note: Set-on nozzles are not allowed.

8.2.11 For pressure vessels constructed of steels with tensile properties enhanced by heat treatment, nozzle to shell attachments not readily radiographable are not allowed. Attachments as shown in Figure UHT-18.2 of ASME BPVC Section VII Division 1 are not allowed.

8.2.12 Utilization of Half-Couplings as Nozzles

8.2.12.1 Nozzles up to NPS 1 1/2 may be of forged half-coupling, since it is allowable for the vessel service. Coupling-to-vessel attachment shall be a full-penetration weld.

8.2.12.2 Half-couplings shall be at least class 6000, for socket weld end. For instruments threaded half-couplings are allowed only when all requirements below are met:

a) Service with following fluids: water, compressed air or inert gases;

b) Nozzle without impact test requirement.

Note: Internal couplings, not subjected to pressure loading, need not to meet above requirements. In this case, threaded couplings class 3000 are acceptable.

8.2.12.3 Half-coupling length shall be greater than the vessel thickness and the other dimensions shall conform to ASME B16.11.

8.2.13 MANUFACTURER is responsible for checking the stress on nozzles as well as for providing adequate reinforcements on nozzles or on the vessel wall to withstand the external piping loads.

Note: The following methods may be used to verify stresses in nozzle-to-shell junction

a) Finite elements method (FEM);

b) WRC Bulletin: 107, 297 and/or 537 respecting its limitations.

8.2.14 Unless any service restriction applies nozzle and manhole reinforcements may be obtained by one of the systems shown in Figure 8.3 or by combinations of these systems, with the recommendations and limitations specified in items 8.2.14.1 to 8.2.14.4.

8.2.14.1 Reinforcing pad welded to the tubular neck and to the vessel wall [Figure 8.3 (a)]. This system is allowed for any diameter but shall not be used when the
wall thickness of the vessel is equal to or greater than 50 mm. It is not allowed for low temperature service, for cyclic services or for service with H₂.

Note: Reinforcing pads shall have a 6 mm diameter hole, with NPT thread, for vent and for weld test. For nozzles NPS 10 and greater there shall be two 6 mm holes diametrically opposite. After tests, these holes shall be left open and filled with grease.

8.2.14.2  Insert plate of greater thickness, butt welded to the vessel [Figure 8.3 (b)]. This system is allowed for any diameter and may be used when the reinforcing pad of Figure 8.3 (a) is unacceptable.

8.2.14.3  Integral forged part [Figure 8.3 (c)]. This system is allowed for any diameter without limitations.

8.2.14.4  Integral reinforcement of greater thickness [Figure 8.3 (d)]. This system is allowed without limitations for nominal diameters up to 10". The integral reinforcement shall be made of seamless or forged pipe (forged pipe is preferred in these cases).

8.2.15 Nozzles closed with blind flange weighing over 350 N (36 kgf) shall be provided with a davit or hinges for removal of the blind flange, as specified in item 8.3.

8.3 ADDITIONAL REQUIREMENTS FOR MANHOLES

8.3.1  Manholes shall be provided with davits for covers removal. Hinges might be used for manholes pressure class 150 NPS up to 24.

8.3.2  Manholes with the cover on the horizontal plane opening downward shall be avoided; in those cases in which they are inevitable, a safe device shall be provided to remove and handle the cover.

8.3.3  Vessels with the cover on the vertical plane shall be provided with stairs on the inside, except when internals preclude access to the manhole or make those stairs unnecessary.
Figure 8.3 - Allowable Nozzles and Manholes Reinforcements
8.4 FLANGES

8.4.1 Flanges shall be suitable for the design and test conditions of the vessel, specified according to ASME B16.5, ASME B16.47, API 6A or ISO 27509. Only flanges not available in these standards shall be calculated according to ASME BPVC Section VIII.

8.4.2 Nonpressure internal flanges may have a flat face and be made of cut plate.

8.4.3 Flange type shall be according to Table 8.5.

<table>
<thead>
<tr>
<th>NPS</th>
<th>Flange Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1 ½</td>
<td>Long welding neck flange (LWN);</td>
</tr>
<tr>
<td></td>
<td>Welding neck flange (WN), sch. 160 or XXS.</td>
</tr>
<tr>
<td>2 to 12</td>
<td>Welding neck flange (WN).</td>
</tr>
<tr>
<td>14 and greater</td>
<td>Ring type flange (RT) according Figure 2-4 (7) or (11) of ASME BPVC Section VIII Division 1 or Figure 4.16.1 (a) of ASME BPVC Section VIII Division 2. These flanges shall be made of seamless forged steel, or made from bar or plate.</td>
</tr>
</tbody>
</table>

Notes:

NOTE 1: Slip-on flanges (SO) may be used since all the following requirements are met:
  a) Nozzles flanges pressure class 150, or manhole flanges pressure class up to 300;
  b) Service with following fluids: compressed air, inert gases or water;
  c) Corrosion allowance up to 3 mm;
  d) Impact test is not required;
  e) PWHT is not required.

NOTE 2: Welding neck and slip-on flanges shall be made of forged steel.

NOTE 3: For nominal diameter 14” and greater ring type flange (RT) according to Figure 2-4 (8), [8(a)], (9), [9(a)], (10) or [10(a)] of ASME BPVC Section VIII Division 1 may be used since all the following requirements are met:
  a) Design pressure up to 2 000 kPa;
  b) Service with following fluids: compressed air, inert gases or water;
  c) Corrosion allowance up to 3 mm;
  d) Impact test is not required;
  e) PWHT is not required

NOTE 4: For vessels made of stainless steel or nonferrous metals, having design pressure less than 400 kPa (4.1 kgf/cm²) and design temperature below 250 °C, lap joint type flanges may be used on vessel nozzles.

8.4.4 Flanges made from a bar or plate shall be obtained by machining of rolled or pressed rings, having not more than 2 fully radiographed butt welds. These flanges shall be heat treated as specified in code ASME BPVC Section VIII and the surfaces of the original plate shall be parallel to the axis of the finished flange. Flanges cut from plate shall only be allowed for internal vessel parts not subject to pressure.
8.4.5 Companion flanges of nozzles are part of the vessel only in exceptional cases, as expressly required in the Material Requisition.

8.4.6 Flanges according to ISO 27509, API 6A or designed according to ASME BPVC Section VIII should be supplied with companion flanges. [RECOMMENDED PRACTICE]

8.5 GASKETS, FACE FINISHING, STUDS AND NUTS

8.5.1 Gaskets, face finishing, studs and nuts of each flange shall be according to specification of piping or instrument connected to it.

Note: Flanges not connected to piping shall follow piping specification applicable to the section of the vessel where they are located.

8.5.2 The faces of ring type joint (RTJ) flanges shall have hardness 30 Brinell higher than the gasket.

8.5.3 All flanges shall be installed in such a position that the vertical line or N-S and E-W design lines pass through the middle of the space between 2 bolt holes.

8.5.4 When the face of nozzle flanges are of the tongue and groove type, the groove shall be located on the vessel nozzle flange, except when the face of the nozzle flange is facing down, in which case the tongue shall be located in the vessel nozzle flange.

8.5.5 Internal flanges of vessels shall be supplied with bolts (or studs), nuts and gaskets.

8.6 PIPING LOADS ON NOZZLES

The tables below list the design piping loads on nozzles of pressure vessels (including shell and tube heat exchangers) connected to process piping, when the piping loads are not furnished by a proper piping flexibility analysis.

The most stringent case caused by radial force “Frad” acting inward or outward shall be considered. See Figure 8.4.
Figure 8.4 – Nozzles Loads

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>Frad</th>
<th>Flong</th>
<th>Flang</th>
<th>Mtors</th>
<th>Mtang</th>
<th>Mlong</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N)</td>
<td>(N)</td>
<td>(N)</td>
<td>(N.m)</td>
<td>(N.m)</td>
<td>(N.m)</td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td>1200</td>
<td>1200</td>
<td>900</td>
<td>90</td>
<td>60</td>
<td>78</td>
</tr>
<tr>
<td>1 ¼&quot;</td>
<td>1500</td>
<td>1500</td>
<td>1120</td>
<td>141</td>
<td>94</td>
<td>122</td>
</tr>
<tr>
<td>1 ½&quot;</td>
<td>1800</td>
<td>1800</td>
<td>1350</td>
<td>203</td>
<td>135</td>
<td>176</td>
</tr>
<tr>
<td>2&quot;</td>
<td>2400</td>
<td>2400</td>
<td>1800</td>
<td>360</td>
<td>240</td>
<td>312</td>
</tr>
<tr>
<td>2 ½&quot;</td>
<td>3000</td>
<td>3000</td>
<td>2250</td>
<td>563</td>
<td>375</td>
<td>488</td>
</tr>
<tr>
<td>3&quot;</td>
<td>3600</td>
<td>3600</td>
<td>2700</td>
<td>810</td>
<td>540</td>
<td>702</td>
</tr>
<tr>
<td>4&quot;</td>
<td>4800</td>
<td>4800</td>
<td>3600</td>
<td>1440</td>
<td>960</td>
<td>1248</td>
</tr>
<tr>
<td>5&quot;</td>
<td>6000</td>
<td>6000</td>
<td>4500</td>
<td>2250</td>
<td>1500</td>
<td>1950</td>
</tr>
<tr>
<td>6&quot;</td>
<td>7200</td>
<td>7200</td>
<td>5400</td>
<td>3240</td>
<td>2160</td>
<td>2808</td>
</tr>
<tr>
<td>8&quot;</td>
<td>9600</td>
<td>9600</td>
<td>7200</td>
<td>5760</td>
<td>3840</td>
<td>4992</td>
</tr>
<tr>
<td>10&quot;</td>
<td>12000</td>
<td>12000</td>
<td>9000</td>
<td>9000</td>
<td>6000</td>
<td>7800</td>
</tr>
<tr>
<td>12&quot;</td>
<td>14400</td>
<td>14400</td>
<td>10800</td>
<td>12960</td>
<td>8640</td>
<td>11232</td>
</tr>
<tr>
<td>14&quot;</td>
<td>16800</td>
<td>16800</td>
<td>12600</td>
<td>17640</td>
<td>11760</td>
<td>15288</td>
</tr>
<tr>
<td>16&quot;</td>
<td>19200</td>
<td>19200</td>
<td>14400</td>
<td>23040</td>
<td>15360</td>
<td>19968</td>
</tr>
<tr>
<td>18&quot;</td>
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### Requirements for Pressure Vessels Design

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### PRESSURE VESSELS DESIGN

#### REQUIREMENTS FOR PRESSURE VESSELS DESIGN

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</tbody>
</table>
8.7 QUICK-ACTUATING CLOSURES

8.7.1 Quick-actuating (quick-opening) closures may be used only with previous PETROBRAS approval.

8.7.2 Swing bolts shall not be considered as a quick-opening closure.

9 SUPPORTS

9.1 GENERAL REQUIREMENTS

9.1.1 Each vessel shall have its own support and may not be supported by piping even in the case of small vessels.

9.1.2 Supports shall be designed in accordance with Part 4.15 of ASME BPVC Section VIII Division 2. For pressure vessels designed according to ASME BPVC Section VIII Division 1, PD 5500 may be used, except that allowable stresses shall in any case be according to ASME BPVC Section VIII Division 1.

9.2 VERTICAL VESSELS

9.2.1 Vertical vessels shall be supported by a cylindrical skirt.

9.2.2 A conical skirt with an angle not exceeding 30 degrees may be used only when one of the following conditions are satisfied:
   a) The vessel is supported at an intermediate level;
   b) Conical skirt is required to limit the overall deflection;
   c) Conical skirt is required to adequate spacing between anchor bolts.

9.2.3 The minimum thickness of support skirts is 6.3 mm.

9.2.4 Leg and lug supports shall be limited to vessels less than 1.8 meters in diameter, operating below 129ºC, and not in cyclic temperature service nor subjected to vibration.

9.2.5 The mean diameters of the shell bottom course must coincide to the mean diameter of the cylindrical skirt, or to the neutral axis of the leg.

9.2.6 Full penetration welds must be used for all support construction, for welding of the supports to the vessel and to the secondary supports structure.

9.2.7 Access to the bottom part of the vessel shall be possible at all times, and the minimum height of the support of vertical vessels shall be defined in accordance with the following criteria:
   a) the lowest point of the bottom head shall be at least 1 200 mm from the top of the skid base for vessels greater than 800 mm in diameter;
   b) the lowest point of the horizontal section of the piping connected to the bottom head shall be at least 300 mm from the top of the skid base.

9.3 VENTS AND OPENINGS IN SKIRT

9.3.1 Support skirts shall have at least one access opening. The minimum diameter shall be the same as specified in Table 8.2.
9.3.2 All opening in skirt shall be properly reinforced.

9.3.3 Support skirts shall have vents as close as possible to the junction with the head, in the amounts and diameters specified in Table 9.1.

Table 9.1 - Skirt Vents

<table>
<thead>
<tr>
<th>Vessel Internal Diameter, [mm]</th>
<th>Number of Vents</th>
<th>Vent Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 914</td>
<td>2</td>
<td>3” Sch. 40</td>
</tr>
<tr>
<td>915 – 1,830</td>
<td>4</td>
<td>3” Sch. 40</td>
</tr>
<tr>
<td>1,831 – 2,740</td>
<td>6</td>
<td>4” Sch. 40</td>
</tr>
<tr>
<td>2,741 – 3,660</td>
<td>8</td>
<td>4” Sch. 40</td>
</tr>
<tr>
<td>3,661 – 4,570</td>
<td>10</td>
<td>4” Sch. 40</td>
</tr>
<tr>
<td>4,571 – 5,490</td>
<td>12</td>
<td>4” Sch. 40</td>
</tr>
</tbody>
</table>

9.4 HORIZONTAL VESSELS

9.4.1 Horizontal vessels shall be supported by 2 metallic saddles covering at least 120° of the vessel circumference.

9.4.2 Saddles shall be placed symmetrically in relation to the midpoint of length between tangent lines.

9.4.3 One of the saddles shall always have elongated holes for anchor bolts, to accommodate vessel expansion.

9.4.4 Saddles shall be joined to the vessel shell by a continuous weld.

9.4.5 When the operating weight of vessel is greater than 200 kN (20 t) PTFE, or other low friction material, sliding plates shall be used in the mobile saddle in accordance with Figure 9.1.
Figure 9.1- Details of Saddle, Support Members and Sliding Plates

10 INTERNALS

10.1 GENERAL REQUIREMENTS

10.1.1 Internals to be supplied are defined in Material Requisition.
10.1.2 All internal dismountable parts shall be designed in such a manner that the maximum weight does not exceed 250 N (25 kgf), excluding major beams for supporting trays, gratings and similar parts. Dimensions shall also be such as to allow the easy passage through the manhole.

10.1.3 Internal bolts and nuts shall be made of a material not susceptible to attack by the operating fluid of the vessel. Stainless steel types 304 or 405 shall be required as a minimum.

10.1.4 Vortex breakers shall be placed in vertical nozzles located at bottom head connected to the suction line of pumps. Internal baffles shall also be placed in the upper nozzles of level instruments in vertical vessels, as well as impingement baffles in nozzles for inlet of liquid where impact of the liquid stream in internal parts or on the vessel wall is likely to occur.

Note: For horizontal nozzle connected to the suction line of pumps a device shall be foreseen in order to avoid vortex formation

10.1.5 Internal non-pressure pipes and accessories made of carbon-steel and low alloy steels (up to 6 % Cr) shall have the following minimum thicknesses and pressure classes:

a) pipes up to NPS 10: sch. 40;
b) pipes over NPS 10: 6 mm wall thickness;
c) threaded accessories: pressure rating class 2000.

10.1.6 Internal non-pressure high alloy steel pipes and accessories (11 - 13 % Cr or over) shall have the following minimum nominal thicknesses and pressure classes:

a) pipes up to 1 1/2": sch. 40S;
b) pipes over 1 1/2": sch. 10S;
c) threaded accessories: pressure class 2000.

11 EXTERNAL ACCESSORIES

11.1 GENERAL REQUIREMENTS

11.1.1 The following external parts are part of the vessel, as applicable:

a) reinforcement plates of nozzles and manholes;
b) reinforcement rings for vessels having thin walls or subject to external pressure;
c) support skirt, columns or lugs for towers and vertical vessels;
d) supporting saddles for horizontal vessels;
e) bars, studs, nuts or other devices for support and attachment of external thermal insulation;
f) attachment plates, lugs or beams for supporting piping, platforms, ladders or other structures;
g) bolts, clips, nuts or other elements for attachment of fire-proof lining;
h) supports for davits;
i) lifting eyes, lugs, plates or other parts required for moving the vessel or its parts during assembly or maintenance;
j) davits for covers of manholes and other blind flanges;
k) blind flanges with gaskets and bolts, for manholes, inspection holes and closed flanged nozzles;
l) Grounding lug, 6.3 mm thick, made of AISI 316, as per Figure 11.1.

![Figure 11.1 - Grounding Lug](image)

11.1.2 Vertical vessels having dismountable internal parts shall have a davit placed on top for moving these internal parts whenever the top of the vessel is more than 3000 mm from the ground.

11.1.3 For all vessels, ladders for access to the following points shall be provided:
   a) manholes whose centerline is more than 3000 mm from the ground;
   b) safety or relief valve;
   c) level instrument;
   d) instrument or equipment requiring local reading or operation or frequent inspection.

11.1.4 The supports shall be installed in accordance with recognized standard previously approved by PETROBRAS

12 FABRICATION

12.1 GENERAL REQUIREMENTS

12.1.1 Fabrication shall comply with ASME BPVC Section VIII and with I-ET-3010.00-1200-540-P4X-002 – REQUIREMENTS FOR PRESSURE VESSEL FABRICATION.

12.1.2 Welding shall comply with I-ET-3010.00-1200-955-P4X-001 – WELDING and with item 12.2.

12.2 WELDS

12.2.1 All welds subjected to pressure loads, in the shell and heads, shall be double-butt welded, full penetration and allow radiography. When the internal weld is impracticable, only the external weld may be done, adopting a method that guarantees the quality of the weld root, meeting the requirements in item 4.10.
12.2.2 Welds of nozzle necks and manholes in the shell shall also be of the full penetration type. When this provision is impracticable due to the high thickness of the wall, the welded connection design shall be submitted to PETROBRAS for previous approval.

12.2.3 Welds between materials having different “P-numbers” require previous approval by PETROBRAS.

Note: These welds, if approved, shall not be placed in contact with the fluid contained in the vessel nor placed in contact with pressure wall of the vessel.

12.2.4 The fabrication design of the vessel shall clearly indicate the location of all welds in the shell and heads of the vessel.

12.2.5 Welds of the shell and heads shall be arranged in such a manner as not to interfere with: vessel supports, welded internal, nozzles, manholes, nozzles and manholes reinforcements.

Notes:
1) Shell welds hidden by reinforcement plates require previous approval by PETROBRAS. If approved, they shall be ground, examined by magnetic particles or liquid penetrant and be fully radiographed.
2) Longitudinal welds of the shell on the bottom generatrix of horizontal vessels are not allowed.
3) Saddles shall be located in such a manner as not to interfere with the circumferential welds of the vessel and allow the inspection of these welds.

12.2.6 All welds shall be in such a position as to allow inspection without the need for dismounting the internal parts of the vessel.

12.2.7 For vertical vessels the weld of the skirt to the vessel shell shall be located so as not to interfere with the weld of the shell to the lower head and to allow inspection of this weld.

12.2.8 For vessels less than 2000 mm in internal diameter, only a single longitudinal weld per joint is allowed, or forged rings shall be used. For diameters equal to or greater than 2000 mm, commercial length plates shall be used and smaller plates shall only be allowed for adjustment purposes. In any case the longitudinal welds of adjacent rings shall be at least 45° apart from each other.

12.2.9 Welds of lifting lugs and similar devices shall be kept at a distance at least equal to that given in item 12.2.12 from major welds.

Note: If the interference is inevitable, PETROBRAS approval is required. In this case the shell weld shall be ground and examined by magnetic particles or liquid penetrant before the welding of the lifting lug.

12.2.10 All welds of parts externally attached to the vessel shall have a continuous weld fillet.

Note: Overlapping parts in vessels operating at a temperature equal to or greater than the ambient temperature shall have a 6 mm diameter hole.

12.2.11 All welds of parts internally attached to the vessel shall have a 10 mm weld bead interruption along the bottom part of the weld bead.
12.2.12 The distance between the edges of 2 full penetration and parallel welds, in any case, shall not be less than 3 times the thickness of the thinnest plate or 50 mm, whichever is larger.

12.2.13 The same corrosion allowance specified for the vessel shall be added to the minimum dimension of the throat of the fillet welds. Full fillet welds to which this addition is already a result of the weld geometry are an exception to this rule.

12.3 POSTWELD HEAT TREATMENT

In the mechanical design of pressure vessels, the PWHT indicated in code ASME BPVC Section VIII or by vessel service shall be specified and required. The additional requirements of items Erro! Fonte de referência não encontrada. to 12.3.4 shall apply.

12.3.1 Table UCS-56.1 and Table 6.16 of ASME BPVC Section VIII Division 1 and Division 2 respectively shall not be applicable.

12.3.2 The PWHT between dissimilar materials shall meet the requirements of the material requiring more restrictive conditions and shall be verified by procedure qualification tests. PWHT between ferritic and austenitic materials shall be approved by PETROBRAS.

12.3.3 Localized PWHT may only be carried out according procedure approved by PETROBRAS.

12.3.4 The maximum temperature for PWHT shall not affect mechanical properties of material nor exceed the lower of the following values:

a) the maximum temperature specified in the applicable code;

b) the tempering temperature, in case the component has been subjected to such treatment at the plant.

Note: Higher temperatures require PETROBRAS approval, and in this case mechanical properties shall be guaranteed by tests performed in the test specimens after the simulated heat treatment.

13 INSPECTION

13.1 RADIOGRAPHIC EXAMINATION

13.1.1 The type of radiographic test to be performed on the welded joints of the vessel should follow what was established in the vessel design according to item 4.10.

13.1.2 The ultrasonic examination may be used in lieu of radiographic examination for vessels designed according to ASME BPVC Section VIII only with PETROBRAS approval and all requirements of Code Case 2235 of ASME BPVC are met for Division 1 and all requirements of item 7.5.5. are met for Division 2.

13.1.3 The ultrasonic examination may be used in lieu of radiographic examination for vessels designed according to item 7.5.5. of ASME BPVC Section VIII Division 2 only with PETROBRAS approval.

13.2 OTHER NONDESTRUCTIVE EXAMINATIONS
13.2.1 Fabrication design shall include other nondestructive examinations required by I-ET-3010.00-1200-540-P4X-002 – REQUIREMENTS FOR PRESSURE VESSELS FABRICATION.

13.2.2 In following cases the pressure vessel shall be fully examined by MT or PT:

a) Vessel subjected to cyclic service;
b) Vessel subjected to stress corrosion crack;
c) When required by vessel service.

13.3 VISUAL EXAMINATION

Visual examination shall conform to REQUIREMENTS FOR PRESSURE VESSELS FABRICATION: I-ET-3010.00-1200-540-P4X-002.

13.4 DIMENSIONAL INSPECTION

Dimensional inspection shall conform to REQUIREMENTS FOR PRESSURE VESSELS FABRICATION: I-ET-3010.00-1200-540-P4X-002.

14 ASSEMBLY

Pressure vessel assembly shall conform to REQUIREMENTS FOR PRESSURE VESSELS FABRICATION: I-ET-3010.00-1200-540-P4X-002.

15 TAGGING

Pressure Vessels tagging shall be according latest revision of I-ET-3000.00-1200-940-P4X-001 - TAGGING PROCEDURE FOR PRODUCTION UNITS DESIGN.

16 PRESSURE TEST

16.1 GENERAL REQUIREMENTS

16.1.1 The MAP (new and cold) and the MAWP shall be calculated and indicated on vessels drawings. Test pressure shall be calculated according to ASME BPVC Section VIII.

16.1.2 Due to the high risks involved, the pneumatic test shall only be allowed in exceptional cases, which shall be previously approved by PETROBRAS.

Note: When a vessel is pneumatically tested, all welds shall be fully radiographed and the welds of the skirt, nozzles and lugs shall be fully examined by magnetic particles or liquid penetrant before the test

16.1.3 Requirements of fabrication shall be fulfilled according to I-ET-3010.00-1200-540-P4X-002 – REQUIREMENTS FOR PRESSURE VESSELS FABRICATION.

17 NAMEPLATE

17.1 GENERAL REQUIREMENTS
17.1.1 Nameplate shall be made of AISI 316 stainless steel plate with a minimum thickness of 1.5 mm.

17.1.2 All the pressure vessels shall have an identification plate containing at least the information shown in Figure 17.1.

![Figure 17.1 - Nameplate (for translation of terms see Figure 17.2)](image)

17.1.3 The model given in figure above seeks to guide the PACKAGER / MANUFACTURER as to the layout of the minimum data that shall obligatorily figure on the plate; in case necessary, at the discretion of the manufacturer, or as required in the vessel materials requisition, the plate may have other additional data.
17.1.4 The plate shall be situated on the cover of the lower inspection cover of the vessel, or in another visible and easily accessible location. The localization of the identification plate shall be defined in the vessel manufacturing drawing.

17.1.5 For fixation there shall be used Ø 5/16” x 5/8” screws made of stainless steel or tin, with a six sided nut and a washer in a Ø 8.5 mm holes as shown in the drawing. In vessels with thermal insulation or with any other external cladding, the identification plate shall be fixed to a support welded to the body of the vessel, in a manner that it stands out well from the external surface of the insulation or cladding.

Figure 17.2 - Translation of Terms Used in Figure 17.1
17.1.6 The characters shall be engraved or stamped and shall have a minimum dimension of 3 mm.

17.1.7 Nameplate shall fastened at a visible and accessible place

*NOTES:

NOTE 1: Dimension in mm.

NOTE 2: The units shall be completed in the international system and in the technical system.

NOTE 3: The language to be used for engraving all nameplate information shall be Portuguese. For translation of the terms see Figure 17.2.

NOTE 4: Equipment Identification (Tag Number). It shall be engraved as mentioned on Process Data Sheet, P&ID and Equipment List.

NOTE 5: The year of the edition of the design code/standard adopted shall be shown.

NOTE 6: When applicable

NOTE 7: The minimum temperature of water for hydrostatic testing of the equipment shall be determined according to I-ET-3010.00-1200-540-P4X-002 - REQUIREMENTS FOR PRESSURE VESSELS FABRICATION

NOTE 8: The hydrostatic pressure test for a new vessel shall be determined according to the ASME SECTION VIII standard Hydrostatic Test.

NOTE 9: Show the equipment position and equipment point where the hydrostatic pressure test is measured (e.g. vertical position/ at the top)

NOTE 10: The Maximum Allowable Working Pressure (MAWP) shall be determined using the nominal vessel thicknesses, without the corrosion allowance, and the allowable stress value in the working temperature.

NOTE 11: In this space shall be written “SERVIÇO COM HIDROGÊNIO” (service with hydrogen) or “SERVIÇO COM H₂S “(service with H₂S) when applicable.

NOTE 12: In this space shall be inscribed the requirements for the hydrostatic test water.