PETROBRAS | N-253 | REV. M | ENGLISH | 10 / 2023

Pressure Vessel Design

Procedure

This Standard replaces and cancels its previous revision.

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS System that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

Technical Requirement: A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS System that uses this Standard. It is characterized by imperative nature.

For adoption of the Standard, the effective deadline for implementation to replace the previous review is up to 180 days from the date of its publication. If the Department of PETROBRAS System that is applying the Standard understands that it is not possible to implement it within this period, it must register an Implementation Plan within 180 days defining the necessary actions and the respective deadlines.

The definition of the effective deadline for implementing the requirements of this Standard, when it is referenced in contracts for the provision of services and acquisition of goods, is the exclusive prerogative of PETROBRAS.

Recommended Practice: A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the specific application. The alternative adopted shall be approved and registered by the Department of PETROBRAS System that uses this Standard. It is characterized by verbs of a nonmandatory nature. It is indicated by the expression: **[Recommended Practice]**.

For the continuous improvement of the Standard, copies of the records of technical-managerial decisions prepared by the Departments of PETROBRAS System that may contribute to the improvement of this Standard are requested to be sent to the Authoring Subcommittee.

CONTEC
Comissão de Normalização Técnica

SC - 02
Tanks and Pressure Vessels

Introduction

The PETROBRAS Technical Standards are prepared by Working Groups (WG), formed by experts from the PETROBRAS System, commented and voted on by the PETROBRAS System Units and approved by the Authoring Subcommittees (SC). The PETROBRAS Technical Standard is subject to review at any time by the SC and must be re-analyzed every 5 years to be revalidated, revised or canceled. PETROBRAS Technical Standards are prepared in accordance with PETROBRAS Technical Standard N-1. To see the collection, see PETROBRAS Technical Standards Catalog. (click here)

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Foreword

This Standard is the English version (issued in 04/2024) of PETROBRAS N-253 REV. M 10/2023. In case of doubt, the Portuguese version, which is the valid document for all intents and purposes, shall be used.

1 Scope

1.1 This Standard establishes the technical conditions required for the execution of the Mechanical Design and the Fabrication Design of Pressure Vessels used in refineries, petrochemical units, terminals, pipeline stations, onshore production stations, offshore production platforms and other similar installations.

1.2 This Standard is based on ASME BPVC Section VIII Division 1 and 2 and presents the supplementary requirements to be followed in the mechanical and fabrication design of pressure vessels for PETROBRAS.

1.3 The design of pressures vessel executed according to other internationally accepted standards or design codes is allowed only when previously approved by PETROBRAS.

1.4 When the pressure vessel is an integral part of steam generation equipment it shall be designed and built in accordance with the requirements of ASME BPVC Section I.

1.5 When the design is carried out in accordance with a standard or code other than ASME BPVC Section VIII, the construction shall be fully carried out in accordance with the adopted standard or code, and this code shall be used when applicable.

1.6 Other technical requirements not mentioned in this Standard, if necessary, shall be followed according to the specific application and service of the vessel, such as, service with H2, service with H2S, equipment with internal coating, equipment with toughness requirements and others.

NOTE When designing vessels for service with aqueous sodium hydroxide solution (caustic soda), NACE SP0403 shall be followed.

1.7 Serial production (mass production) of pressure vessels in compliance with INMETRO Regulation are not part of the scope of this standard.

1.8 This revision of this Standard does not apply to procedures initiated before this publication.

1.9 This Standard contains Technical Requirements and Recommended Practices.

2 Normative References

The documents listed below are essential for the application of this document. For dated references, only the mentioned editions apply. For undated references, the most recent editions of the aforementioned documents are applied.

NR-13 - Caldeiras, Vasos de Pressão, Tubulações e Tanques Metálicos de Armazenamento;

PETROBRAS N-266 - Presentation of Pressure Vessel Design;

PETROBRAS N-268 - Pressure Vessel Fabrication;

PETROBRAS N-269 - Pressure Vessel Assembly;

PETROBRAS N-1521 - Identification of Industrial Equipments;

PETROBRAS N-2054 - Acessório Externo de Vaso de Pressão;

ABNT NBR 6123 - Forças devidas ao Vento em Edificações;

ASME B16.5 - Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard;

ASME B16.11 - Forged Fittings, Socket-Welding and Threaded;

ASME B16.47 - Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard;

API RP 571 - Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

API STD 618 - Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services;

ASME BPVC Section I - Boiler and Pressure Vessel Code - Section I: Rules for Constructions of Power Boilers;

ASME BPVC Section II Part D - Boiler and Pressure Vessel Code - Section II: Materials - Part D: Properties;

ASME BPVC Section VIII Division 1 - Boiler and Pressure Vessel Code - Section VIII: Rules for Construction of Pressure Vessels - Division 1;

ASME BPVC Section VIII Division 2 - Boiler and Pressure Vessel Code - Section VIII: Rules for Construction of Pressure Vessels - Division 2: Alternative Rules;

NACE SP0403 - Avoiding Caustic Stress Corrosion Cracking of Carbon Steel Refinery Equipment and Piping;

BSI PD 5500 - Specification for Unifired Fusion Welded Pressure Vessels;

ISO 12944-2 - Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments;

ISO 21457 - Petroleum, petrochemical and natural gas industries - Materials selection and corrosion control for oil and gas production systems

TEMA - Standards of Tubular Exchanger Manufacturers Association;

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

3 General Conditions

3.1 Drawings and other pressure vessel design, fabrication and assembly documents shall comply with PETROBRAS N-266.

3.2 The nomenclature adopted in this Standard is in accordance with PETROBRAS N-266.

3.3 The vessel design shall be in accordance with ASME BPVC Section VIII Division 1 and, when required by PETROBRAS, the vessel design shall be in accordance with ASME BPVC Section VIII Division 2.

3.4 Stresses due to concentrated loads may be analyzed, when applicable, by the following methods:

a) Finite Element Analysis (FEA);
b) in accordance with Annex G of BSI PD 5500:2009;
c) in accordance with WRC Bulletin 537 and/or WRC Bulletin 297, as long as it meets its usage limitations.

3.5 When there are divergences between standards and other documents, the following precedence order shall be observed:

a) basic drawings of the pressure vessel, Data Sheet or other specific document for the pressure vessel;
b) this Standard;
c) other standards referenced to in this Standard.

NOTE In case of doubt, PETROBRAS shall be consulted beforehand.

4 Design Criteria

4.1 Basic Allowable Stresses

4.1.1 For pressurized parts, the values tabulated in ASME BPVC shall be adopted ASME BPVC Section II Part D prescribed by ASME BPVC Section VIII.

NOTE In cases where there is a need for stress analysis in a vessel component designed by ASME BPVC Section VIII Division 1, such analysis shall be carried out in accordance with Part 5 of ASME BPVC Section VIII Division 2 using the basic allowable stress corresponding to the ASME BPVC Section VIII Division 1.

4.1.2 For welds connecting non-pressurized parts with pressurized parts, such as main internal supports, the allowable stress values for pressurized parts shall be considered.

4.1.3 Carbon steel anchor bolts shall be calculated with a basic allowable stress of 98 MPa (1,000 kgf/cm2), based on the root area. For the assembly condition, a maximum allowable stress of 118 MPa (1 200 kgf/cm^2).

4.1.4 For flanges, tubesheet and other parts of the vessel, made of austenitic stainless steels, which may be subject to leakage or malfunction due to small permanent deformations, the lower value of the two allowable stresses available in the table shall be adopted of the ASME BPVC Section II Part D.

4.2 Design Conditions

4.2.1 Unless when otherwise specified by PETROBRAS, design conditions, pressures and temperatures shall be determined in accordance with ASME BPVC Section VIII.

4.2.2 The minimum design temperature to be used in the calculations, when not indicated in the basic design, shall be determined as -2°C or the lowest average daily temperature in the region where the vessel is installed, plus 8°C, whichever is lower.

4.2.3 The design calculations of the vessels or part of the vessels, subject to vacuum whether in normal, abnormal or transient operating regimes, shall be calculated at least, for the total vacuum situation, regardless of the pressure differential value, except when expressly specified in otherwise by PETROBRAS.

4.2.3.1 Abnormal or transient non-operational conditions, such as “steam-out” (cleaning with steam), shall not be considered when sizing for the vacuum condition. This shall be addressed by specific execution procedures.

4.3 Load Cases

4.3.1 All pressure vessels designed in accordance with ASME BPVC Section VIII Division 1, including support structures, shall be checked for the following conditions:

a) I - assembly;
b) II - test;
c) III - normal operation;
d) IV - shutdown.

NOTE Pressure vessels designed in accordance with ASME BPVC Section VIII Division 2, including support structures, shall follow the loading conditions and their combinations established there.

4.3.2 The applied loads, allowable stresses values and thicknesses that shall be considered for each of the conditions in 4.3.1 are described in Table 1.

Table 1 – Loads Cases Applicable to Vessels Designed According to ASME BPVC Section VIII Division 1

Case	Loads	Allowable tensile membrane stresses (see Note 7)	Thicknesses
I - Assembly	Simultaneous consideration of the following loads: a) vessel dead weight (see Note 1); b) loads due to the action of wind or earthquake (see Note 2).	Allowable stresses increased by 20% of the tables referring to ASME BPVC Section VIII Division 1 for the vessel material at ambient temperature.	Nominal plate thicknesses. (see Note 6)
II - Test	Simultaneous consideration of the following loads: a) internal pressure of hydrostatic test; b) weight of the vessel completely fully filled with water (see Note 1); c) weight of all permanent loads supported by the vessel during the test (see Note 3).	The maximum stress shall not exceed 90 % of the material Yield Stress at ambient temperature. For nonpressure parts, a 33.3 % increase in the basic allowable stress may be considered.	Nominal thicknesses and corroded thicknesses. (see Note 6)
III - Normal Operation (see Note 5)	Simultaneous consideration of the following loads: a) internal or external design pressure at design temperature; b) weight of the fluid at the operating level; c) self-weight of the vessel; d) weight of all permanent loads supported by the vessel (see Note 4); e) loads due to the action of wind or earthquake (see Note 2).	Allowable stresses from the tables referring to ASME BPVC Section VIII Division 1 for vessel material at design temperature. (see Note 7).	Corroded thicknesses, that is, nominal thicknesses minus corrosion allowance. (see Note 6)

Table 1 - Loads Cases Applicable to Vessels Designed According to ASME BPVC Section VIII Division 1 (Continuation)

Cases	Loads	Allowable tensile membrane stresses (see Note 7)	Thicknesses
IV - Shutdown	Simultaneous consideration of the following loads: a) vessel dead weight; b) weight of all permanent loads supported by the vessel (see Note 4); c) loads due to the action of wind or earthquake (see Note 2).	Allowable stresses increased by 20% from the tables referring to ASME BPVC Section VIII Division 1 for the vessel material at ambient temperature.	Corroded thicknesses. (see Note 6)

NOTE 1 Includes the shell and welded accessories; Excludes removable external and internal accessories.
NOTE 2 Wind loads do not need to be considered for the design of horizontal vessels; however, they shall be considered in the design of their foundations and structures.
NOTE 3 Excludes internal or external thermal insulation.
NOTE 4 Includes removable internals, internal or external thermal insulation, external accessories and piping systems.
NOTE 5 In special cases, at the designer's option, it may be necessary to consider under condition III the simultaneous effect of other active loads, such as thermal expansion of the pressure vessel itself, thermal expansion of piping systems and other structures connected to the pressure vessel, pressure fluctuations, dynamic loads caused by internal fluid movement and vibrations.
NOTE 6 For parts whose thickness is reduced during the fabrication process, the minimum thicknesses expected shall be considered.
NOTE 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 or according to WRC Bulletin 443 (in the case of a pressure vessel design temperature above 482 °C for vessels with a carbon steel and low alloy steel support skirt, and 649° C for vessels with austenitic stainless steel support skirt).

4.3.3 Effects of Wind Loading

4.3.3.1 Wind Loads (static and dynamic) shall be calculated in accordance with ABNT NBR 6123. The effect of wind induced vibrations on vertical vessels shall be considered in the direction of the wind and in the direction perpendicular to the wind.

4.3.3.2 For vessels installed in offshore structures, another standard with international recognition may be applied if previously approved by PETROBRAS.

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

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

4.3.4 Occasional Short-Term Operating Conditions and Emergency Conditions

4.3.4.1 Any short-term operating conditions foreseen in the equipment process design shall be considered and analyzed individually when sizing the vessel. Emergency conditions shall also be considered when sizing the vessel. Some examples of these emergency conditions:

a) emergency depressurization of low molecular weight gases, causing lowering of the temperature on the vessel wall;
b) Gas deflagration inside equipment generating over pressure (see appendix H of ASME BPVC Section VIII Division 1);
c) temperature trips (“runaway”) of hydrotreatment reactors.

4.3.4.2 It is not necessary to consider the simultaneous occurrence of 2 loads resulting from short-term events, unless otherwise defined in the basic project.

4.3.4.3 Wind and earthquake loads do not need to be combined with short-term loads.

4.3.4.4 For non-pressurized parts, the basic allowable stress may be increased by 33.3%.

4.4 Pressure Vessels Subjected to Cyclic Loading

All pressure vessels subjected to cyclic loading defined by the basic design, even those designed by ASME BPVC Section VIII Division 1, shall have assessed the need for fatigue analysis assessed, according to the criteria for assessing the need for fatigue analysis in ASME BPVC Section VIII Division 2 (Screening criteria for fatigue analysis).

NOTE 1 Examples of pressure vessels subjected to cyclic loadings: adsorption vessels of the PSA system, coke drum reactors, pulsation dampening equipment, intercoolers, and aftercoolers belonging to reciprocating compressor systems.
NOTE 2 Equipment belonging to reciprocating compressor systems and their interconnections shall also comply with the requirements of API STD 618 and 12.2.2 of this Standard.
NOTE 3 Heat exchangers of the lubrication system, when the compressor is located in hazardous locations, shall comply with TEMA class “R”; in other locations TEMA class “C” is admitted for that heat exchanger.

4.5 Service Life

Unless otherwise specified by PETROBRAS, the minimum values from Table 2 shall be considered for service life of pressure vessels. These service lifetimes shall be used as a basis for material selection, determination of corrosion and erosion allowance, fatigue and creep deformations calculations, and any other time-based criteria. When it is technically or economically unfeasible to meet these service lifetimes, PETROBRAS shall be consulted in advance to decide in each case.

Table 2 – Service Life of Pressure Vessels

Equipment classes	Refineries, terminals, and other non-petrochemical facilities	Petrochemical units
Reactors, Columns, Vessels and Heat Exchangers	20 years	15 years
Removable or replacement parts (tube blundle, removable columns internals, and others).	8 years	5 years
NOTE For equipment not included in Table 2, PETROBRAS shall be previously consulted.		

4.6 Maximum Allowable Working Pressure – MAWP

It is mandatory to calculate the MAWP ("Maximum Allowable Working Pressure") and indicate the part of the vessel that limits this pressure. MAWP is the maximum allowable pressure calculated for corroded and hot condition, that is, corroded component thicknesses with the vessel at design temperature.

4.7 Radiographic Efficiency of Welded Joints

For calculating the thickness of any pressurized pressure vessel component designed in accordance with ASME BPVC Section VIII Division 1, the radiographic examination to be chosen for welded joints shall be at least spot radiography, such as specified in paragraphs UW-11 and UW-12 of ASME BPVC Section VIII Division 1 and described in paragraph UW-52 (Spot Examination of Welded Joints) of ASME BPVC Section VIII Division 1. Therefore, non-radiographed welds for pressurized components are not permitted for pressure components of pressure vessels, even in cases where ASME BPVC Section VIII Division 1 allows this type of welding. In the case of a pressure vessel designed by ASME BPVC Section VIII Division 2, the criteria for using spot radiography shall comply with tables Table 7.1 and Table 7.2 of said code.

NOTE 1 When required by the service (see 1.6) in which the vessel is included, the vessel shall be examined by full radiography.
NOTE 2 Vessel subject to cyclic service shall be designed to be examined by full radiography.

5 Materials

5.1 Material for construction of shells, heads, and other pressure parts shall conform to the specifications given in ASME BPVC Section II Part D and those permitted in Section VIII. However, ASTM materials are allowed, provided the deviations are described in detail and submitted to PETROBRAS for prior approval.

5.2 The acceptance of materials equivalent to those in the ASME code, or in accordance with other standards, is subject to prior approval by PETROBRAS, and materials not listed in the ASME code shall be included in specifications from internationally recognized standardization societies (examples: BS, DIN, JIS etc.). In these cases, the proponent shall present the complete text of the proposed specification in Portuguese or English containing the necessary tests for material requalification, in accordance with the ASME code.

5.3 Materials listed in the current ASME Code Cases may be used, as long as they are previously approved by PETROBRAS.

5.4 It is recommended for the steels of pressurized parts to have a carbon content of no more than 0.30%, and for the shell and head plates, the carbon content of no more than 0.26%. Steels with a carbon content higher than the above limits can only be used in the following cases:
[Recommended Practice].

a) non-welded parts, such as: blind flange, flat heads heat exchanger and manhole cover;
b) plates with thickness greater than 50 mm.

5.5 The use of steels containing alloy elements other than manganese and silicon, and/or with ultimate tensile strength greater than 485 MPa (70 kpsi) (nominal value given in the material specification), as well as quenched and tempered steels is subject to prior approval from PETROBRAS.

5.6 Regardless of the temperature limits established in ASME BPVC Section II Part D for use in ASME BPVC Section VIII, the materials indicated in Table 3 should, in principle, only be used in continuous

service at temperatures up to the limits given in Table 3. Use at higher temperatures is permitted for occasional and short-time conditions when there is no technically or economically viable alternative. In any case, prior approval from PETROBRAS is required. The limits for pressurized parts are mainly based on the mechanical strength (creep resistance) of the material. Limits for non-pressurized parts are based on the scaling temperature of the material.

Table 3 - Temperature Limits

Materials	Maximum operating temperature (°C)	
	Pressure parts	Non-pressure parts
Structural quality carbon-steels (see Note 1).). (examples as per ASME BPVC Section II Part A: SA-36, SA-283, SA-572 and others).	150	530
Unkilled carbon steels (qualified materials) (see Note 1).	400	530
Killed carbon steel with Si. (see Note 1).	450	530
1 1/4 Cr - 1/2 Mo alloy steels.	530	550
2 1/4 Cr -1 Mo alloy steels.	530	570
2 1/4 Cr -1 Mo -V alloy steels.	482	482
5 Cr – 1/2 Mo alloy steels.	480	600
405, 410, 410S stainless steels (see Notes 2 and 5).	480	700
304, 316 stainless steels (see Notes 3, 4 and 5).	600	800
304L, 316L stainless steels (see Note 5).	400	800
310 stainless steels (see Notes 4 and 5).	600	1 100

NOTE 1 Extended exposure above 425 ºC may cause graphitization in the carbon steel.

NOTE 2 These materials are susceptible to embrittlement when operating at around 475 °C for long periods of time.

NOTE 3 For design temperatures above 550 °C, the use of “H” type stainless steels is recommended. **[Recommended Practice]**

NOTE 4 Attention is drawn to the possibility of “Sigma Phase” formation, for temperatures between 538 °C and 954 °C, resulting in severe material embrittlement. Such change in the metallurgical structure mainly occurs for type 316 and 310 steels.

NOTE 5 Attention is drawn to the possibility of sensitization occurring in stainless steels. There shall be assessed limit temperatures and times required for this phenomenon to occur.

5.7 Table 4 shows the basic criteria for specifying materials for the different parts of pressure vessels. These criteria shall be met, except when otherwise specified for a particular vessel. The classes of vessel parts mentioned in the first column of Table 4 are described in 5.7.1 to 5.7.6.

Table 4 – Criteria for Specification of Materials of Pressure Vessel Components

Class of vessel part under consideration	Basic vessel material		
	Carbon steel	Low temperature carbon steel	Alloy steels, stainless steels, and nonferrous metals
I	Same material as for shell.	Same material as for shell	Same material as for shell.
II	Same material as for shell.	Same material as for shell.	Material with the same 'P-Number' as the material of the shell.
III	Structural quality carbon steel.	Carbon steel for low temperatures.	Material with the same 'P-Number' as the material of the shell. (See Note)
IV	Materials specified for each case.	Materials specified for each case.	Materials specified for each case.
V	Structural quality carbon steel.	Structural quality carbon steel.	Structural quality carbon steel.
VI	Structural quality carbon steel.	Structural quality carbon steel.	Material with the same 'P-Number' as the material of the shell.
NOTE The same material used for the shell shall be adopted whenever it is required for corrosion-resistance reasons.			

5.7.1 Class I

Parts of the vessel pressure wall in contact with the process fluid (shells, heads, nozzle necks, flanges, blind flanges and others) and other pressurized parts in contact with the process fluid (for example: tubesheets). This class also includes the internal parts welded to the vessels and subjected to main stresses (rings, plates and other support elements for trays, grids, internal heads, and others). This class also includes reinforcements (of any type) of openings in the vessel's pressure wall.

5.7.2 Class II

Parts of the vessel pressure wall not in contact with the process fluid. Examples: external reinforcements, vacuum reinforcements and others. Reinforcements of openings are excluded from Class II, as they are included in Class I.

5.7.3 Class III

Internal parts welded to the vessel, but not subject to major stresses (baffles, deflectors, vortex breakers, weir plates and others). External parts welded to the vessel, subjected to stress in operation, such as: support of any type (skirts, columns, saddles and others), support elements for ladders, platforms, external pipes, external reinforcements, vacuum reinforcements and others. For supports, this class includes only those parts of the supports directly welded to the vessel or very close to the vessel.

NOTE The support skirt shall have a section at least 1 000 mm long from the attachment to the vessel with the same material specification as the shell, in the following cases:

a) design temperature of 15 °C or below, including additional requirements;
b) design temperature above 340 °C;
c) pressure vessels made of alloy steels, stainless steels, and nonferrous materials
d) hydrogen services (see 1.6).

5.7.4 Class IV

Removable internal parts (not welded to the vessel), such as: trays, bubblers, grids, support beams, distributors, tube bundles and others.

5.7.5 Class V

Parts of supports of any type not included in classes III and VI. For all parts of this class the design temperature is always the room temperature.

5.7.6 Class VI

External parts, directly welded to the vessel, but subjected to loads only in assembly, maintenance, disassembly and others, such as: lifting lugs, davits, and others. For all parts of this class the design temperature is always the room temperature.

5.8 The specification of materials for the vessel components, the definition of the need or not for impact tests and heat treatment, as well as the temperature and energy of the impact test, shall be carried out by the mechanical design based on the information from the basic design.

5.9 The specification of materials for vessels with low temperature conditions, including welding consumables, shall meet the requirements of the ASME code, not only in the shells and heads but also, mandatory, in all other parts subjected to pressure, such as: flanges, necks, coupling, bolts, nuts and others.

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

5.11 The use of casting steel in pressure vessels is not permitted by PETROBRAS.

5.12 The use of plate materials in pressurized parts according to paragraph UCS-6 (b) of ASME BPVC Section VIII Division 1, such as SA-36 and SA-283, is only acceptable if, in addition, all of the following conditions are met:

a) equipment working with fluids that are not classified in classes A, B or C of NR -13;
b) equipment without the need for heat treatment;
c) pressure vessel without impact test requirements;
d) pressure rating class 150.

5.13 Material for bolts, nuts and washers

5.13.1 In environments classified as C5M by ISO 12944-2, the requirements of ISO 21457 shall be met.

5.13.2 The use of 300 series austenitic stainless steel bolts and nuts with galvanized coating is not permitted. For other metal/coating pairs, the item referring to “liquid metal embrittlement” (LME) of API RP 571 should be consulted.

5.13.3 The use of bolts, nuts and washers coated with zinc or nickel is not permitted, except when previously approved by PETROBRAS.

6 Thicknesses

6.1 The thicknesses indicated in the drawings are the minimum thicknesses of the plates that shall be adopted for vessel fabrication. The manufacturing tolerances of plates (under tolerances) need not be considered as long as the plates comply with the following paragraphs of the ASME BPVC Section VIII:

a) UG-16 for vessels designed by ASME BPVC Section VIII Division 1;
b) 4.1.3.2 for vessels designed by ASME BPVC Section VIII Division 2.

6.2 For formed heads and other forming or formed parts, an adequate increase in the thickness of the plates shall be foreseen, to compensate for the loss of thickness during pressing or forming, so that the final thickness of the finished part has, at least, the value calculated or the value shown in the drawings.

6.3 In vessels where different plate thicknesses are provided for the different shells height, the designer is allowed to modify these thicknesses further, in order to adjust the heights of the shells to the commercial dimensions of the plates.

6.4 An adequate corrosion allowance shall always be added for corrosion, except when:

a) there is an appropriate anti-corrosive internal coating;
b) corrosion is non-existent or negligible.

NOTE In either case, prior approval from PETROBRAS is required.

6.5 Corrosion allowances shall be based on the service life, as specified in this Standard. As a general rule, when the expected corrosion rate is greater than 0.3 mm/year or when the corrosion allowance results in a value greater than 6 mm, the use of other materials that are more resistant to corrosion shall be economically evaluated.

6.6 A minimum corrosion allowance of 1.5 mm shall be adopted for carbon steel or low alloy steel vessel components, even when the estimated corrosion rate results in a lower value.

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

a) Columns, vessels and heat exchangers in general for services with hydrocarbons: 3 mm;
b) accumulation pots (sumps) for the above vessels: 6 mm;
c) vessels in general for steam and air: 1.5 mm;
d) pressurized liquefied gas storage vessels and spheres: 1.5 mm.

6.8 The criteria in Table 5 shall be adopted for the application of corrosion allowance.

Table 5 – Corrosion Allowance Application Criteria

Pressure vessel parts	Criteria
Parts of the pressure containing wall in contact with the process fluid: shells, heads, nozzle necks, tubesheets, flanges, blind flanges, and others.	Add the full value of the corrosion allowance on each face of the component in contact with the fluid.
Non-removable internal parts subjected to primary loads: tray supports, bed supports, lifting lugs, welded trays and others	Add the total corrosion allowance value on each surface of the part in contact with the fluid.
Non-removable internal parts and not subject to loads: deflectors, vortex breakers, baffles and others.	Add one-half of the corrosion allowance value to each surface in contact with the fluid.
Removable internal parts subject to loads (excluding trays and their accessories): beams, tie rods and other supporting parts.	

6.9 Regardless of the value calculated for the thickness, in carbon steel and low alloy steel vessels, shells and heads shall have a minimum thickness after fabrication equal to the higher of the two values given below:

a) $t_{mín}$ = 4,8 mm;
b) $t_{mín}$ = 2,5 + 0,001 Di + C.

Where:

t_{min} = is the minimum thickness, mm;
Di = is the inside diameter, mm;
C = is the corrosion allowance, mm.

6.10 In vessels made of stainless steel and non-ferrous metals, the minimum corroded thickness shall not be less than 2 mm.

6.11 Except when expressly specified otherwise, the alignment of plates of different thicknesses on the shell or heads of the vessel, shall be done on the internal surface.

7 Heads and Transition Sections

7.1 Heads shape shall be one of the those accepted by ASME BPVC Section VIII.

7.2 For welded flat heads of ASME BPVC Section VIII Division 1, the types shown in Figures UW-13.2 (a), (b), (c), (e) and (f) are permitted. For Welded Flat heads of ASME BPVC Section VIII Division 2 all types shown in Table 4.2.6 are supported.

7.3 Ellipsoidal or torispherical heads shall have a ratio between semi-axes of 2:1. Torispherical heads, known as “false ellipse”, may be calculated as ellipsoidal head.

NOTE 1 Torispherical head known as “false ellipse”: It is the torispherical head that has a toroidal section with an internal radius equal to 0.173 D and a spherical central cap with an internal radius equal to 0.904 D, with D being the internal diameter of the vessel.

NOTE 2 The use of a torispherical head with another relationship between the semi-axes shall be submitted to PETROBRAS for approval.

7.4 Ellipsoidal or torispherical heads made of carbon steel and low-alloy steel, with an internal diameter of up to 1,800 mm, shall be constructed in a single piece, without welding. For torispherical heads with an internal diameter greater than 1,800 mm and for cladded heads or in other materials other than carbon steel and low alloy steel of any diameter, Figure A.1 shows some permitted and unacceptable weld arrangements. Except for welds in a radial position, welds entirely in the toroidal region of the head are not permitted. In radial section construction, the central crown shall not have a radius of less than 20% of the radius of the head.

NOTE For a vessel designed per ASME BPVC Section VIII Division 2, Figure 4.3.3 of the said code is acceptable for any diameter of torispherical head.

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

7.6 The skirt or legs supports of a vertical vessel shall not be welded to a conical section of the shell.

8 Nozzles and Other Openings

8.1 General Requirements

8.1.1 In all vessels, or in any vessel compartment, that are not completely drainable through piping, a drain nozzle is mandatory, for complete internal drainage. Drain nozzles that require a welded elbow in their arrangement shall have a minimal diameter NPS 2”.

8.1.2 Vessels shall have at least the number of manholes or inspection openings in each pressurized compartment, as shown in Table 6.

Table 6 – Pressure Vessel Manholes and Inspection Opening

Inside vessel diameter (mm)	Vessels with internals	Vessels without internals
DI ≤ 10”	Flanged top head.	two NPS 2” inspection openings.
10” < DI ≤ 815 mm	Flanged top head (see Note).	two NPS 4” inspection openings
DI > 815 mm	Manhole (s)	Manhole (s)
NOTE Check whether or not it is convenient to use a conical transition in the shell to reduce the diameter of the flanged cover, and to use a dished head instead of the blind flange.		

8.1.3 The minimum nominal diameter of the manholes shall be as indicated in Table 7.

Table 7 – Minimum Nominal Diameter of Manholes

Pressure Vessel Inside Diameter (DI) [mm]	Pressure Vessels With or Without Internals
815 ≤ DI ≤ 1 015	NPS 18" (see Note)
1 015 < DI ≤ 1 220	NPS 20"
DI >1 220	NPS 24"
NOTE Check whether or not it is convenient to use a conical transition in the shell to reduce the diameter of the flanged head, and to use a dished head instead of the blind flange.	

8.1.4 For vessels with trays, grids, or other similar parts, which are dismountable or which are provided with internal bolted manway, the minimum number of manholes for clean services shall be as specified in Table 8. Additional manholes shall be considered near the feed inlet nozzle where internal piping and baffles may require frequent cleaning.

Table 8 – Minimum Number of Manholes

Number of Trays or Gratings	Minimum Number of Manholes
Up to 25	2
26 - 41	3
42 - 60	4
Over 60	One for every 20 trays

8.1.5 In services where frequent cleaning is expected or for safety reasons, the number of manholes indicated in Table 8 may be increased, according to the severity of the service, up to a maximum of one manhole for each 6 trays.

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

8.1.7 For horizontal vessels, the manhole, when technically feasible, shall be located on one of the heads. The second manhole, when available, shall be located in the top of the shell, close to the opposite end. Horizontal vessels over 10 m in length shall have 2 manholes.

8.1.8 The product inlet nozzles shall be sufficiently far from the level measurement instrument to avoid disturbances in the level that affect the instrument's reading

8.1.8 Os bocais de entrada de produto devem estar suficientemente afastados do instrumento de medição de nível, para evitar perturbações no nível que afetem a leitura do instrumento.

8.1.9 The inlet and outlet nozzles shall be located far apart, to avoid "short circuits" inside the vessel. For horizontal vessels, it is recommended that these nozzles be located near to each end of the vessel. **[Recommended Practice]**

8.1.10 For Columns and vertical vessels, the orientation of the nozzles, when not determined for process reasons, shall firstly meet the convenience of the piping layout. The orientation of manholes shall meet the convenience of arranging requirements of platforms and ladders. It is recommended, as far as possible, that 8.1.10.1 and 8.1.10.2 are also observed. **[Recommended Practice]**

8.1.10.1 The manholes shall be on the same vertical line, or on 2 diametrically opposite vertical lines.

8.1.10.2 The nozzles shall be oriented so that the vertical piping is concentrated in 1 or 2 restricted sectors of the vessel circumference.

8.1.11 Valves, flanges, threaded connections or beveled ends for weld shall not be placed inside the skirt support of columns or other pressure vessels supported by cylindrical skirts support which are not accessible from the bottom. If the bottom nozzles of the vessel require valves connected directly to the vessel, the arrangement shall conform to Figure A.2 to avoid valves inside the skirt support.

8.2 Construction of Nozzles and Manholes

8.2.1 All nozzles NPS 2” or larger shall be flanged, except when specified for butt welding on piping. Butt welding nozzles should be avoided; however, they can be adopted for large diameter nozzles or for high pressures, requiring prior approval from PETROBRAS. For nozzles smaller than NPS 2”, the use of threaded connections is only acceptable if all the following conditions are met:

a) service with the following fluids: water, compressed air or inert gases;
b) nozzle without impact test requirements.

8.2.2 The minimum nominal diameter of nozzles, for any purpose, shall be NPS 3/4”. Exceptionally, 1/2” threaded nozzles are only permitted for thermometer wells or other instruments, as long as all of the following conditions are met:

a) service with the following fluids: water, compressed air or inert gases;
b) nozzle without impact test requirements.

8.2.3 Nozzles NPS 1 1/4”, 2 1/2”, 3 1/2”, 5” and 7” should not be used.

8.2.4 The necks of nozzles smaller than and including NPS12” shall be made of seamless tube, unless made of long neck flanges (LWN) or forged material. For NPS14”, or larger, the neck may be made from:

a) welded or seamless pipe;
b) forged part;
c) rolled plate with a single longitudinal weld.

NOTE In cases which rolling is impracticable due to the thickness, pressing with two longitudinal welds is allowed provided this is previously approved by PETROBRAS.

8.2.5 When nozzle necks are constructed of carbon steel or low alloy steel pipes, the following minimum thicknesses shall be as follows:

a) diameter up to NPS 2”: Sch. 80;
b) diameter from NPS 3” to 10”: Sch. 40.

8.2.6 The external projection of nozzles and manholes shall be as small as possible, but sufficient to:

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

NOTE Figure A.3 shows a recommended practice for the external projection of nozzles and manholes, based on the above considerations. **[Recommended Practice]**

8.2.7 There should only be internal projection in the nozzles due to process needs or when previously approved by PETROBRAS.

NOTE The nozzles for drains and vents shall not have any internal projection.

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

8.2.9 Except in exceptional cases subject to prior approval by PETROBRAS, pad type nozzles with holes drilled for stud bolts are not permitted, as shown in the examples in Figures UG-40 (a-1 and a-2) and UW- 16.1 (p) of ASME BPVC Section VIII Division 1, or other similar construction details with stud bolts.

8.2.10 The connection of the nozzle neck and manhole to the vessel component shall always be by full penetration weld. Likewise, when reinforcing plate is used, the weld of this plate to the nozzle neck or manhole shall also always be of full penetration weld.

NOTE Nozzles welded externally to the vessel component (“set-on” type) may only be used with the prior approval of PETROBRAS.

8.2.11 For vessels constructed with high strength steels (UHT Section of ASME BPVC Section VIII Division 1), all nozzles and manholes are required to have integral reinforcement, as shown in Figure UHT 18.1 of the code, and none of the types shown in Figure UHT 18.2 are allowed.

8.2.12 Use of Nozzle Couplings

8.2.12.1 Forged steel couplings may be used for nozzles NPS 2" and smaller, as long as this is also permitted for the type of service (see 1.6) of the vessel. The coupling-to-vessel wall shall always be of full penetration welding.

NOTE Couplings welded externally to the vessel component (“set-on” type) can only be used with the prior approval of PETROBRAS.

8.2.12.2 Couplings shall be at least class 6000 for socket weld, except for instruments, in which case threaded couplings are allowed, provided the following conditions are fulfilled:

a) service with the following fluids: water, compressed air or inert gases;
b) nozzle without impact test requirements.

NOTE Internal couplings not subject to pressure need not comply with the above conditions and may be 3000 class threaded type.

8.2.12.3 The length of the coupling shall be greater than the thickness of the vessel, with the other dimensions being in accordance with ASME B 16.11, to avoid interference between the socket weld and the shell weld.

8.2.13 The designer is responsible for stress analysis on the nozzle-to-vessel shell junction to withstand the external loads transmitted by piping, providing proper reinforcement whenever necessary.

NOTE The following methods are permitted for stress analysis in junction between the nozzle and vessel envelope (shell and heads).

a) Finite Element Methods (FEM);
b) in accordance with WRC Bulletin 537 and/or WRC Bulletin 297, as long as it meets its limitations of use.

8.2.14 The necks of nozzles, manholes and their respective reinforcements, in no case shall not limit the hydrostatic test or the maximum allowable working pressure in new and cold or corroded and hot conditions, except for vessels of small dimensions, whose thickness is defined by the minimum structural value.

8.2.15 Nozzles and manholes reinforcements when required by ASME BPVC Section VIII, shall be obtained by one of the systems shown in Figure A.4 or by a combination of these systems, considering the requirements and limitations indicated in 8.2.15.1 to 8.2.15.4 and also the requirements and limitations indicated in the special services (see 1.6) in which the vessel is included.

8.2.15.1 Reinforcing pad welded to the tubular nozzle neck and the vessel wall [Figure A.4 (A)]. This system is permitted for any diameter, but should not be used when the vessel wall thickness is equal to or greater than 50 mm. It is not recommended for low temperature services, pressurized LPG storage sphere, cyclic services, nor H2 service.

NOTE Reinforcing pads shall have a 6 mm diameter hole, with NPT thread, for vent and for weld test. For nozzles NPS10” or larger, there shall be two Ø 6 mm holes diametrically opposite each other. Plugs shall not be placed in these holes, and the holes shall be left open and filled with grease.

8.2.15.2 Insert plate butt welded to the vessel [Figure A.4 (B)]. This system is permitted for any diameter and may be used in cases which the reinforcing pad of Figure A.4 (A) is not permitted or not recommended.

8.2.15.3 Integral forging part [Figure A.4 (C)]. This system is permitted for any diameter, without limitations.

8.2.15.4 Thicker tubular neck [Figure A.4 (D)]. This system is permitted without limitations for NPS 10” and smaller, but the thicker tubular neck shall be made of seamless or forged pipe (forged pipe is preferred in these cases).

8.2.16 Closed nozzles with a blind flange whose weight is greater than 350 N (36 kgf) shall be provided with a lifting lug, davit or hinges for the removal of the blind flange, whose positioning shall be as established in 8.3.

8.2.17 The use of quick-actuating or quick-opening closures is only permitted with prior approval by PETROBRAS.

8.3 Additional Requirements for Manholes

8.3.1 All manholes with the cover in the horizontal plane, opening upwards, shall have a davit for removing the cover. Manholes with the cover in a horizontal plane, opening downwards, should be avoided whenever possible. When unavoidable, a safe device shall be provided for removing and handle the cover.

8.3.2 Manholes with cover in a vertical plane, with a pressure rating class of up to 150, with a diameter NPS 24” or smaller, may have davits or hinges to open the cover; for higher pressure rating classes, or larger diameter, it is mandatory to have a davit, and hinged heads are not permitted.

8.3.3 For manholes with cover in the vertical plane, steps and a safety handle shall always be placed on the inside of the vessel, except when there are internal parts in the vessel that make these steps impossible or unnecessary.

8.3.4 Selection of flange type for manholes shall meet the requirements in 8.4.

8.3.5 It shall be ensured that manholes are free from internal and external interference such as structures and pipes that prevent and/or limit full access and full opening.

8.4 Flanges

8.4.1 Flanges shall be suitable for the vessel design and test conditions, specified by ASME B16.5 or B16.47 or designed by ASME BPVC Section VIII.

8.4.2 The type of nozzle flange, its facing and holes, when connected to piping and instruments, shall be in accordance with the applicable piping and instrumentation specifications, except when otherwise specified by PETROBRAS.

NOTE The use of flanges designed by ASME BPVC Section VIII shall be approved preview of PETROBRAS.

8.4.3 Non-pressurized internal flanges may be flat-faced and made from cut plate.

8.4.4 Flanges NPS 1½” and smaller, may be of one of the following types:

a) “Long Welding Neck” flange (LWN);
b) “Welding Neck” flange (WN) with sch 160 or XXS neck;
c) “Slip-On” (SO) flange for pressure rating class 150, provided that all the following conditions are met:

— service with the following fluids: water not contaminated by toxic substances, air compressed or inert gases;
— flange without impact test requirements;
— nozzle with corrosion allowance up to 3 mm (when the weld is in contact with the fluid);
— equipment not requiring postweld heat treatment.

NOTE In any of the above cases, the flanges shall be made of forged steel.

8.4.5 Flanges NPS 2” and larger shall be type WN in accordance with ASME B16.5 or B16.47, made of forged steel. Other types of flanges are also acceptable, as long as they meet the conditions described below in 8.4.5.1 and 8.4.5.2.

8.4.5.1 Slip-on (SO) flanges may only be acceptable to use in nozzles NPS 2” and larger if the following conditions are met:

a) pressure rating classes 150 and 300;
b) flange without impact test requirements;
c) nozzle with corrosion allowance up to 3 mm (when the weld is in contact nozzle with the fluid);
d) equipment not requiring postweld heat treatment.

NOTE In any of the above cases, the flanges shall be made of forged steel.

8.4.5.2 For NPS 14” and above, it is acceptable to use ring type flanges, made of seamless forged steel, or manufactured from forged bar or plate, as shown in Figures 2-4 (7) or (11) of ASME BPVC Section VIII Division 1 or as per Figure 4.16.1 (a) of ASME BPVC Section VIII Division 2, which specify full penetration weld between the flange and the nozzle neck or manhole.

NOTE 1 Figures 2-4 (8), [8 (a)], (9), [9 (a)], (10) or [10 (a)] of ASME BPVC Section VIII Division 1 and Figure 4.16.5 of ASME BPVC Section VIII Division 2 are also permitted, provided that all of the following conditions are met:

a) design pressure up to and including 2000 kPa (290 psi);
b) flange without impact test requirements;
c) nozzle with corrosion allowance up to 3 mm (when the weld is in contact nozzle with the fluid);
d) equipment not requiring postweld heat treatment.

NOTE 2 Flanges manufactured from bar or plate, of any pressure rating class, shall be obtained by machining rolled or pressed rings with a maximum of two fully radiographed butt welds. These flanges shall be postweld heat treated as required by ASME BPVC Section VIII and the original plate surfaces shall be parallel to the axis of the finished flange. Flanges cut from plate shall only be used for internal parts of the vessel that are not subject to pressure.

8.5 Gaskets, Face Finish, Studs and Nuts

8.5.1 Gaskets, face finish, studs and nuts of nozzle flanges shall be in accordance with the applicable piping specifications to which they are connected.

NOTE Manholes and other nozzle flanges not connected to the piping, as well as nozzles of instrumentation, shall follow the piping specification applicable to the region where they are installed in the vessel.

8.5.2 The faces of the matting flanges that work with ring-type joints (RTJ) shall have a Brinell hardness 30HB greater than that of the gasket material, whose hardness shall be in accordance with the applicable piping specification.

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 the nozzle flanges is of the tongue and groove type, the groove shall be on the nozzle flange, except when the face of the nozzle flange is facing downwards, in which case the tongue shall be on the nozzle flange.

8.5.5 For economic reasons and if previously approved by PETROBRAS, the use of loose flanges ("lap-joint") is permitted on the nozzles of vessels made of stainless steel or non-ferrous metals, with a design pressure of less than 400 kPa (4.1 kgf/cm^2) and design temperature below 250 °C.

8.5.6 The internal flanges of the vessels shall be provided with bolts, nuts and gaskets.

8.5.7 Companion flanges of nozzles are only part of the vessel in exceptional cases, when expressly required in the equipment drawings or in the Material Requisition (RM).

9 Supports

9.1 General Requirements

9.1.1 Every vessel shall have its own support and grounding lug, and it is not permitted for it to be supported by piping.

9.1.2 The constructive details of the supports and grounding lugs of the vessels shall be in accordance with PETROBRAS N-2054.

9.2 Vertical Vessels

9.2.1 Vertical vessels may be supported by means of cylindrical or conical skirts, legs (columns) or lugs. Whenever possible, vertical vessel shall be supported by legs.

9.2.2 The selection of the type of support for vertical vessels shall be made in accordance with Figure A.5, unless other requirements are applicable.

NOTE 1 The skirt support shall always be used where there is a possibility of vibration, such as in the case of vessels connected to compressors.

NOTE 2 Columns and reactors shall be supported by skirt support.

9.2.3 The minimum thickness of the skirt support shall be 6.3 mm and its material shall be in accordance with subsection 5.7.3 of this Standard.

9.2.4 There shall always be access to the lower part of the vertical vessel, and the minimum height of its support, skirt or leg, supported directly on a concrete base, shall be defined in accordance with the following criteria:

a) the lowest point of the bottom head shall be at least 1200 mm from the top of the concrete base, for vessels with a diameter greater than 800 mm;
b) the lowest point of the horizontal section of the piping connected to bottom head shall be at least 300 mm from the top of the concrete base.

9.3 Openings and Vents of Skirt Supports

9.3.1 Skirt supports shall have, at least, one opening for access to the interior of the skirt.

9.3.2 The opening for access to the interior of the skirt, as well as the openings for passing pipes through the skirt, shall be adequately reinforced.

9.3.3 The constructive detail of the access openings, piping passages and vents of skirt supports shall be in accordance with PETROBRAS N-2054.

9.3.4 Vent nozzles shall be positioned as close as possible to the junction with the head in quantities and diameters as per Table 9.

Table 9 – Skirt Vents

Inside diameter of vessel (mm)	Number of vents	Vent diameter (NPS)
Up to 914	2	3” sch 40
915 - 1 830	4	3” sch 40
1 831 – 2 740	6	4” sch 40
2 741 – 3 660	8	4” sch 40
3 661 – 4 570	10	4” sch 40
4 571 – 5 490	12	4” sch 40

9.4 Horizontal Vessel

9.4.1 The horizontal vessel shall be supported by 2 saddles or metal cradles (see subsection 9.1.2 of this Standard), covering at least 120° of the vessel's circumference. The saddles shall be located symmetrically in relation to the middle of the vessel's length. One of the saddles, called sliding, shall always have elongated holes for anchor bolts to accommodate the vessel's own expansion.

NOTE The rolled band plates of the two saddles shall be welded to the shell of the vessel by means of a continuous weld bead.

9.4.2 The location of the saddles and the verification of the effect of reactions on the vessel shell shall be carried out analytically (“Design by Rule Requirements”) in accordance with ASME BPVC Section VIII Division 2.

NOTE For vessels designed by ASME BPVC Section VIII Division 1, checks may be carried out using the ASME BPVC Section VIII Division 2 method, however, using the allowable stresses corresponding to ASME BPVC Section VIII Division 1.

10 Internal Items

10.1 The criteria for inclusion or exclusion of internal parts and accessories under the responsibility of the pressure vessel designer is indicated in the Material Requisition (RM) of the pressure vessel.

NOTE Internal accessories shall comply with PETROBRAS N-2054.

10.2 All dismountable internal parts, with the exception of the major support beams for trays, grids and the similar structures shall be designed so that the weight shall not exceed 250 N (25 kgf), unless when previously approved by PETROBRAS. They shall also have dimensions that allow easy passage through the manhole.

10.3 Fasteners, standard bolts, and nuts of internals internal parts shall be made of material that not susceptible to be attacked by the vessel's internal operating fluid, requiring as a minimum quality stainless steel types 304 or 405.

10.4 Vortex breakers shall be installed in all nozzles installed on the bottom of the vessel with outlet nozzle in a vertical position connected to the suction piping of pumps. Internal baffles shall also be installed 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 on internal parts or on the vessel wall is likely to occur.

NOTE For nozzles connected to the pump suction line, which have a horizontal outlet, you shall use a device to prevent vortex formation.

10.5 Non-pressurized carbon steel and low-alloy steel (up to 6% Cr), internal pipes and fittings shall have the following nominal thicknesses and minimum pressure classes:

a) pipes up to NPS 10”: Sch. 40;
b) pipes over NPS 10”: 6 mm thickness;
c) threaded fittings: pressure rating class 2000.

10.6 Non-pressurized high alloy steel (11-13% Cr or above), internal pipes and fittings shall have the following nominal thicknesses and minimum pressure rating classes:

a) pipes up to NPS 1 1/2: Sch. 40S;
b) pipes above NPS 1 1/2”: Sch.10S or made of 12 USS size plate (0.3708 mm);
c) threaded fittings: pressure rating class 2000.

11 External Items

11.1 The following external accessories or components, which apply in each case, are part of the vessel design:

a) reinforcement plates of nozzles and manholes;
b) stiffing rings for vessels with thin walls or those subject to external pressure;
c) skirt support, legs or lugs of vertical vessels;
d) support saddles for horizontal vessels;
e) angles, bars, studs, nuts or other devices for supporting and fixing external thermal insulation;
f) attachment plates, lugs or brackets to support piping, platforms, ladders or other structures;

g) anchors for fixing fire-proofing;
h) supports for load lifting davits;
i) lifting lugs and other devices necessary for moving the vessel or its component parts, during assembly or maintenance;
j) davits for manhole covers and other blind flanges;
k) blind flanges with gaskets and bolts, for manholes, inspection openings and closed flanged nozzles;
l) electrical grounding detail.

NOTE External accessories shall comply with PETROBRAS N-2054.

11.2 Unless otherwise specified in the Material Requisition (RM), the following external parts are not normally part of pressure vessels:

a) valves and instruments of any type;
b) companion flanges;
c) anchor bolts;
d) thermal insulation material;
e) fire protection material;
f) platforms, ladders or other structures;
g) “template” for the location of the anchors.

11.3 Vertical vessels that have dismountable internal parts shall have a load davit placed at the top, to move these internal parts whenever the top of the vessel is at a height greater than 3000 mm from the ground.

11.4 For all vessels, a means of safe access shall be provided to the following points:

a) manholes whose center line is more than 3000 mm from the ground;
b) safety or relief valve installed on the vessel itself;
c) instruments or equipment that shall have local reading or operation or inspection frequent.

NOTE For items “a” and “c” access shall be permanent.

12 Fabrication Design

12.1 General Requirements

The manufacture of the pressure vessel shall comply with the requirements of ASME BPVC Section VIII and PETROBRAS N-268 and N-269.

12.2 Welds

12.2.1 All welds subjected to pressure loads on the shell and heads shall be butt weld, full penetration, made on both sides and radiographable. When internal welding is impracticable, only the external welding may be done, since adopting a method that guarantees the quality of the weld root, respecting what is prescribed in subsection 4.7 of this Standard.

12.2.2 The welds on the nozzle necks and manholes to the vessel shall also have full penetration. When, this provision is impracticable due to the high thickness of the wall, the welded connection design shall be subjected to prior approval by PETROBRAS.

NOTE The weld connecting the neck of nozzles and manholes to pressure vessels belonging to reciprocating compressor systems shall be designed to be 100% radiographable or examined using recordable ultrasound (“phased array”). This examination requirement shall be included in the equipment design notes list. In the case of austenitic stainless steel equipment, the examination procedure shall be previously approved by PETROBRAS.

12.2.3 Dissimilar welds (as defined in N-133) and with different “P-numbers” are only permitted with prior approval from PETROBRAS.

NOTE Except when previously approved by PETROBRAS, dissimilar welds shall be placed outside the contact of the fluid contained in the vessel and also outside the pressure wall of the vessel.

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

12.2.5 Shells and heads welds shall be arranged in such a way that they do not interfere with: the vessel supports; pipe supports; with internal and external parts welded to the vessel; with the nozzles; with manholes or with respective nozzle and manhole reinforcements.

NOTE 1 Shell welds that are hidden by reinforcement plates, piping support pads and internal and external parts welded to the vessel are only permitted with prior approval from PETROBRAS and shall be ground, examined by magnetic particles or penetrating liquid and designed to be fully radiographed.

NOTE 2 Longitudinal welds on the lower generatrix of the horizontal vessel shell are prohibited.

NOTE 3 Saddles of horizontal vessel shall also be located so as not to interfere with the circumferential welds of the vessel and to allow full examination of these welds.

12.2.6 All welds shall be positioned so that they can be inspected without the need to disassemble internal parts of the vessel.

12.2.7 In vertical vessels, the weld of the skirt support to the vessel shell shall be located in such a way that it does not interfere with the weld of the shell to the lower head and allows inspection of this weld.

12.2.8 For vessels with a diameter smaller than 2000 mm, only a single longitudinal weld per shell segment is allowed. 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. For both cases there shall be a spacing of at least 45° between longitudinal welds of adjacent shell segments.

NOTE It is permitted to use forged rings to manufacture vessel shells.

12.2.9 Welds of lifting lugs and other lifting devices shall be located away from the main welds as specified in subsection 12.2.12 of this Standard.

NOTE Where interference cannot be avoided, prior approval from PETROBRAS is required. In this case the shell weld shall be ground and examined with magnetic particles or liquid penetrant before welding lifting lugs and other lifting devices.

12.2.10 In order to avoid gaps, all fillet welds of parts connected to the shell externally shall have a continuous sealing bead.

NOTE Overlapping parts in vessels that operate at temperatures equal to or higher than ambient temperature shall have a vent hole with a diameter of 6 mm at the bottom.

12.2.11 All welds of parts internally attached to the vessel shall have a sealing weld fillet with a 10 mm gap on the bottom part.

12.2.12 The distance between the edges of 2 parallel full penetration welds, in any case, shall not be less than 3 times the thickness of the thinnest plate, with a minimum of 50 mm.

12.2.12.1 The distance between the edges of 2 full penetration welds (longitudinal or circumferential) for nozzles, nozzle reinforcements and other welded connections shall be in accordance with 12.2.12, except when previously approved by PETROBRAS.

12.2.12.2 It is recommended that the welds of the shell and heads should be arranged in such a way as not to interfere with the vessel supports, lifting lugs, nozzles, manholes and respective reinforcements **[Recommended Practice]**.

12.2.13 The same corrosion allowance specified for the vessel shall be added to the minimum throat dimension of the fillet welds. An exception to this rule is full fillet welds, for which this increase is already a result of the geometry of the weld.

12.3 Postweld Heat Treatment (PWHT)

In the design of pressure vessels, the postweld heat treatments provided for by ASME BPVC Section VIII or when required by the service in which the vessel is included shall be specified and required (see 1.6). The additional requirements described in 12.3.1 to 12.3.4 apply.

12.3.1 Any alternative condition of PWHT of ASME BPVC Section VIII Division 1 and Division 2, that allows the temperature to be reduced shall be previously approved by Petrobras.

12.3.2 Postweld heat treatment of welds between dissimilar materials shall meet the requirements of the material that requires more stringent conditions. The required mechanical properties shall be measured in tests carried out in the Procedure Qualification Record (PQR). The procedure for PWHT of welds
between ferritic and austenitic material shall be previously approved by PETROBRAS.

12.3.3 Any and all localized PWHT may only be carried out according to a procedure previously approved by PETROBRAS.

12.3.4 The maximum stress relief or PWHT shall not alter the mechanical properties of the material stipulated by the design code nor exceed the lowest of the following values:

a) the maximum PWHT temperature when stated in the code;
b) the tempering temperature, if the component has been subjected to this heat treatment at the steel mill.

NOTE The use of higher temperatures, when there is no technical alternative, requires prior approval from PETROBRAS, requiring the guarantee of mechanical properties through tests carried out on the specimens after simulated PWHT.

13 Inspection

13.1 Radiographic Exam

The type of radiographic examination to be performed on the welded joints of the pressure vessel shall follow the conditions specified in the vessel design (see 4.7) and PETROBRAS N-268 and N-269.

NOTE 1 Replacing radiographic examination by ultrasonic examination is acceptable if the requirements of ASME BPVC Section VIII Division 1 and Division 2 are met.
NOTE 2 Spot radiography is required as a minimum radiographic examination for welded joints (see subsection 4.7 of this Standard).
NOTE 3 In the case of replacing spot radiography examination by ultrasonic examination, the extension of the examination shall meet the requirements of ASME BPVC Section VIII Division 2.

13.2 Other Exams

13.2.1 The pressure vessel fabrication design shall include other non-destructive exams as specified in the design and/or required by PETROBRAS N-268 and N-269.

13.2.2 Design fabrication shall provide magnetic particles (MP) and/or penetrating liquid (PL) examinations on 100% of welded joints in pressurized parts, when one of the following situations occurs:

a) vessel subject to cyclic service;
b) vessel subject to stress corrosion;
c) vessel with service requirement (see subsection 1.6 of this standard).

13.3 Visual Exam

It shall be carried out in accordance with PETROBRAS N-268 and N-269.

13.4 Dimensional Exam

It shall be carried out in accordance with PETROBRAS N-268 and N-269.

14 Assembly

The assembly of pressure vessels shall comply with PETROBRAS N-268 and N-269.

15 Test

15.1 It is mandatory to calculate and indicate in the drawings the MAWP (see 4.6), the MAP (Maximum Allowable Pressure calculated for new and cold condition) and the hydrostatic test pressure of the vessel. The test pressure shall be determined as indicated in ASME BPVC Section VIII.

15.2 Due to the serious risk it represents, pneumatic testing is only permitted exceptionally, and in each case, prior authorization from PETROBRAS shall be obtained.

NOTE When a pressure vessel is tested pneumatically, all welds shall be fully radiographed and skirt support welds, nozzles and lifting devices shall be 100% examined by magnetic particles or liquid penetrant before testing.

15.3 The requirements of ASME BPVC Section VIII and PETROBRAS N-268 and N-269 shall be met for carrying out the pressure test.

16 Nameplate

16.1 All pressure vessels shall have a nameplate containing at least the information shown in Figure A.6, which aims to guide the manufacturer regarding the provision of the minimum data that shall be mandatory included on the nameplate; if necessary, at the manufacturer's option, or as required in the pressure vessel Material Requisition, the plate may have other additional data.

NOTE It is mandatory that the nameplate and vessel drawings contain a warning note about the minimum temperature of the hydrostatic test water and, in the case of austenitic stainless steel equipment, there shall also be a warning note about the maximum chloride content in the water of hydrostatic test, meeting the requirements of PETROBRAS N-268 and N-269.

16.2 The nameplate shall be located in a visible and easily accessible location that protects the plate from damage during equipment maintenance operations. The location of the identification plate shall be defined in the vessel fabrication drawing.

16.3 Characters shall be engraved or stamped and shall follow the format set out in ABNT NBR 16861, with a minimum dimension of 3 mm.

16.4 The nameplate shall be made of stainless steel plate with a minimum thickness of 1.5 mm.

16.5 For fixing Ø 5/16" x 5/8" stainless steel or brass screws shall be used, with hexagonal nut and washer, in Ø 8.5 mm diameter holes as indicated in the drawing. On vessels with thermal insulation or any other external coating, the nameplate shall be fixed to a support welded to the equipment, so that it sufficiently projects outward beyond the outside surface of the insulation or coating.

Annex A - Figures

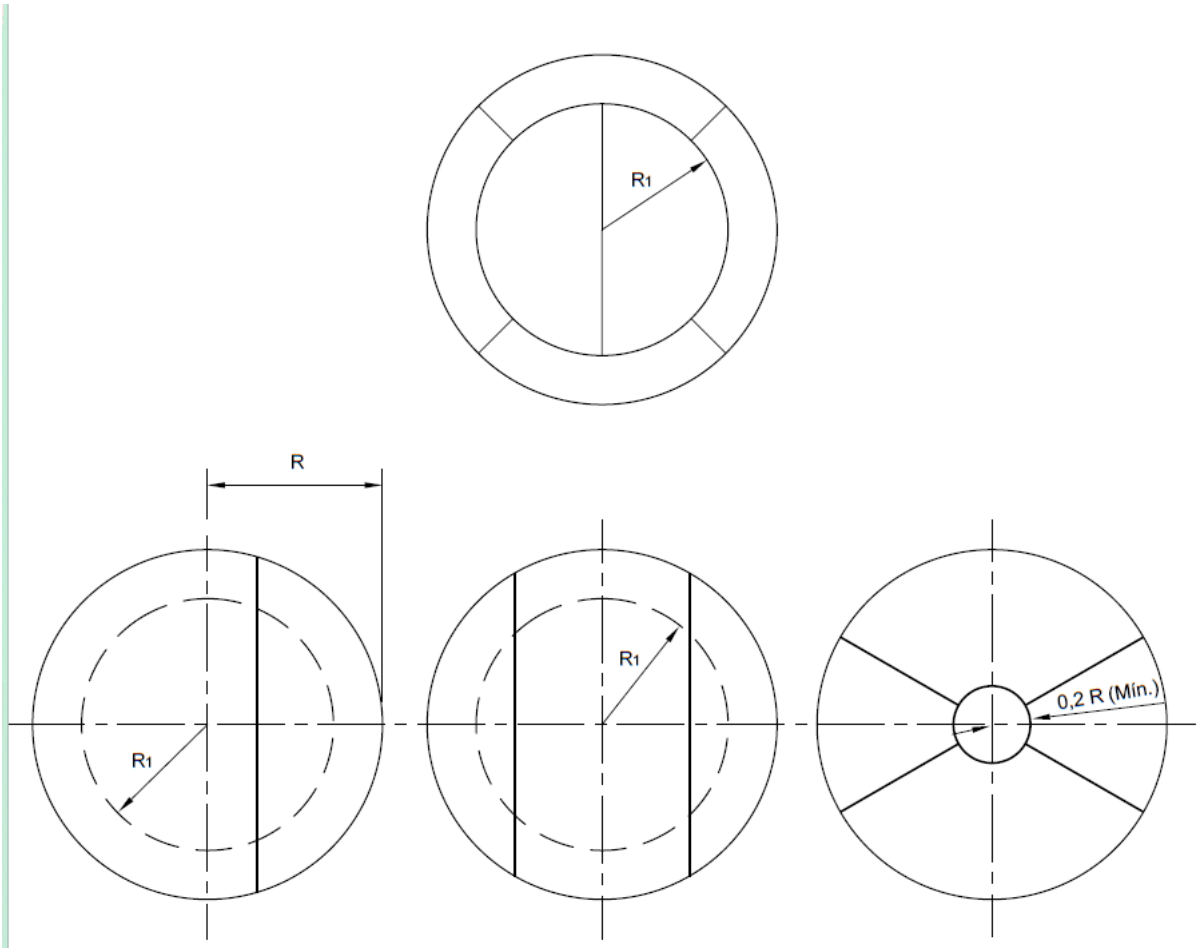


Figure A.1.1 - Examples of Permitted Weld Arrangements

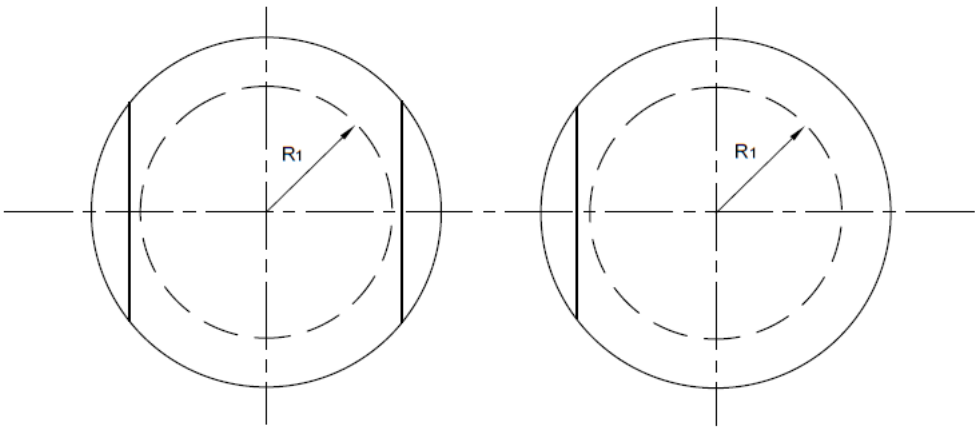


Figure A.1.2 – Examples of Not Permitted Weld Arrangements

NOTE R_1 is the projection radius of spherical cap

Figure A.1 - Heads with Welds

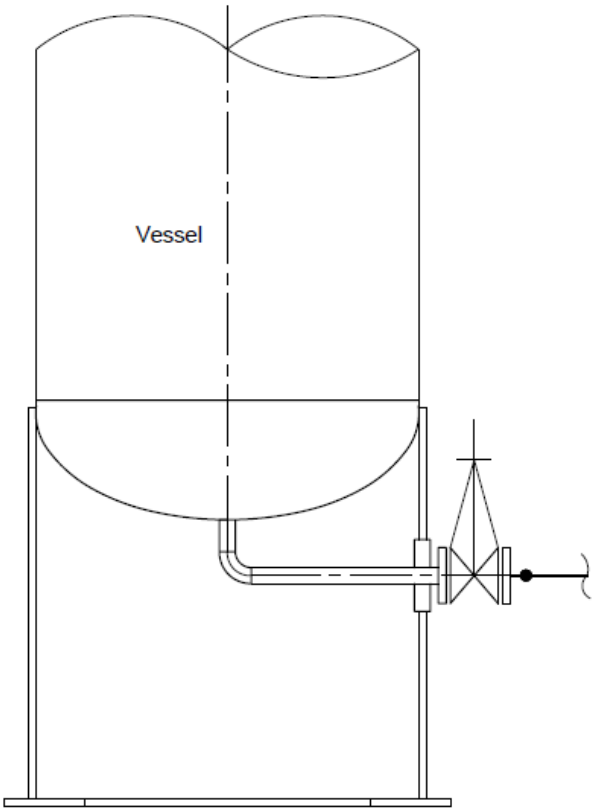


Figure A.2.1 - Recommended Arrangement

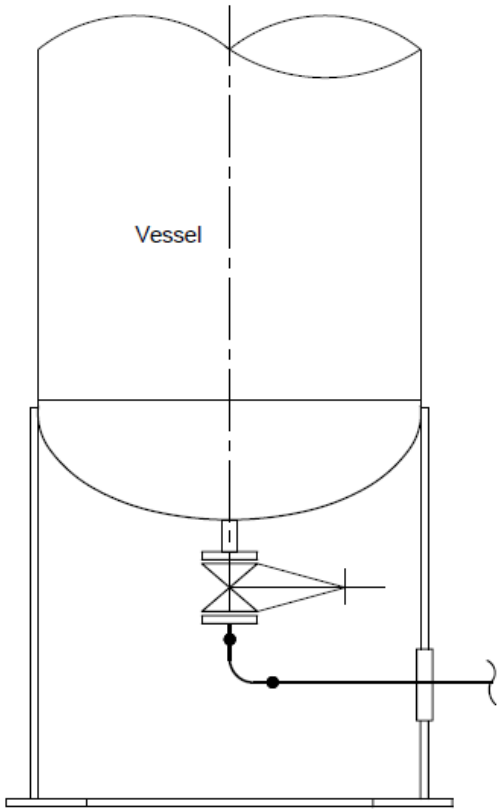
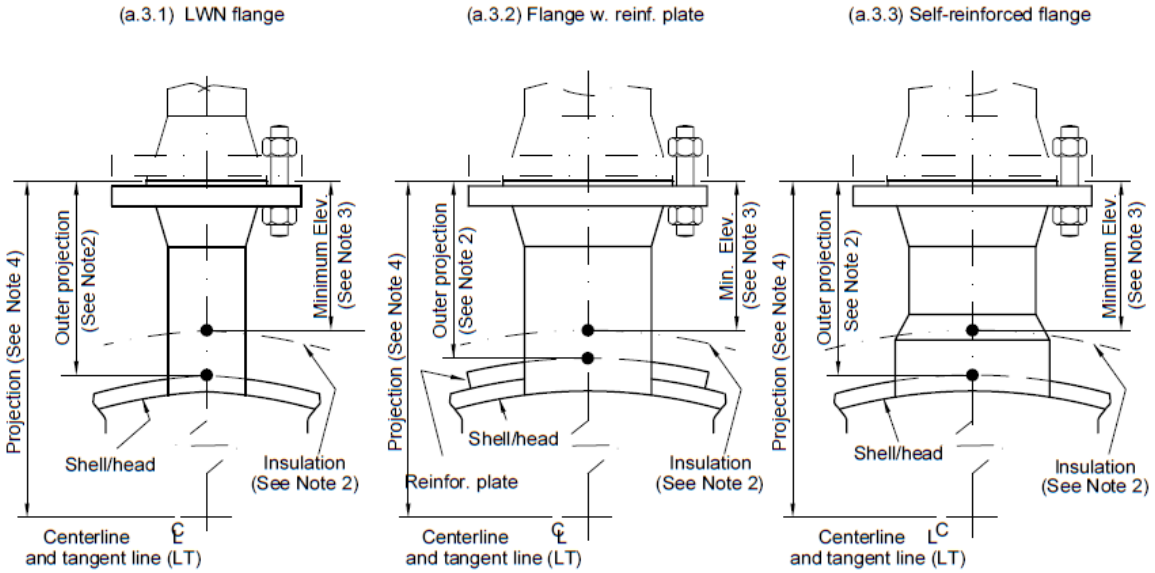


Figure A.2.2 - Unpermitted Arrangement

Figure A.2 - Bottom Outlet Nozzle with Valve Near Vessel



Pipe ND	Flange class (ANSI B16.5)						
	150	300	400	600	900	1500	2500
1 1/2"	200						
2"							
2 1/2"							250
3"							
4"							300
6"							350
8"						300	400
10"						350	500
12"					300		550
14"	250					400	
16"							
18"				300	350	450	
20"							
24"					400	500	

NOTE 1 Dimensions in millimeters, unless otherwise noted.

NOTE 2 This table indicates minimum external projections of nozzles and manholes for vessels without insulation or with insulation. up to 75 mm thick. When the thickness of the insulation is greater than 75 mm, the tabulated value must be added to insulation thickness exceeding 75 mm.

NOTE 3 See 8.2.6.

NOTE 4 The projections given from the lc/lt of the vessel to the external face of the flange must be rounded off based on the values indicated in the Table.

NOTE 5 For manholes, add 50 mm to the projection value indicated in the table, when the davit support is located in the neck.

NOTE 6 The drilling of the flanges must be offset from the main axes of the equipment (longitudinal and transversal).

Figure A.3 – External Projection of Nozzles and Manholes

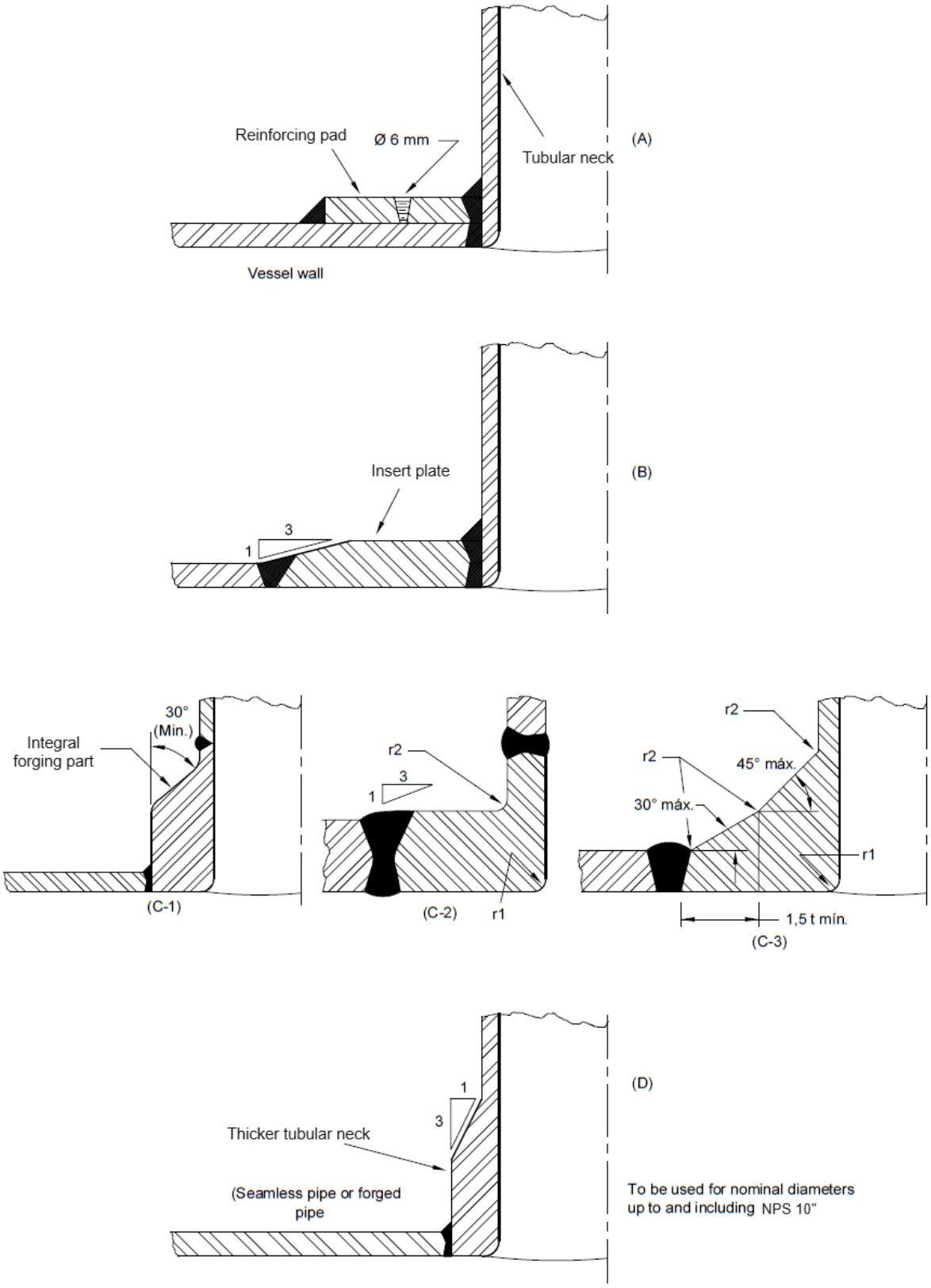
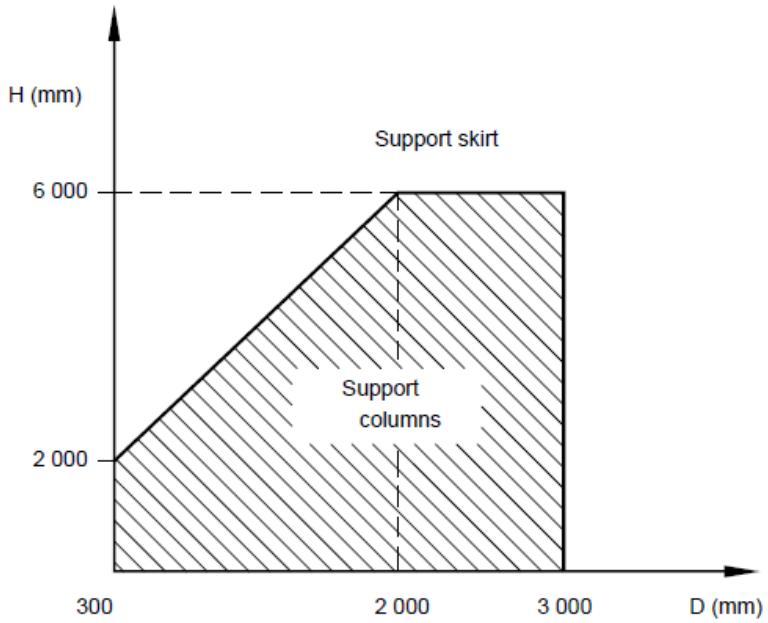


Figure A.4 - Nozzle and Manhole Reinforcements

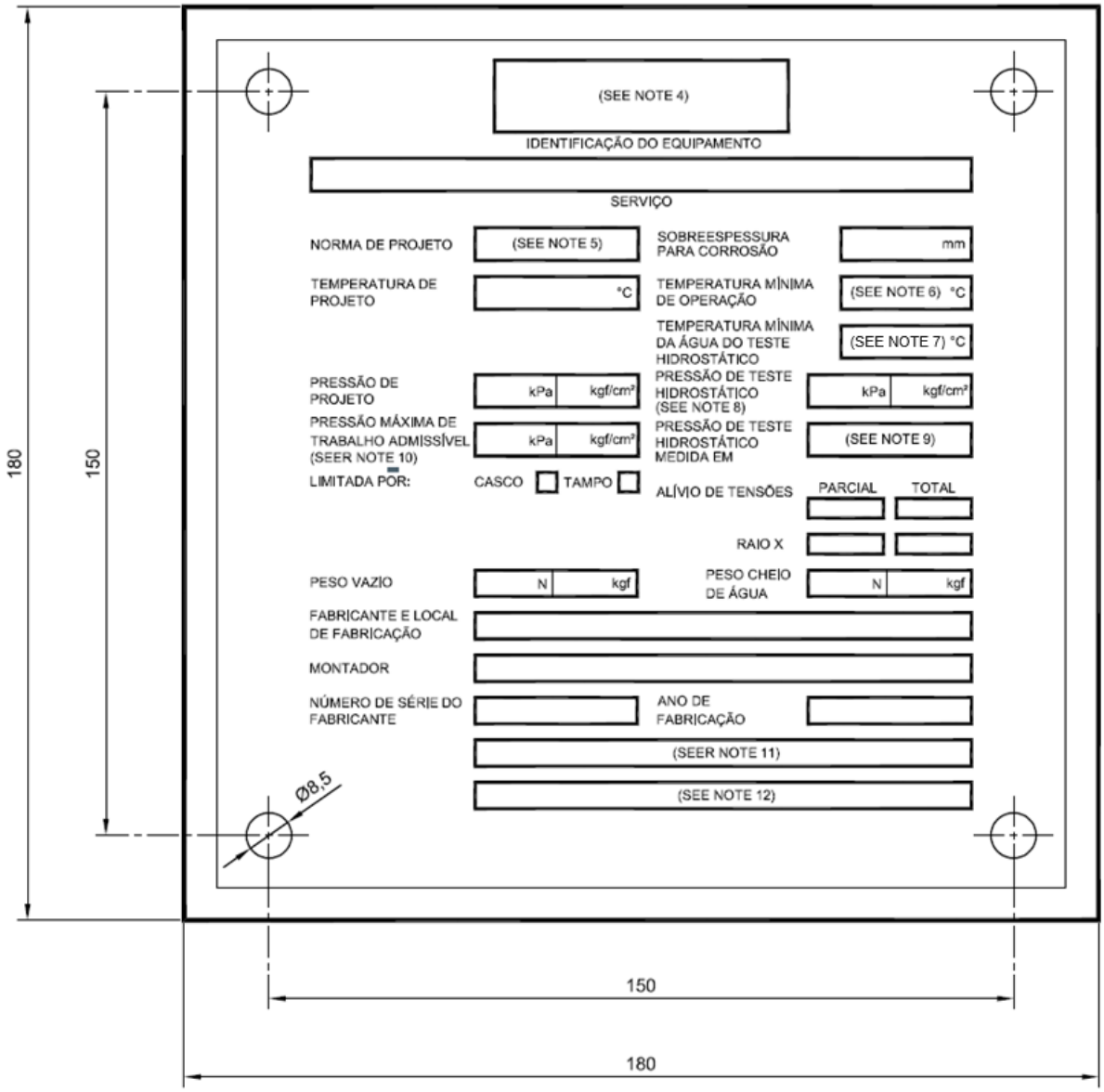


Legend:

D is the Diameter;

H is the total height of vessel, including its support

Figure A.5 - Selection of Type of Support for Vertical Pressure Vessels



NOTE 1 The dimensions of the Figure are in mm.
NOTE 2 Units shall be filled in considering the international system and technical system.
NOTE 3 The language to be used in recording all information on the nameplate shall be Portuguese.
NOTE 4 The vessel identification shall comply with PETROBRAS N-1521.
NOTE 5 The edition year of the standard adopted shall be indicated.
NOTE 6 When applicable.
NOTE 7 The minimum temperature of water for hydrostatic testing of the equipment shall be determined according to PETROBRAS N-268.
NOTE 8 The hydrostatic test pressure for vessel fabrication shall be determined according to ASME BPVC Section VIII.
NOTE 9 Indicate the position and point where the hydrostatic test pressure is measured (Vertical/top or Horizontal/top generatrix, according to the type of vessel).
NOTE 10 The Maximum Allowable Working Pressure (MAWP) shall be determined for vessel corroded and hot vessel condition.
NOTE 11 Whenever the equipment is specified to operate with a special service, the type of service, such as, for instance, “H2 Service”, “H2S Service, and “Caustic Service”, shall be described in this field.
NOTE 12 The requirements for the water used for hydrostatic testing, as specified in the note of 16.1, shall be included in this space.

Figure A.6 – Nameplate

IMPACT REGISTRATION FORM (FRI)

REV. 0 a L

There is no Impact Registration Form.

REV. M

Standard Item	Change	Reason for Change	Potencial Impacts
Title page and Section 1	Inclusion of requirements inherent to the implementation period of the standard.	Enable users of this standard to have time to implement requirements and manage the changes.	The impacts are positive, allowing the user to adequately plan the implementation of this standard.
Section 2	Change of title of NR-13.	Metallic tanks became part of NR-13.	No impact, since NR-13 was already a reference for this standard and already had pressure vessels in its scope.
Section 2 and Subsection 5.13.2	Inclusion of the API RP 571 standard.	To allow damage mechanisms in static equipment are included as design requirements for pressure vessel.	Enhancing the assurance of equipment integrity throughout its useful lifetime.
Section 2 and Subsection 5.13.1	Inclusion of ISO 12944-2 and ISO 21457 standards.	Inclusion of requirements for equipment corrosion protection.	Enhancing the assurance of equipment integrity throughout its useful lifetime.
Section 2 and Subsections 3.4 and 8.2.13	Replacement of WRC Bulletin 107 with WRC Bulletin 537.	Update of mechanical design criteria.	Better guarantee of equipment integrity throughout its useful lifetime.
Section 5.13	New subsection.	Inclusion of material requirements for bolts, nuts and washers.	Enhancing the assurance of equipment integrity throughout its useful lifetime.
Subsection 8.3.5	New subsection.	Inclusion of requirements to ensure free and unimpeded access to manholes.	Guaranteed access for inspection and maintenance of equipment.
Subsection 9.1.1	Change of text.	Inclusion of the requirement for a grounding lug on vessel supports.	Enhancing the assurance of equipment integrity throughout its useful lifetime.
Subsection 9.4.1	Change of text.	A reference to Subsection 9.1.2 of this Standard has been included.	Better understanding of the text by users of the Standard.
Subsection 11.4	Change of text.	The reference to vertical or inclined ladders has been removed.	Increased flexibility for the designer to define the safest access to equipment.
Subsections 12.2.12.1 and 12.2.12.2	New subsections.	More details of welding requirements.	Better understanding of the text by users of the Standard.