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Pressure Vessel Fabrication

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)

Foreword

This Standard is the English version (issued in 04/2024) of PETROBRAS N-268 REV. H 12/2020. 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 conditions required for the manufacture of metallic pressure vessels of any type, used in petroleum and petrochemical industrial facilities.

1.2 A pressure vessel is considered the equipment defined in PETROBRAS N-253, such as: vessel, column, heat exchanger and sphere.

1.3 This Standard is based on ASME BPVC Section VIII and presents the supplementary requirements to be complied with when fabricating pressure vessels for PETROBRAS.

1.4 When the design is made according to a standard or code different from ASME BPVC Section VIII, the fabrication shall be fully performed in accordance with the adopted standard or code, and this Standard shall be used only to complement the adopted standard or code.

1.5 For equipment with special services, the technical requirements of respective Standards and Technical Specifications prevail, for example, H_2 service, H_2S service, equipment with controlled toughness requirements and others.

1.6 This Standard applies to fabrication of pressure vessel starting from its issue date.

1.7 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-133 - Soldagem;

PETROBRAS N-253 - Pressure Vessel Design;

PETROBRAS N-266 - Presentation of Pressure Vessel Design;

PETROBRAS N-466 - Projeto de Tocador de Calor Casco e Tubo;

PETROBRAS N-1593 - Ensaio Não Destrutivo - Estanqueidade;

PETROBRAS N-1594 - Ensaio Não Destrutivo - Ultrassom em Solda;

PETROBRAS N-1595 - Ensaio Não Destrutivo - Radiografia;

PETROBRAS N-1596 - Ensaio Não Destrutivo - Líquido Penetrante;

PETROBRAS N-1597 - Ensaio Não Destrutivo Visual;

PETROBRAS N-1598 - Ensaio Não Destrutivo - Partículas Magnéticas;

PETROBRAS N-1707 - Projeto de Vaso de Pressão com Revestimento Metálico;

PETROBRAS N-1738 - Descontinuidades em Juntas Soldadas, Fundidos, Forjados e Laminados;

PETROBRAS N-2301 - Elaboração da Documentação Técnica de Soldagem;

PETROBRAS N-2913 - Revestimento Anticorrosivos para Tanque, Esfera, Cilindro de Armazenamento;

ABNT NBR 15523 - Qualificação e Certificação de Inspetor de Controle Dimensional;

ABNT NBR 14842 - Critérios para a qualificação e certificação de inspetores de soldagem;

ABNT NBR 16137 - Ensaios não destrutivos — Identificação de materiais por teste por pontos, espectrometria por fluorescência de raios X e espectrometria por emissão óptica

ISO 8501-1 - Preparation of Steel Substrates Before Application of Paints and Related Products - Visual Assessment of Surface Cleanliness - Part 1: Rust Grades and Preparation Grades of Uncoated Steel Substrates and of Steel Substrates After Overall Removal of Previous Coatings;

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

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

ASME PCC-1 - Guidelines for Pressure Boundary Bolted Flange Joint Assembly;

ASTM A380 - Standard Practice for Cleaning, Descaling and Passivation of Stainless Steel Parts, Equipment and Systems;

ASTM E384 - Standard Test Method for Knoop Vickers Hardness of Materials;

TEMA - Standards of the Tubular Exchanger Manufacturers Association;

WRC Bulletin 452 - Recommended Practices for Local Heating of Welds in Pressure Vessels.

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1
Quality certificate
document issued by the material manufacturer showing its compliance with the standardized specification of material and which allows its traceability

3.2
Welding Procedure Specification - WPS
document issued by the organization executing the service, based on specifications of designer, consumables, and base metals, providing the welding variables required for production of welded joints with the same properties and characteristics of joint tested in qualification. See PETROBRAS N-2301

3.3
equipament “classe A”

nomenclature adopted in this Standard to designate pressure vessels subject to all the requirements of this Standard and not categorized in class B

3.4
equipament “classe B”
nomenclature adopted in this Standard to designate pressure vessels with less complex service and which have **all** of the following characteristics:

a) fluid: hydrocarbon with flash point higher than 60 °C at ambient temperature and design temperature between atmospheric and 196 kPa (2 kgf/cm^2 gauge), water not contaminated by toxic substances, compressed air or non-flammable fluid;
b) is not classified as equipment with Special Service such as, for example, H_2 service, H_2S service, toxic service and others;
c) does not have controlled toughness requirements;
d) is made of carbon steel and without metallic internal lining, example: clad;
e) is designed in accordance with ASME BPVC Section VIII Division 1 and its fabrication does not require postweld heat treatment or full radiography;
f) in case of heat exchanger, be TEMA-type class C.

NOTE Silos, flare stacks and cyclones for FCC units, despite not being classified as pressure vessels, can be classified in class B of this Standard.

3.5
fabrication
all activities developed in factory regarding the construction of pressure vessel.

3.6
manufacturer
company, firm or organization responsible for the complete or partial fabrication of the vessel, in those cases in which fabrication is completed at the job site.

3.7
Positive Material Identification (PMI)
examination performed to confirm the employed material through analysis of its chemical composition.

3.8
Instruction for Execution and Welding Inspection (IEIS)
document based on qualified WPS, detailing the suitable welding parameters for each joint or service, as well as the applicable non-destructive exams, mechanical tests and respective extensions. See PETROBRAS N-2301.

3.9
map of repaired defects
report indicating all welded repairs in plates. This report shall allow the precise location of repaired areas in the equipment.

3.10
Inspection and Test Plan (ITP)
document prepared by the supplier, contained in its Quality Plan, following the standards established by ISO standards of quality management. The ITP aims to ensure the compatibility of the equipment to be supplied with the design, procedures and contractual documentation.

3.11
inspection body
third-party company hired to provide the manufacturing inspection service.

3.12
Procedure Qualification Record - PQR
document issued by the organization in charge for the service, where there is a record of variables recorded during the welding of the test coupons and qualification tests are recorded; it shall also have the certificates required in PETROBRAS N-2301 and other supplementary test certificates required in technical specifications.

3.12

Material Requisition (RM)
document defining the scope of supply of the equipment.

3.13
screening test
sampling receipt test performed on welding consumables.

4 Vessel Classification for Fabrication

The equipment shall be classified in the fabrication documents as Class A or B, in accordance with the definitions in items 3.3 and 3.4

5 General Conditions

5.1 Manufacturer's Responsibility

5.1.1 Manufacturing shall comply with the requirements contained in the Material Requisition or in the contract and shall be carried out in accordance with the technical specifications and approved fabrication drawings. If the manufacturer finds omissions, conflicting information or errors in any documents provided by PETROBRAS, it must notify PETROBRAS for the appropriate solution, so that the manufacturer continues with full responsibility for manufacturing the equipment.

5.1.2 The manufacturer shall issue vessel fabrication documentation in accordance with NR-13 and PETROBRAS N-266.

5.2 Fabrication Documents

The fabrication of pressure vessels shall comply with the fabrication documents prepared by the manufacturer and submitted for PETROBRAS' approval or for Inspection Body when applicable.

5.2.1 Fabrication documents involve, at least, the following items (when applicable):

a) ITP (see 5.2.2);
b) technical specification of acquisition of welding consumables and materials;
c) identification and marking transfer procedure for materials;
d) WPS, PQR, IEIS, welding plans according to PETROBRAS N-2301;
e) screening test procedure, when required in other technical document or contract;
f) production test plans, according to PETROBRAS N-2301;
g) non-destructive examination procedures;
h) PMI procedure;
i) torque procedure;
j) expanding procedure;
k) sealing (tightness) test procedure;
l) pneumatic test procedure;
m) ferrite number (FN) measurement procedure;
n) hardness examination procedure;
o) refractory lining instalation procedure;
p) internal lining application procedure;
q) procedure for performance of other required examinations, including equipment (tolls) to be used;
r) repair procedure, including type of removal of defect, type of repair and types of examinations to be made after the repair is done;
s) procedure for dimensional examination, indicating tolerances;
t) postweld heat treatment procedure;
u) hydrostatic test procedure;
v) drainage, clean-up and drying procedure for the vessel after the hydrostatic test;

w) external coating application procedures (painting and others);
x) procedure for pickling, passivation and inertization;
y) transport and storage procedure.
z) procedure for repair warped parts.

NOTE For class B, the items described in b), e), f), h), m), n), t) and x) are not mandatory.

5.2.2 The ITP shall have at least:

a) identification of stages throughout the entire manufacturing cycle of the equipment, where checks or inspections are carried out by the manufacturer, the customer, the Inspection Body (when applicable) and the Classification Society (when applicable), including those carried out in sub-suppliers, and shall indicate the types of examinations, tests or checks to be carried out;
b) care taken with temporary welds, including the method to be used for their removal and subsequent inspection;
c) indication of the qualification/certification of the personnel who carry out inspection, verification and special production processes activities;
d) indication of procedures, reference documents and acceptance criteria for all characteristics and quality requirements, including those of a subjective nature and those of sub-supplies;
e) identification and preparation of quality records, citing their various types of records;
f) indication of devices/equipment, including the required accuracies, to obtain quality, in the verification of critical dimensions, functioning and performance tests;
g) classification of equipment according to Section 4 of this Standard.

5.3 Submission of Technical Documents

Procedures and/or plans specified in item 5.2, as well as the documents specified below, shall be submitted to the inspector for verification before the beginning of the corresponding activity:

a) mechanical design and fabrication drawings released for execution;
b) material quality certificates;
c) consumable quality certificates;
d) record of welders/welding operators qualification, including tack welders, according to PETROBRAS N-2301;
e) report indicating procedures and inspectors and/or qualified non-destructive exams operators and qualified welding inspectors;
f) report of welding record, according to PETROBRAS N-2301.

5.4 Technical manufacturing documentation book (Data Book)

In addition to documents mentioned in 5.2, the manufacturer shall furnish a technical manufacturing documentation book in the number of samples required, containing at least the following documents (when applicable):

a) Purchase and Service Order (PCS);
b) certified mechanical design and fabrication drawings and documents;
c) technical specifications;
d) Data sheet;
e) quality certificates for materials for pressurized parts, internal parts and supporting parts of the equipment;
f) quality certificates of welding consumables, including drying control;
g) traceability map of materials and welding consumables;
h) report with record non-destructive examination results;
i) location drawing of the radiographs;
j) map of repaired defects;
k) PMI examination report;
l) Production Testing Records (RETP), according to PETROBRAS N-2301;
m) dimensional examination protocol, informing the dimensions found;

n) Postweld Heat Treatment Record Report (RRTT), including temperature charts and other records regarding heat treatment, according to PETROBRAS N-2301;
o) sealing (tightness) test report;
p) pneumatic test report, including charts and/or records;
q) hardness test report, according to PETROBRAS N-2301;
r) hydrostatic test certificate signed by a qualified professional (PH), including graphs and/or records and water quality report (chloride content), when dealing with austenitic stainless steel;
s) ferrite number examination report;
t) internal lining inspection report;
u) external coating inspection report (painting and others);
v) refractory lining inspection report;
w) reports of nonconformances, if any;
x) Material Release Notification (CLM);
y) hibernation procedure;
z) procedure for installation in field;
aa) digital files of recordable non-destructive exams (“soft copies”). Examples: TOFD and “Phased Array”;
bb) Inspection and Test Plan (ITP).

NOTE 1 The assembly documents required to prepare the pressure vessel data report registration, as per NR-13 shall be contained in technical manufacturing documentation book.

NOTE 2 The technical manufacturing documentation book (Data Book) in digital copy shall be subdivided into parts indexed by chapters in order to allow navigation and search of each document

5.5 Files

In addition to documents listed in a) and b) below, the manufacturer shall keep a copy of the technical documentation data book in an organized file for a period of 5 years after the shipping date of equipment, which is to made available for the examination of PETROBRAS or its authorized representative.

a) records of qualification of welders and weld operators, including tack welders;
b) radiographic films: when this exam is required and NDE records.

6 Nondestructive Examinations

Nondestructive examinations, when required in the equipment design, shall be carried out in accordance with the requirements of this Section.

6.1 Liquid Penetrant Testing (PT)

It shall be performed in accordance with PETROBRAS N-1596, the evaluation of results shall be in accordance with code ASME BPVC Section VIII, Division 1 or Division 2.

6.2 Magnetic Particle Testing (MT)

It shall be performed in accordance with PETROBRAS N-1598, the evaluation of results shall be in accordance with code ASME BPVC Section VIII, Division 1 or Division 2.

6.3 Ultrasonic Testing (UT)

It shall be performed in accordance with PETROBRAS N-1594, the evaluation of results shall be in accordance with code ASME BPVC Section VIII, Division 1 or Division 2.

NOTE If present in specific service standard of vessel, the manufacturer shall adopt a prescription stricter than the one mentioned in this item.

6.4 Radiographic Testing (RT)

It shall be performed in accordance with PETROBRAS N-1595, the evaluation of results shall be in accordance with code ASME BPVC Section VIII, Division 1 or Division 2.

6.5 Visual testing (VT)

It shall be performed in accordance with standard PETROBRAS N-1597, the evaluation of results shall be in accordance with code ASME BPVC Section VIII, Division 1 or Division 2.

6.6 Dimensional

It shall be performed in accordance with applicable code ASME BPVC Section VIII and with tolerances of Figure A.1 and TEMA.

6.7 PMI

It shall be performed in accordance with ABNT NBR 16137.

6.8 Leak Tightness Testing

6.8.1 For reinforcement plate, a bubble formation test with positive pressure shall be performed in accordance with PETROBRAS N-1593. No leak is allowed.

6.8.2 When it is specified a seal welding for tube to tubesheet connection, the leak tightness test shall be performed in accordance with PETROBRAS N-466.

6.8.3 When a leak tightness test using helium gas is required for a full strength weld of the tube to tubesheet connection, it shall be carried out before expanding the tubes and before the postweld heat treatment (when applicable), with a procedure previously approved by Petrobras, in accordance with ASME BPVC Section V, Article 10, Appendix IV, including the test conditions and acceptance criteria.

6.9 Hardness

6.9.1 When qualifying the welding procedure and in production tests, hardness measurement shall be carried out in accordance with the requirements established by PETROBRAS N-133 for “hardness measurement test”.

6.9.2 When measuring hardness in equipment, a portable device shall be used, in accordance with the requirements established by PETROBRAS N-133 for “hardness measurement test”.

7 Material Identification, Control and Inspection

7.1 Material supply shall be as specified in the Material Requisition and in design documentation approved by PETROBRAS

7.2 Certificates of Quality

7.2.1 For pressure parts (including parts welded to those and flanged connections) and supporting parts made of plates and pipes (example: skirt and legs), materials certificates shall be checked to verify compliance with their respective specifications.

7.2.2 The certificates of quality shall have: the specification the material meets, the heat number, the treatment to which the material was subjected, results of chemical analyses and mechanical tests, as well as results of complementary tests

7.2.3 When certificate of quality of sub-suppliers are required and they do not have the original certificates of quality available, the manufacturer shall perform tests and analyses and issue a certificate, listing the results of tests and analyses.

7.2.4 For piping accessories, studs/bolts and flanges fabricated according to an approved standard, certificates of quality are required, even if they are identified with mark required by code ASME BPVC Section VIII.

7.3 The materials used shall be perfectly identified and traceable to their respective certificates of quality.

7.3.1 The physical storage of materials shall allow traceability of materials with receiving documents.

7.3.2 The release of materials for work fronts shall be made in accordance with procedure that allows the traceability of material in work fronts.

7.3.3 Pressurized components shall be subjected to PMI examination upon receipt, except for carbon steel material. Inspection of 100% of the batch. Non-conforming parts shall be identified and discarded.

7.3.4 Fastening elements (bolts/screws and nuts) shall be subjected to PMI examination, by sampling 20% of the batch upon receipt, except for the case of material in carbon steel. In case of non-conformity in any inspected part, sampling shall be extended to 100%. Non-conforming parts shall be identified and discarded.

7.3.5 Heat treated fastening elements (cases/screws and nuts) shall be subjected to hardness examination, by sampling 20% of the batch upon receipt. In case of non-conformity in any inspected part, sampling shall be extended to 100%. Non-conforming parts shall be identified and discarded.

7.3.6 Equipment internals shall be subjected to PMI examination upon receipt, sampling inspection on 20% of the batch upon receipt, except in the case of carbon steel material. In case of non-conformity in any inspected part, sampling shall be extended to 100%. Non-conforming parts shall be identified and discarded.

7.4 A visual inspection shall be performed in all materials, sections and equipment used, which shall be free of:

a) defects which reduce the thickness of the part to a value lower than that mentioned in 7.14;
b) corrosion above grade C of standard ISO 8501-1 for the following materials:
— carbon steels;
— molybdenum alloy steels;
— chromium molybdenum allow steels;
c) any degree of corrosion for stainless steels and nonferrous metals.

7.5 A map of the defects repaired on plates shall be prepared. Except for class B equipment.

7.6 Flange faces shall be visually checked, for verification of the condition and type of grooves, being unacceptable corrosion, scratches or notches.

7.7 PT examination shall be carried out in the sealing surface of RTJ flanges lined by weld overlay.

7.8 The hardness of flange seal face and solid metallic gaskets (example: ring-type joints - RTJ) shall be checked. The flange faces shall be harder than the gasket material, whose values shall be in accordance with PETROBRAS N-1693.

NOTE Hardness measurement in flanges for ring-type joints (RTJ) is at the bottom of the channel.

7.9 Clad Plates

In addition to PETROBRAS N-1707, the following requirements shall be followed:

7.9.1 A visual examination shall be carried out on the surface of the clad plates of corrosion-resistant linings for the existence of pits and other types of corrosion, thinning, cracks, pores and contamination, and the surfaces of the clad plate and linings shall be free of these defects.

7.9.2 The thickness of the stainless steel clad shall be measured generally at the edge of the plate, at four points, using a copper sulfate solution attack in accordance with ABNT NBR 16137. The thickness of the corrosion-resistant linings shall be measured by sampling. The measured thicknesses of the “clad” and the weld overlay shall comply with the prescription in 7.14.

7.9.3 Ultrasonic examination shall be carried out on clad plates to check the bonding of the clad before forming. After forming, ultrasonic shall be performed again only in places with the greatest degree of deformation, such as the toroidal region of heads and the central region of rolled rings (half the length of the ring). Meeting the requirements of 10.2.

7.10 Welding consumables shall comply with PETROBRAS N-133 and applicable technical specifications.

7.11 Identification by means of punching shall only be used when permitted by the equipment service and for nominal thickness greater than 6.4 mm in carbon steel and low alloy steel, provided that this marking is not exposed to operating conditions of the equipment that may cause stress corrosion.

NOTE The punching shall be of “low-stress type”.

7.12 Stainless steel, nickel or titanium alloys and their alloys shall be stored, handled and processed completely segregated from other materials, in order to avoid the risk of contamination.

7.13 Materials rejected during inspections shall be identified and segregated from other materials to avoid the risk of misuse.

7.14 The thickness of all manufactured sections shall be checked. Attention shall be drawn to regions with a greater degree of forming, such as the toroidal region of torispherical heads (transition region between the smaller radius and the larger radius). The measured thickness shall be greater than or equal to the thickness defined in the manufacturing drawing and indicated in the calculation report.

8 Fabrication

8.1 Fabrication Design

8.1.1 If the equipment is not delivered in one piece, the sections manufactured at shop shall consist of parts that are as large as possible for transportation, and shall be planned to minimize field fabrication and welding.

8.1.2 The opening for nozzles in shells and heads and the welding of components and accessories such as: supporting lugs, rings, couplings, nozzle reinforcements, stiffening rings, supports for thermal insulation and internals, both on the internal and external sides, located less than 150 mm from field welds, shall be done in accordance with the following criteria:

a) if the equipment was delivered in the assembled condition, all accessories indicated shall be welded at the shop;
b) if the equipment was delivered in parts or sections, and if postweld heat treatment was not provided, indicated accessories shall be welded in the field;
c) If the equipment was delivered in parts or sections and if postweld heat treatment was provided, the welding of the indicated accessories shall be carried out at the factory, and pre-assembly shall be carried out at the factory, whenever possible.

NOTE All parts to be welded in the field shall be furnished after they have been properly prepared, cut out in the correct dimensions and with bevels properly finished.

8.2 Auxiliary Assembly Devices

8.2.1 Auxiliary assembly devices shall comply with PETROBRAS N-133.

8.2.2 The spacing between rigid devices shall be equal to or greater than 500 mm. If it is necessary to use shorter spacing, technical justification shall be presented for analysis/approval by PETROBRAS.

8.3 Bevels

8.3.1 Bevels shall be dimensionally and visually checked for cleanliness and absence of the following defects:

a) lamellar decohesion;
b) pores;
c) cutting irregularities;
d) notches;
e) cracks;
f) discontinuities transverse to the surface;
g) discontinuities parallel to the surface, over 25 mm in length.

NOTE Paragraphs e), f) and g) shall be verified by non-destructive tests, when there is suspicion of those defects existence.

8.3.2 The visual examination shall be supplemented with the liquid penetrant or magnetic particle test in the following cases:

a) all bevels in any materials except carbon steel without impact test requirement;
b) bevel thicknesses greater than 38mm and bevels for openings for nozzles NPS 3” and greater in carbon steel equipment without impact test requirement;
c) all bevels recovered by welding.

NOTE The same defects listed in 8.3.1 are considered unacceptable.

8.4 Repair of Defects Found in Materials

Welding repairs in base metal or welded joint shall be done in accordance with 8.6. The same requirements of nondestructive examinations for welded joints shall be applied to their repairs.

8.5 Adjustment

8.5.1 Sections or plates of equipment shall be adjusted within the following tolerances::

a) joint opening: ± 1,5 mm in relation to design dimension;
b) misalignment: code ASME BPVC Section VIII Division 1 or Division 2;
c) out-of-roundness along the sections, on the upper and bottom edges and on the supporting region of the skirt:
   — for spheres: code ASME BPVC Section VIII, but not over 50 mm;
   — for other equipment: see Figure A.1, reference 19;
d) perimeter on the upper and bottom edges of each section, see Figure A.1, reference 20;
e) leveling of upper and bottom edges, measured by the difference between the maximum and minimum points of each edge:
   — 3 mm if the circular arc between the maximum and minimum points is equal to or smaller than 3 000 mm;
   — 4 mm if the same arc is greater than 3 000 mm;
f) curvature: see code ASME BPVC Section VIII, being applicable only to:
   — equipment subject to external pressure;
   — heads;
   — rolled plates;
g) total height or of sections or plates: see Figure A.1, reference 9;
h) verticality (plumb line);
   — for sphere legs: according to tolerances specified in the design;
   — for other equipment: see Figure A.1, reference 1;
i) angular deformation (peaking- see definition in PETROBRAS N-1738): see Figure A.1, reference 31;
j) offset between longitudinal joints: ± 10 mm in relation to design dimension;
k) distance between tangent lines: see Figure A.1, reference 2;
l) distance between the reference plan and bottom tangent line: see Figure A.1, reference 22;
m) maximum clearance between shell and skirt: see Figure A.1, reference 21.

8.5.2 It shall be made a pre-assembly, in the factory, of internal and external accessories of the pressure vessel (trays, cyclones, platforms and others). The scope and detailing of pre-assembly shall be agreed between the manufacturer and PETROBRAS, considering the particularities of each equipment item.

8.6 Welding

8.6.1 It shall be performed in accordance with this Standard and requirements of PETROBRAS N-133 and N-253.

8.6.2 The preheating, interpass heating, and post-heating methods allowed are gas burners, electric resistance or by induction, and **single-flare burners shall not be allowed**. It shall be preferred the use of electric resistance or induction. It shall be made a rigid control in the operation of preheating, interpass temperatures and post-heating.

8.6.3 For low temperature vessels or with controlled toughness, production test shall be carried out in accordance with code ASME BPVC Section VIII and applicable technical specification of PETROBRAS.

8.6.4 Temporary welds, such as: welds of auxiliary assembly devices, attachment welds of thermocouples and of supports of thermal insulation (placed for heat treatment), shall be removed after performing their function. These welds shall be removed without mechanical impacts. The region of these welds shall be ground smooth to eliminate points of stress concentration and examinations with liquid penetrant or magnetic particles. Comply also with item 10.5.

8.6.5 Internal reinforcements (excess reinforcement) in welds category C defined by ASME BPVC Section VIII shall be grinded in order to ensure the design tolerances of weld reinforcement established in ASME BPVC Section VIII.

8.6.6 When the use of assembly devices is required to keep the circularity (“bracing” type devices), it shall be observed the minimum distance of 250 mm from the circumferential joint to be welded.

8.6.7 The reinforcement of welds of the equipment shall be within the limits required by the equipment construction code.

8.6.8 The tolerances listed in 8.5.1 shall be checked after the welding of sections and at the end of fabrication, with the completed equipment.

8.6.9 If any repair in welding is required, it shall be done in accordance with standard PETROBRAS N-133.

8.7 Spin-holes

8.7.1 The spin-hole at the center of formed heads shall be closed with a plate disc with the same material specification of the head, welded and examined as required by ASME BPVC Section VIII.

8.7.2 Welds to close the spin-holes at the center of formed heads shall be fully radiographed.

8.8 Nozzles

8.8.1 Nozzles shall be located, adjusted and welded within the tolerances presented in Figure A.1, according to the corresponding number of references:

a) elevation: references 15 or 16;
b) deviation from nozzle axis measured in the arc: reference 32;
c) angular deviation from nozzle axis: reference 29;
d) projection; references 11 or 13;
e) perpendicularity of flange face in relation to the manhole or nozzle axis: references 12 and 14;
f) orientation of connecting flange holes with piping: references 27 and 28;
g) clearance between diameters for slip-on flanges: reference 10;
h) distance from nozzle flange face to tangent line: reference 23;
i) distance between centerlines of nozzles for level instruments: reference 30;
j) deviation between centerlines of nozzle and head: reference 26.

8.8.2 Welds of shell nozzles shall be examined by liquid penetrant or magnetic particle after the completion of the nozzle-to-shell weld.

8.8.3 Welds of the reinforcement plate shall be examined with liquid penetrant magnetic particle.

8.8.4 Nozzles equal to or greater than NPS 4” and self-reinforced nozzles with the opening in the shell having a diameter equal to or greater than 100 mm shall undergo ultrasonic examination at the following welded joints:

a) full penetration welded joint between nozzle neck and vessel shell;
b) welded joint between nozzle neck and reinforcement plate (if any).

NOTE 1 Adopt a stricter requirement than that stated in this item if it exists in the standard for the specific service of the vessel.

NOTE 2 It is not applied to equipment “Class B”.

8.8.5 A leak tightness test shall be performed in the nozzle reinforcement plates to ensure perfectly tightness.

8.8.5.1 For postweld heat treated equipment, the leak tightness test shall be carried out before the heat treatment.

8.8.5.2 Holes used for leak tightness test shall be filled with grease after the hydrostatic test.

8.8.6 Nozzle flange faces, bolts and nuts shall be protected against mechanical damage and corrosion in grooves and threads.

8.9 Thermal Insulation and Refractory Supports and Devices

The supports and devices shall be installed in accordance with applicable PETROBRAS standards and technical specifications.

8.10 Internals of Vessels and Columns

8.10.1 Tack welding and welding of rings and supports shall be performed in accordance with a qualified WPS.

8.10.2 When tack welding is performed, the level and elevation of tray support rings shall comply with the tolerances given in Figure A-1, references 5, 6 and 8.

8.10.3 After welding, the leveling of rings shall comply with the same tolerance indicated in Item 8.10.2.

8.10.4 Examinations of liquid penetrant or magnetic particles shall be performed at the welded joint between the rings and supports to the shell courses.

8.10.5 Tray sealing gaskets shall be installed according to the tray manufacturer's recommendations.

8.10.6 After assembly, the dimensions and level for trays and weir plates shall be checked and registered. The maximum tolerances shall be in accordance with Figure A-1, references 3, 4 and 7.

8.10.7 Rings and other supports shall be located, adjusted and welded within the tolerances presented in Figure A.1, according to the corresponding number of reference:

a) elevation of support ring: references 8 and 18;

b) distance between consecutive tray support rings: reference 6;
c) clearance between reinforcement ring or support ring and shell: reference 17;
d) see 10.14.4.

8.10.8 The sealing test of trays shall be carried out in accordance with the tray designer instructions.

8.11 Warped Parts

Repairs of warped parts, including due to welding, shall be done according to a repair procedure previously approved by PETROBRAS. See 10.19.

8.12 Equipment with Internal Metallic Lining and of Stainless Steel

8.12.1 Fabrication of equipment with internal metallic lining shall comply with the requirements of PETROBRAS N-1707.

8.12.2 The manufacturer shall separate an area of the shop to fabricate the equipment item and/or its parts in stainless steel, to avoid its contamination. It shall be adopted coating in rolling.

8.13 Identification of Materials and Welded Joints after Manufacturing

8.13.1 Pressurized components and welded joints shall be subjected to PMI examination after manufacturing (before PWHT or Hydrostatic Test, when there is no PWHT), except in the case of carbon steel material. The examination shall be carried out on 100% of the materials and welded joints, at least two points per welded joint.

8.13.2 Internal parts assembly welds carried out during their installation in the vessel shall be subjected to PMI examination after manufacturing, except in the case of carbon steel material. The examination shall be carried out on 100% of the welded joints, at least two points per welded joint.

9 Postweld Heat Treatment

All heat treatments performed during the equipment fabrication, such as Postweld Heat Treatment (PWHT), Dehydrogenation Heat Treatment (DHT), and Intermediate Stress Relief (ISR) shall follow the requirements of this Section.

9.1 It shall be prepared a specific Postweld Heat Treatment procedure containing at least the following information:

a) type of postweld heat treatment performed;
b) identification of applicable performance standard;
c) parameters required for performance, such as:
   — beginning and ending control temperatures;
   — minimum and maximum heating rate;
   — minimum and maximum treatment temperatures;
   — minimum and maximum treatment times;
   — minimum and maximum cooling rate;
   — maximum difference of temperature between thermocouples;
d) details of support and deformation control devices of equipment;
e) indication of performance method, such as:
   — treatment in furnace;
   — localized treatment;
f) indication of the type heating used;

g) furnace drawing (when applicable), indicating equipment the location inside it, burner nozzles or electrical resistances, and the overlap region when the equipment item is not fully inside the furnace;
h) when localized postweld heat treatment is performed: welded joint drawing, indicating the location and distribution of electrical resistances, width of soak band (SB), width of heated band (HB), width of gradient control band (GCB) including SB, HB and insulation, distribution of thermocouples, and thermal insulation attachment details;
i) type, quantity and identification (number and color in chart) of thermocouples employed;
j) attachment method of thermocouples to equipment;
k) equipment sketch and/or test coupon indicating the location and relative distance between thermocouples.
l) identification of those responsible for preparing and approving the procedure, according to PETROBRAS N-2301.

9.2 The preparation and execution of heat treatment shall be checked by a certified welding inspector.

9.3 The attachment weld of thermocouples shall be carried out according to 8.6.

9.4 Controlling and recording equipment shall be properly calibrated using the standards traced to "Rede Brasileira de Calibração" or ISO 17025 when the vessel is fabricated outside Brazil.

9.5 Nozzles shall be protected to prevent corrosion and warping.

9.6 Hardness Measurement after PWHT

9.6.1 Hardness measurements shall be taken after the postweld heat treatment, as follows:

a) a hardness measurement performed for each 6 m of weld;
b) at least two measurements shall be taken per longitudinal bead and per circumferential bead. The hardness measurement in circumferential joint shall be made in all crossings with longitudinal welds;
c) at least one hardness measurement shall be taken in the flange connection with neck and one in the nozzle connection with vessel;
d) at least one measurement shall be taken for each WPS used;
a) e) one measurement in region of removal of temporary welds.

NOTE The number of points for each measurement shall follow the requirements established by PETROBRAS N-133 for "hardness measurement test".

9.6.2 The maximum allowed removal of metal, when preparing the surface, shall correspond to a layer of 0.5 mm thick.

9.6.3 Hardness shall not exceed the values established by PETROBRAS N-133 for each material or according to the corresponding service standard.

9.7 Production test plates shall be treated together with the equipment. Their localization is established at the option of the PETROBRAS' inspection team.

9.8 Localized Postweld Heat Treatment

9.8.1 Localized postweld heat treatment is only allowed in circumferential welds and with prior approval of PETROBRAS.

9.8.2 Localized postweld heat treatment in welded nozzles and accessories may only be carried out with heated band circumferential to equipment, and with prior approval of PETROBRAS.

9.8.3 A detailed procedure shall be prepared, based on ASME BPVC Section VIII and WRC 452, specific for each weld, as per 9.1.

9.8.4 Linear-elastic stress analysis shall be carried out by means of the finite element method of the region to be submitted to localized postweld heat treated in the following cases:

— when the treated region is close to a geometrical discontinuity (example: head, support skirt, reinforcement ring, thickness transition and others);
— when there is any deviation of requirements established in WRC 452 and ASME BPVC Section VIII;
— when the region to be treated is subject, during heat treatment, to external efforts that may cause collapse or permanent deformation.

NOTE The stress (membrane + bending) in each evaluation point shall not exceed the yield stress of the material in its corresponding temperature.

9.9 Simulated Postweld Heat Treatment

It is the heat treatment performed in test specimens, intended to check the influence of Postweld Heat Treatment (Minimum and Maximum PWHTs) in mechanical properties of base metals, consumables and welds.

a) Minimum Postweld Heat Treatment (**Minimum PWHT**): It is the specified postweld heat treatment considering all manufacturing postweld heat treatments foreseen in the construction and assembly phases of the equipment, including the final PWHT.

b) Maximum Postweld Heat Treatment (**Maximum PWHT**): It is the specified postweld heat treatment considering all manufacturing postweld heat treatments foreseen in the construction and assembly phases of the equipment, including the final PWHT and, at least, one additional PWHT, for future use from PETROBRAS.

NOTE 1 It is recommended to provide 1 (one) additional manufacturing PWHT for repairs to be carried out during the manufacture of the equipment. [**[Recommended Practice]**]

NOTE 2 In the qualification phase of the Welding Procedure, two different PQR shall be generated, one to meet the Minimum PWHT condition and the other for the Maximum PWHT condition.

9.9.1 Equipment with Toughness Requirement

For toughness requirement, the pressure part materials (ex: plates, forgings, connections and others), the welding consumables and welding procedures shall be specified and qualified so as to ensure the mechanical properties after the Simulated PWHT, in accordance with tests required in item 9.9.3.

9.9.2 Equipment without Toughness Requirement

For carbon steel equipment without toughness requirements, the materials of pressurized parts (e.g. plates, forgings, connections and others), welding consumables and welding procedures shall be specified and qualified in order to guarantee the mechanical properties required by the construct code and PETROBRAS N-133.

9.9.3 Tests After Simulated PWHT

Tests after the simulated PWHT shall be performed in the following conditions:

9.9.3.1 Hardness

The hardness test shall be made after the Minimum PWHT and after the Maximum PWHT.

9.9.3.2 Tensile

The tensile test shall be made after the Minimum PWHT and after the Maximum PWHT.

9.9.3.3 Bending

In welding procedure qualification phase, the bending tests shall be performed after the Minimum PWHT and after the Maximum PWHT.

9.9.3.4 Impact Test
When required by the construction code or additional specification, the welded joint impact test (Heat affected Zone - HAZ and Cast Zone) shall be made after the Minimum PWHT and after the Maximum PWHT.

9.9.4 Simulated PWHT Total Time

The simulation of PWHT total time may be accomplished in only one cycle, and the calculation report shall be submitted for prior approval of PETROBRAS.

10 Fabrication Inspection

10.1 The non-destructive exams required after welding shall be carried out within the minimum time established by PETROBRAS N-133 after carrying out the last welding on pressurized parts and supporting parts of the equipment.

10.2 Clad plates (see 7.9.3) shall be ultrasonic examined after forming, in accordance with PETROBRAS N-1594, following the method and acceptance criteria of the clad plate specification with the aim of detecting disbound between the “clad” and the base metal. For equipment or components requiring postweld heat treatment, this examination shall be repeated after postweld heat treatment.

10.3 Welds of any parts, regardless of the material, thickness or service, shall be 100 % radiographed before any severe deformation (thickness to local radius ratio greater than 5 %), by any process, such as: spinning, pressing and rolling. After deformation, the welds and the most deformed areas shall be examined by magnetic particles or liquid penetrant, before any manufacturer operation is subsequently carried out.

10.4 For spot radiography examination, the weld crossing point shall be inspected, in order to achieve all welders and welding operators and the greatest number of positions not easily accessible.

NOTE The crossing examination shall be performed with film length placed on the longitudinal weld.

10.5 The removal of auxiliary assembly devices and temporary welds (see 8.6.4) shall be treated as defined in PETROBRAS N-133.

NOTE If the thickness is reduced, use ultrasonic to measure the thickness. The obtained value shall comply with item 7.14.

10.6 In heat exchangers, a liquid penetrant examination shall be done in tube-to-tubesheet welds and in curved region of U-tubes.

10.7 Liquid penetrant or magnetic particle examination shall be performed in the areas subject to gouging.

10.8 A magnetic particle or liquid penetrant examination shall be performed before the hydrostatic test in the following regions, except for equipment Class B.

a) internally and externally welded joints, covering a 200 mm wide area centered at the joint;
b) plate repair welds;
c) regions of weld removed from auxilia y assembly device and temporary weld;
d) welds for attachment of accessories.

10.9 For equipment subject to postweld heat treatment, the requirements in 10.8 shall be met before and after the postweld heat treatment.

10.10 Liquid penetrant or magnetic particle examination shall be carried out on vessel lifting devices (example: lifting lugs).

10.11 After manufacturing, a complete dimensional inspection shall be carried out with the issuance of a specific report covering all dimensions applicable to the equipment, referenced in Annex A, Figure A.1, including the required dimensions, the values found and their respective tolerances allowed by Figure A.1.

NOTE 1 For heat exchangers, the dimensional tolerances of TEMA are applied when there is no reference in Annex A.

NOTE 2 The dimensional inspection shall be performed by a certified inspector, according to ABNT NBR 15523, or equivalent standard in case of international supply.

10.11.1 All vessels delivered in the disassembled condition shall be fully or partially pre-mounted at the shop for a dimensional check. Pre-assembly shall be done with an adequate temporary attachment and shall cover the entire vessel or at least the largest possible part of the vessel.

10.11.2 Trays, gratings, baffles and other internal parts of the vessel that are dismountable and delivered in the disassembled condition shall also be fully pre-mounted at its installation position inside the vessel, at the manufacturer’s shop, when included within the scope of supply.

10.12 The manufacturer shall make available a template with holes of bases, to perform the foundation and placement of anchor bolts. The template shall be duly identified with the equipment identification name (example: T-501) and a reference point for positioning (example: North of job site, 0° of equipment and others).

10.13 It shall be checked whether the equipment supports are compatible with the arrangement and dimensions of the anchor bolts.

10.14 Equipment and sections sent ready shall be examined as established in 10.14.1 to 10.14.4.

10.14.1 The positioning of the nozzles shall be checked in accordance with the requirements specified in 8.8.1.

10.14.2 The internal supports shall be visually examined, checking the position and whether the attachment details of the supports are in accordance with what is specified in the design.

10.14.3 Baffle plates shall be visually examined, checking whether the position of the plates is in accordance with what is specified in the design, allowing a tolerance of ± 10 mm, in any direction.

10.14.4 The supports for platforms, ladders and piping systems and for reinforcement rings and thermal insulation shall be visually inspected, checking the following requirements for these support:

a) the location shall not interfere with other vessel parts;
b) they shall comply with the design, especially regarding their dimensions and fillet weld dimensions and the clearance specified in the Figure A.1, reference 17;
c) they shall have holes for water drainage, when necessary (if not, holes shall be drilled);
d) they shall have the oblong holes provided in the design for differential expansion between the various parts (if not, oblong holes shall be drilled);
e) if the plates continuously welded to the vessel have the hole functioning as a vent (this hole shall be left open and shall be filled with grease after the hydrostatic test).

10.15 All internals shall be visually examined for mechanical damage and corrosion, as per 7.4.

10.16 The beams shall be examined dimensionally to check whether the counter deflection is at the value specified in the design.

10.17 The beams and their supports shall be dimensionally examined to verify that they have the dimensions and holes for fixing in accordance with the design.

10.18 All internals shall be visually examined to check whether they have the drainage holes provided for in the design.

10.19 After unwarping of warped parts (see 8.11), the parts shall be examined using liquid penetrant or magnetic particles in regions of greatest strain.

11 Hydrostatic Test

11.1 General

11.1.1 It shall be prepared a specific hydrostatic test procedure, including at least the following information:

a) scope of procedure;
b) applicable documents;
c) test preparation requirements for equipment;
d) water quality and temperature;
e) details of filling and emptying connections;
f) location of pressure gauges and/or pressure control instruments;
g) joints and bolts for test;
h) safety devices;
i) parameters required for performance:
  — pressurization and depressurization rate;
  — test pressure;
  — permanence time in test pressure;
j) pressure x estimated time chart, including pressure levels and inspection points;
k) drainage, drying and cleaning after test;
l) acceptance criteria;
m) safety requirements;
n) template of certificate of test.

11.1.2 All vessels that are delivered completed in one piece shall be hydrostatic tested in the manufacturer's workshop, before shipment.

11.1.3 For equipment operating in vertical position, test shall be preferably performed with the vessel in the horizontal position and, in this case, the test pressure applied in factory shall be corrected to correspond to the test pressure established on the equipment nameplate.

NOTE 1 According to PETROBRAS N-266, the test pressure at the factory shall be included in the mechanical design drawing of the equipment.

NOTE 2 The hydrostatic test pressure that shall appear on the nameplate shall be the one calculated for its operating position, determined by the designer in accordance with the ASME BPVC Section VIII code.

11.1.4 All gaskets used in the hydrostatic test shall be in accordance with the design specification, an alternative shall have prior approval from PETROBRAS.

11.1.5 Bolts used in hydrostatic test shall comply with the design specification or have resistance compatible with the calculated torque. The design torque shall be applied in the tightening sequence, according to ASME PCC-1, using a calibrated torque wrench. The record of applied torque shall be presented to inspector at the moment of testing.

11.1.6 The hydrostat testing shall be performed before the equipment item is painted.

11.2 Test Occasion

For equipment without PWHT, the test shall only be performed after the time specified in 10.1. For equipment with PWHT, the test shall only be performed when the equipment reaches room temperature, and the forced cooling with water is not allowed.

NOTE Hydrostatic test shall be performed only after presentation of all examination, inspection and testing records provided in approved ITP.

11.3 Water

11.3.1 The test fluid characteristics shall neither cause degradation of equipment, nor cause scaling or build-up of sediments. If there are any requirements in the design regarding water purity characteristics, they shall be controlled.

11.3.2 For equipment in carbon steel and low alloy, in order to avoid the risk of brittle fracture during the test, the **water temperature** shall be maintained at least 17 ºC above the **minimum design metal temperature**, or at least at 15 ºC, whichever is higher. Therefore, hydrostatic testing with water at temperatures below 15 ºC is prohibited.

NOTE 1 The test temperature shall be equal to or greater than the value established herein, unless there is information on fragile characteristics of the equipment material, indicating the application of a test temperature different from the recommendation, as long as previously approved by PETROBRAS.

NOTE 2 If the water temperature is near the minimum limit, thermometers shall be installed in the bottom region of equipment.

NOTE 3 For materials different from carbon steel and steel alloy, the test water temperature shall be established in the equipment design, regarding its properties.

11.3.3 The maximum chloride content permitted in water shall be defined by the designer, but not greater than 50 ppm for equipment made of austenitic stainless steel or with an internal lining of this material.

11.4 Welding Prohibited

No weld shall be done on the equipment and on any part in electric contact with the equipment while the equipment is holding water.

11.5 Pressure Gauges

Pressure gauge and/or recorders shall have indelible identification and be in adequate physical condition. Calibration of instruments shall be carried out using standards traceable to “Rede Brasileira de Calibração” for national supply or ISO 17025 for international supply.

11.5.1 At least two pressure gauges shall be used, using a third recorder when the test lasts more than 6 hours, complying with the requirements of 11.5.1.1 to 11.5.1.4.

11.5.1.1 At least one of the pressure gauges shall be located in an easily accessible location, visible to the inspector throughout the pressurization and testing time, and one of the pressure gauges shall be located on top of the equipment.

11.5.1.2 The pressure gauges shall be calibrated before the start of the test, allowing a validity of 3 months for calibration.

11.5.1.3 The pressure gauge shall be selected so that the test pressure is within the middle third of the pressure gauge scale.

11.5.1.4 The smallest scale division shall not exceed 5% of the maximum scale indication.

11.5.2 Block valves shall be provided between the pressure gauges and the equipment, to allow replacement, if necessary.

11.6 Pneumatic and Hydro-pneumatic Pressure Tests

Due to the serious risk it represents, the pneumatic test will only be admitted exceptionally, and in each case, there shall be prior authorization from PETROBRAS. In this case, a specific procedure shall be issued and sent for approval by PETROBRAS.

11.7 Safety and Access

11.7.1 Safety conditions shall be provided before the test begins.

11.7.2 Access to all parts to be inspected during the test shall be provided.

11.7.3 Connections of auxiliary fill piping of the vessel shall have their pressure ratings compatible with the test pressure. For non-standardized accessories, the manufacturer shall evidence this compatibility.

11.7.4 No mechanical intervention may be performed in the equipment under test while there is pressure in system, such as, for example, tightening of flanges and bolts.

11.7.5 No inspection shall be performed in test pressure.

11.7.6 Personnel and equipment employed for test shall be in a safe place, which means they shall be out of the space defined by the effective isolation of risk area, corresponding to, at least, the reach water jet.

11.8 Scheme of Hydrostatic Test

The pressurization and inspection scheme for hydrostatic test shall comply with the requirements of items 11.8.1 to 11.8.5, represented in Figure 1.

11.8.1 Elevate the pressure until 50 % of Hydrostatic Test Pressure (PT) and proceed to the initial equipment inspection.

11.8.2 Increase the pressure gradually, with a rise ratio of 20 % of PT or lower, until it reaches the PT (see 11.7.5).

11.8.3 Remain in this pressure during for, at least, 30 minutes (see 11.7.5).

NOTE For shell and tube heat exchangers, the time shall be in accordance with PETROBRAS N-466.

11.8.4 Low down the pressure up to 77 % of the PT, using a similar reduction rate the one used for pressurization, and to execute the final inspection.

11.8.5 Decrease gradually the pressure until the atmospheric pressure, keeping in the same decompression raise, and open the upper nozzles to avoid the emptying vacuum.

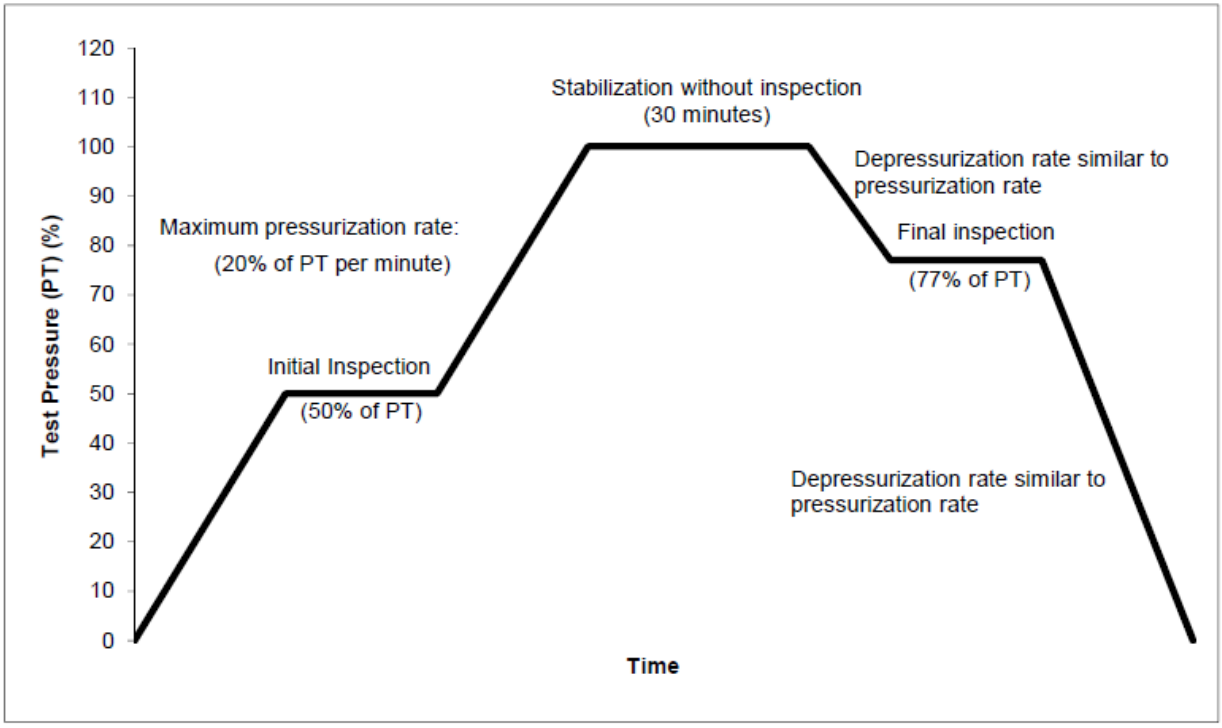


Figure 1 - Pressurization Scheme of Hydrostatic Test.

11.9 Procedure After the Test

11.9.1 The equipment shall be fully drained, dried and cleaned.

NOTE 1 Test water shall be drained immediately after the test conclusion, and it may not remain more than 48 hours inside the equipment.

NOTE 2 No test water waste is allowed after draining, drying and cleaning the equipment.

NOTE 3 It is not allowed to use heating to evaporate water waste on austenitic stainless steel surfaces.

NOTE 4 Pickling treatment is recommended after performing hydrostatic test in equipment made of austenitic stainless steel or with internal lining of this material according to ASTM A 380. [**Recommended Practice]**

11.9.2 In open nozzles, the flange faces shall be protected against corrosion and mechanical damage. In nozzles with RTJ ring flanges, it shall be checked whether there was damage to the sealing faces due to the tightening of the gasket used in the test. In case of damage exceeding the limits established by ASME PCC-1, repairs shall comply with the requirements of ASME PCC-2.

11.9.3 In equipment with cladding, a visual examination shall be performed to check if blistering occurred in the lining; if any, it shall be repaired and reexamined.

11.9.4 A dimensional examination of the perimeter of cylindrical shells and distances between equipment tangent lines shall be performed to check if there is permanent deformation after hydrostatic test.

11.9.5 The test completion certificate shall be issued, according to the approved procedure.

NOTE The pressure gauge graphic record shall always be attached to the test execution certificate.

11.10 Supplementary Requirements for Heat Exchanger Test

11.10.1 Before the beginning of the test, it shall be checked whether the tubesheets and floating head of the exchanger are designed for differential pressure:

a) if designed for differential pressure, each particular case shall be evaluated and the schemes presented in this Standard shall not be used;
b) if not designed for differential pressure, the procedure indicated in 11.10.4 shall be followed.

NOTE 1 In the case of differential pressure, each side of the equipment shall be tested individually, but components that are subjected to the differential pressure condition will be tested with both sides pressurized simultaneously. A device shall be provided to prevent sudden depressurization on just one side, overloading the component subjected to differential pressure.

NOTE 2 It is recommended to pressurize both sides by the same system and simultaneously, in such a way that if one side is depressurized, the other side will be depressurized instantly **[Recommended practice]**.

11.10.2 The hydrostatic test shall be performed in all heat exchangers.

11.10.3 If tube re-expanding is necessary due to leak during the hydrostatic test, the new test shall be performed after the tube has been re-expanded.

11.10.4 Test Procedure

11.10.4.1 The test execution sequence shall follow the exchanger assembly stages, as shown in Figures A.2 to A.6, where the arrows point the locations where sealing shall be checked.

11.10.4.2 The shell and tube bundle shall be tested so that possible leaks in the tube expanding (tube-to-tubesheet joint) be checked at least from one side.

12 Conditioning, Packaging and Shipping

12.1 Preparation for Shipment

12.1.1 All equipment and independent parts that are delivered disassembled shall have a marking made in paint and with letters at least 40 mm high, on the part itself or on the packaging. This marking shall contain, at a minimum, the following information:

a) equipment identification;
b) manufacturer's name;
c) number of Purchase and Service Order (PCS);
d) indication of parts or pieces of the equipment in the case of delivery in the disassembled condition (for this indication, the same numbering criterion of parts of fabrication drawings shall be adopted);
e) indication of the top side of the part or of the “North” direction of the design, so that the part is not assembled by mistake in the inverted position (in the case of pieces or parts of disassembled equipment).

NOTE 1 For all stress relief heat treated pieces of equipment and independent parts on which no field weld shall therefore be done, a sign shall be placed in a visible place reading: “DO NOT WELD”.

NOTE 2 The paint used on austenitic stainless steel equipment shall be free of halogen elements.

12.1.2 Equipment or parts made of thin plates or which in any way may be deformed during transportation or handling shall be adequately supported or stayed.

NOTE It is recommended that temporary transport bracing, when applicable, be identified in a different color so that they can be removed after installing the equipment.

12.1.3 All small parts, such as: bolts, nuts, studs, gaskets, flanges and bubble caps shall be properly boxed. A list of contents shall be placed inside the packaging and a copy of the list shall be sent separately.

12.1.4 Trays shall be protected against damage. Face-to-face piling of trays having installed valves or bubble caps shall not be allowed so as to avoid interlocking.

12.1.5 Plate edges with welding bevel, flange faces and other machined surfaces shall be coated with special anti-corrosive compounds and protected by means of bars, steel plates or wooden parts to be firmly secured against mechanical damage.

12.1.6 Threads of bolts, nuts, studs and stay rods shall be protected against corrosion with anti-seize grease.

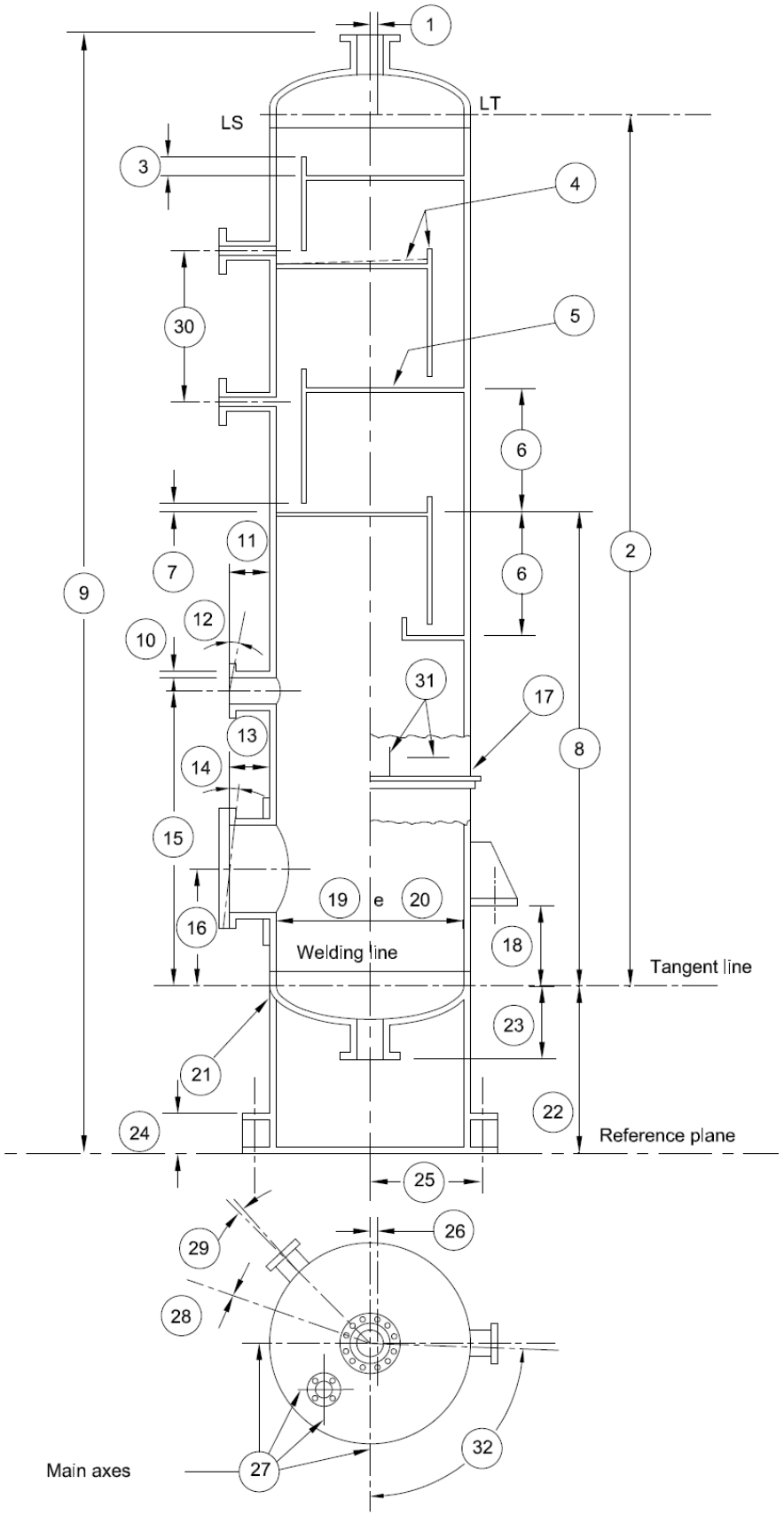
12.1.7 When painting is part of the manufacturer’s scope of supply, it shall be strictly performed as described for the painting plan previously approved, complying with PETROBRAS N-13.

12.2 Shipment

12.2.1 The equipment shall be adequately supported and secured in the transporting vehicle. The rolled or formed parts shall be supported in such a manner as to not be deformed during transportation.

12.2.2 Equipment items made of austenitic stainless steel or lined with this material, when exposed to marine atmosphere during transport or conditioning period at the unit, shall be inerted with nitrogen (at 0,5 kgf/cm^2) or silica gel, with procedure previously approved by PETROBRAS.

Annex A - Figures



NOTE: For items marked with numbers inside circles, see the following references.

Figure A.1 -Assembly Tolerances

References (See Figure A.1)

1 - Verticality (plumb line):

a) maximum deviation allowed from the perpendicular to the reference plane: 1 mm per meter, maximum of 20 m;
b) maximum deviation allowed between adjacent horizontal welds (per ring): ± 3 mm.

2 - Distance between tangent lines: ± 0,5 mm by 300 mm in length, maximum of 25 mm.

3 - Weir plate height: ± 3 mm.

4 - Maximum out-of-levelness of tray and weir plate:

a) Ø < 1 200 mm: 3 mm;
b) 1 200 mm ≤ Ø ≤ 2 800 mm: 5 mm;
c) Ø > 2 800 mm: 7 mm.

NOTE: At least six points per tray shall be measured.

5 - Maximum out-of-levelness of top of the tray supporting ring: 1 mm in any 300 mm measured along the chord.

6 - Distance between consecutive tray support rings: ± 3 mm.

7 - Distance from weir plate to tray: ± 3 mm.

8 - Elevation of tray supporting ring above tangent line: ± 6 mm.

9 - Total height or height of sections or plates: ± 0,5 mm by 300 mm in length, maximum of 25 mm.

10 - Slip-on flanges: maximum clearance between the internal diameters of the flange and the external diameter of the nozzle neck:

a) nominal diameter up to 1 200 mm: 4 mm;
b) nominal diameter up to 1 201 mm to 1 800 mm: 6 mm;
c) nominal diameter of 1 801 mm and above: 8 mm.

11 - Nozzle projection in relation to the external side of the shell: ± 3 mm.

12 - Perpendicularity of the face of the flanges in relation to the nozzle axis: ± 1/2°.

13 - Projection of manholes and handholes in relation to the external side of the shell: ± 6 mm.

14 - erpendicularity of the face of the manhole flanges in relation to the manhole axis:: ± 1°.

15 - Centerline locations of:

a) manholes, handholes and nozzles located near trays and weir plates, in relation to supporting rings: ± 3 mm;
b) nozzles not mentioned in paragraph a), in relation to the tangent line: ± 6 mm.

Figure A.1 - Assembly Tolerances (Continued)

16 - Location of centerlines of manholes and handholes not mentioned in reference 15, paragraph a), in relation to the tangent line: ± 12 mm.

17 - Shell reinforcement rings and insulation rings support shall not have a clearance over 4 mm between the external surface of the shell and the inside diameter of the ring (or support).

18 - Distance from tangent line to support lugs: + 6 mm, -0.

19 - Out-of-roundness along the sections, on the upper and bottom edges and on the supporting region of the skirt: code ASME BPVC Section VIII, but never exceeding:

a) 20 mm, for internal diameter ≤ 4000 mm;
b) 30 mm, for internal diameter > 4000 mm and ≤ 6000 mm;
c) 35 mm , for internal diameter > 6000 mm.

20 - Perimeter of the upper and lower edges of each section:

a) Ø ≤ 1 200 mm: ± 9 mm;
b) 1 200 mm < Ø ≤ 2 100 mm: ± 12 mm;
c) 2 100 mm < Ø ≤ 5 000 mm: ± 18 mm;
d) 5 000 mm < Ø: ± 24 mm.

21 - Maximum clearance between shell and skirt before welding: 3 mm.

22 - Separation between skirt ring and tangent line: +0, -6 mm.

23 - Distance from nozzle flange face to tangent line: ± 3 mm.

24 - Height of anchor bolts: ± 3 mm.

25 - Separation of anchor bolts in relation to the coordinate axes of the equipment: ± 3 mm.

26 - Deviation between centerlines of nozzle and head: ± 3 mm.

27 - The vertical line and the main axes shall always pass through the middle of the space between two adjacent flange bolt holes.

28 - Maximum rotation of flange holes in relation to the position indicated in the design: ± 1,5 mm.

29 - Angular deviation from the nozzle axis for radial or non-radial nozzles: ± 1/2°.

30 - Distance between centerlines of nozzles for level instruments: ± 2 mm.

31 - Peaking: for a 915 mm template, the maximum separation tolerance shall be 6.4 mm.

NOTE Template shall be applied from the inside and outside. Separation shall be measured between the two supported template ends.

32 - Deviation from nozzle axis: ± 3 mm.

Figure A.1 - Assembly Tolerances (Continued)

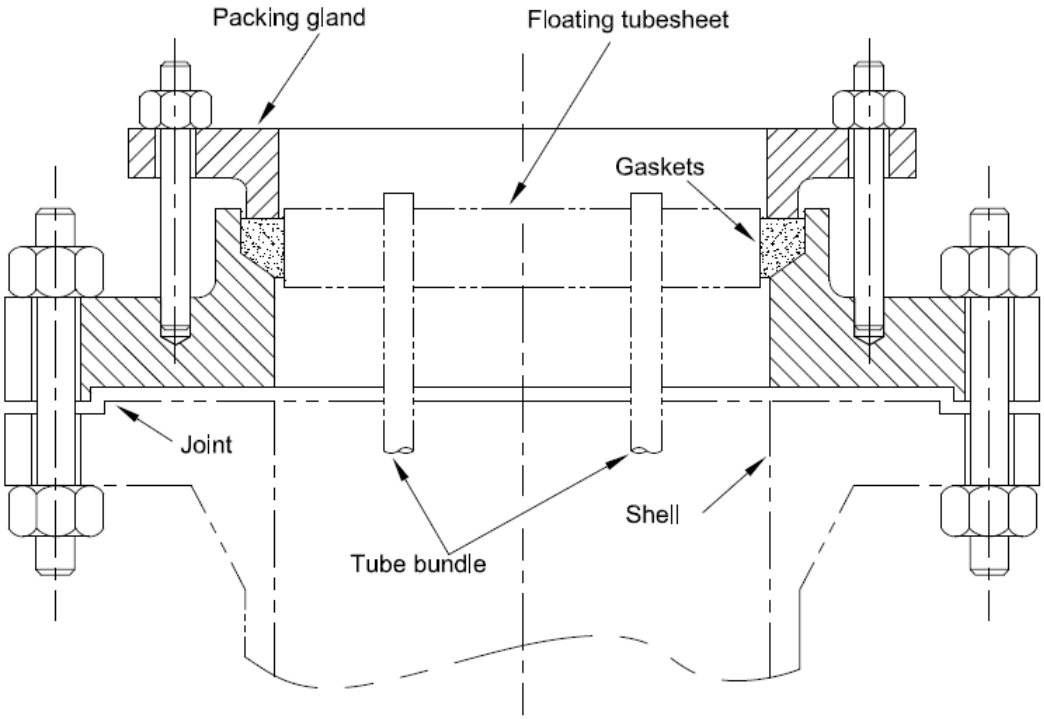


Figure A.2 – Test Ring

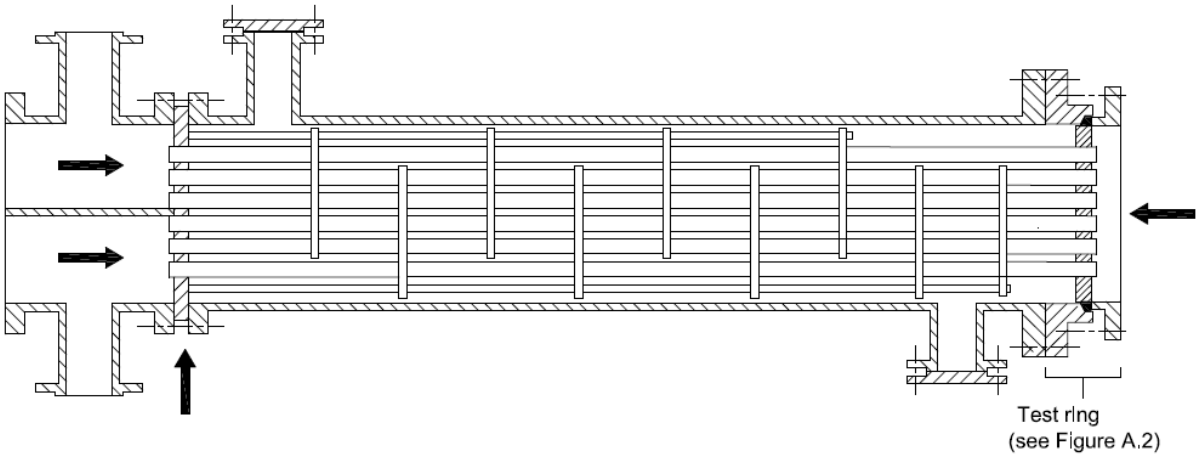


Figure A.3.1 – Shell Test (Pressurized Shell, Shell Cover Dismounted and Replaced by Test Ring)

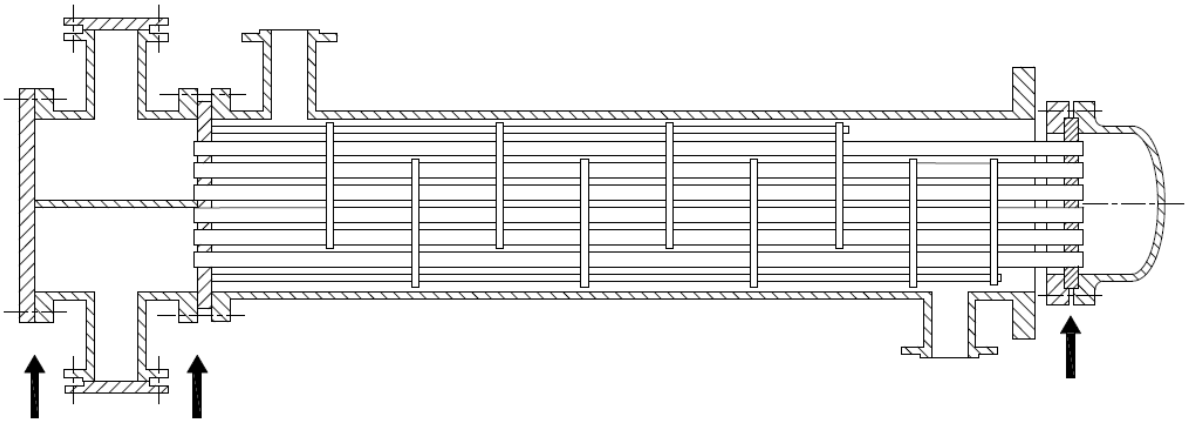


Figure A.3.2 – Tube Bundle Test (Spool and Tube Bundle under Pressure, Shell Cover Dismounted)

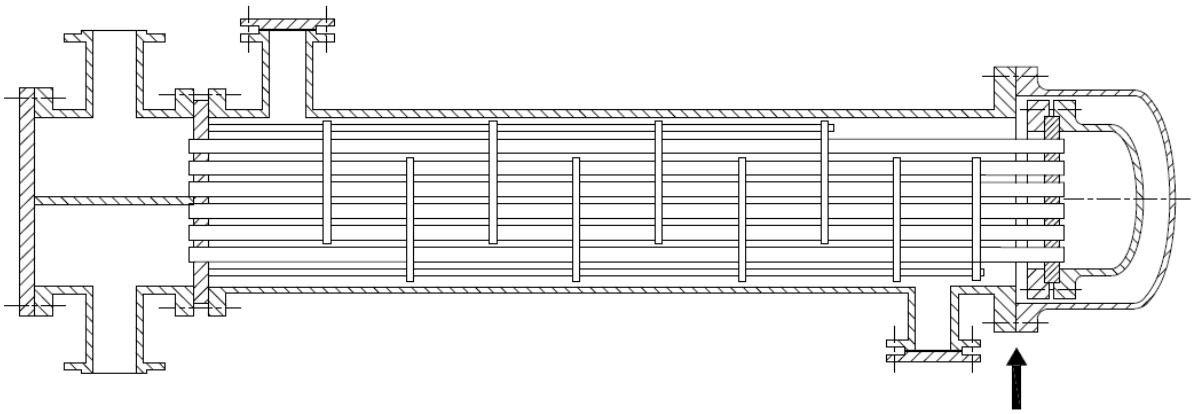


Figure A.3.3 – Shell Cover Test (Pressurized Shell, Shell Cover Mounted)

NOTE: The arrows indicate the places where possible leaks are to be inspected.

Figure A.3 - Testing of Floating Head-type Heat Exchanger, having Shell Design Pressure higher than the Design Pressure of Tubes

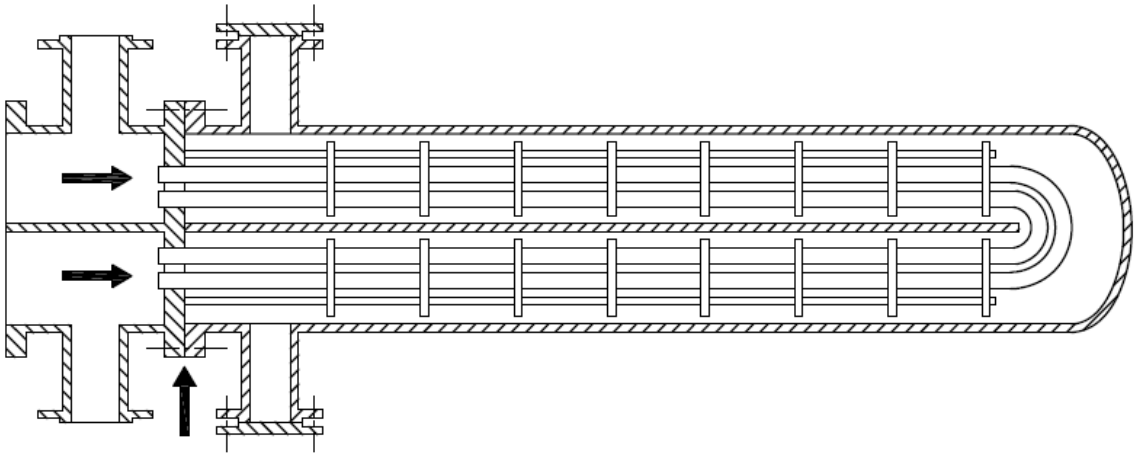


Figure A.4.1 – Shell Test

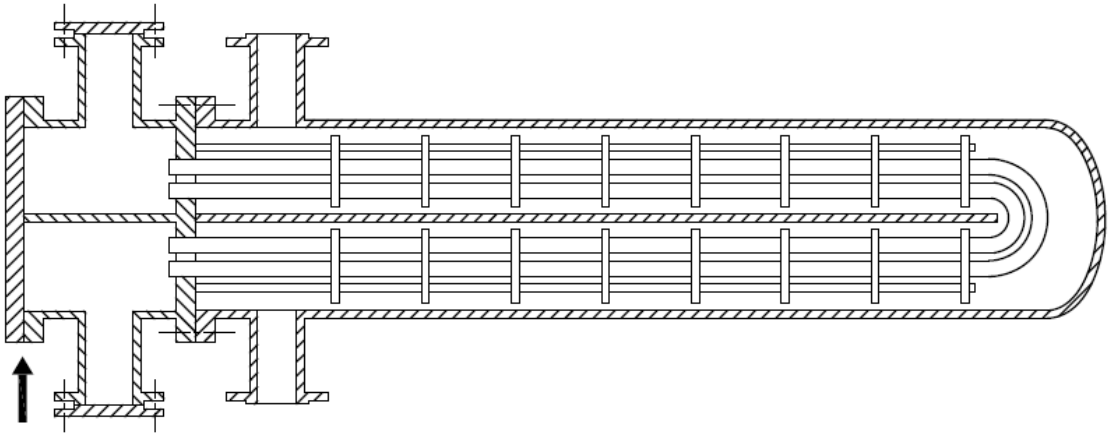


Figure A.4.2 – Tube Bundle Test

NOTE: The arrows indicate the places where possible leaks are to be inspected.

Figure A-4 - Testing of Heat Exchanger with U-tubes, having Shell Design Pressure higher than the Design Pressure of Tubes

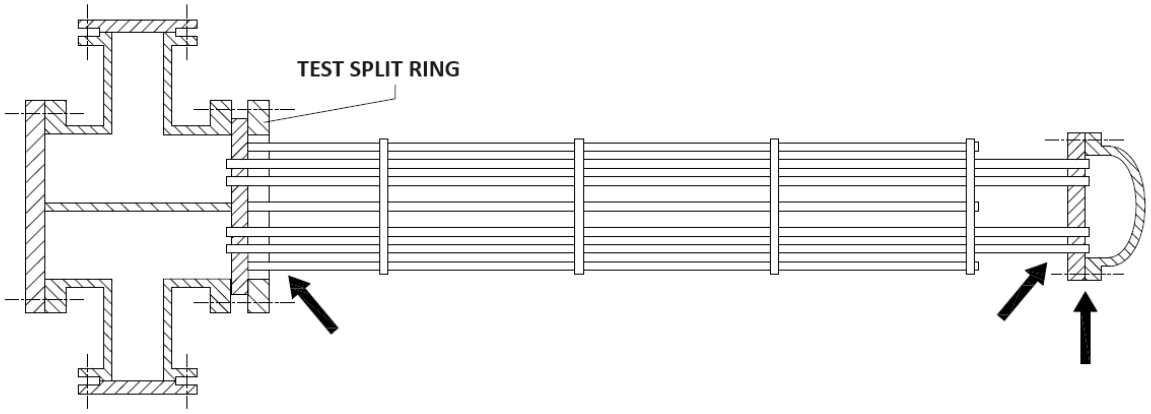


Figure A.5.1 – Tube Bundle Test

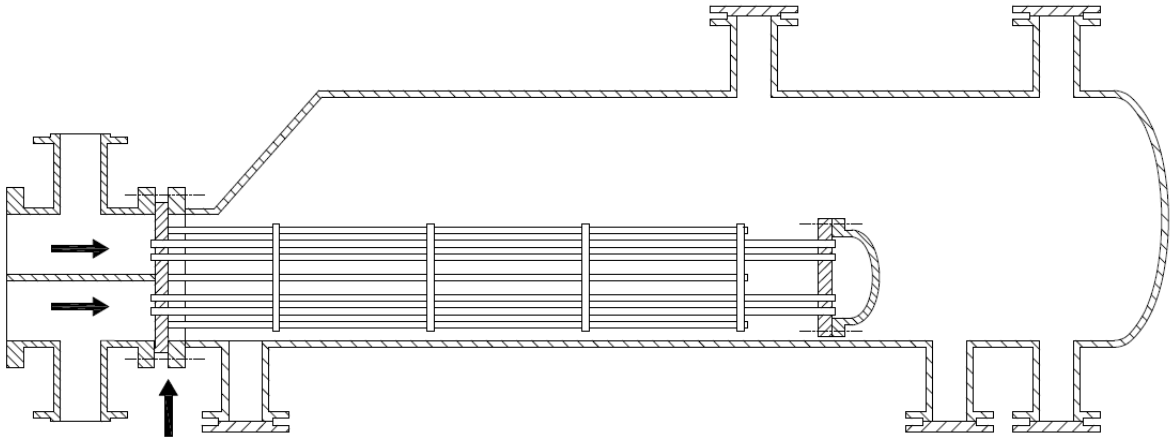


Figure A.5.2 – Shell Test

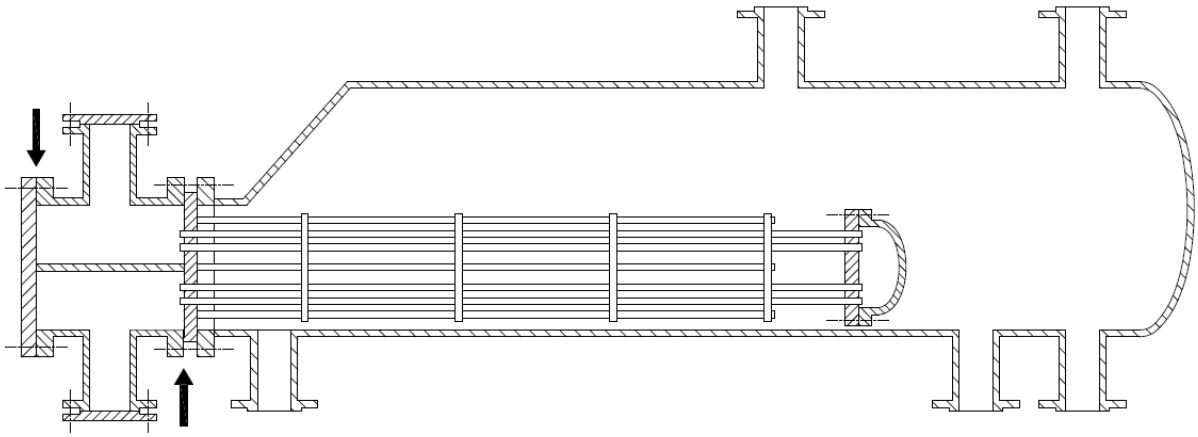


Figure A.5.3 – Chanel Test

NOTE: The arrows indicate the places where possible leaks are to be inspected.

Figure A.5 - Test of Kettle-type Heat Exchanger

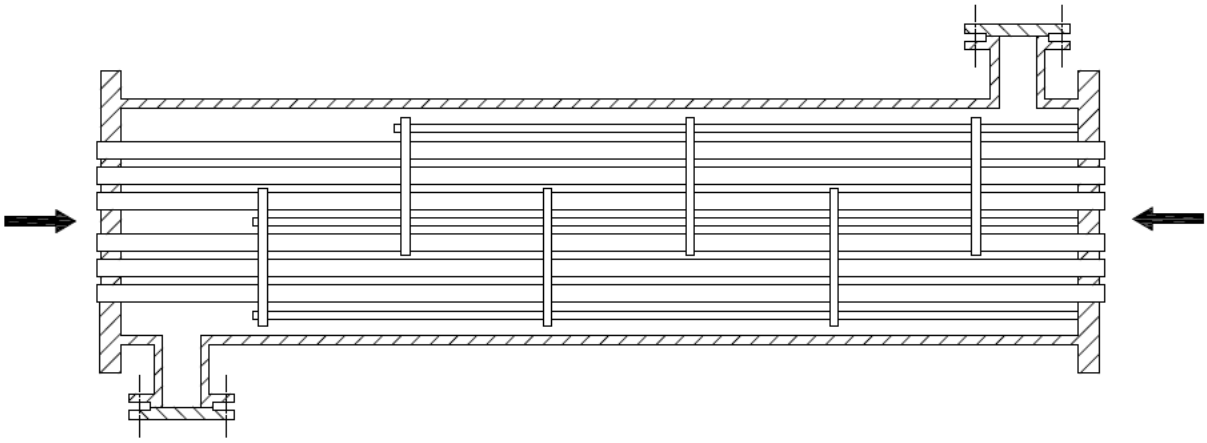


Figure A.6.1 – Shell Test

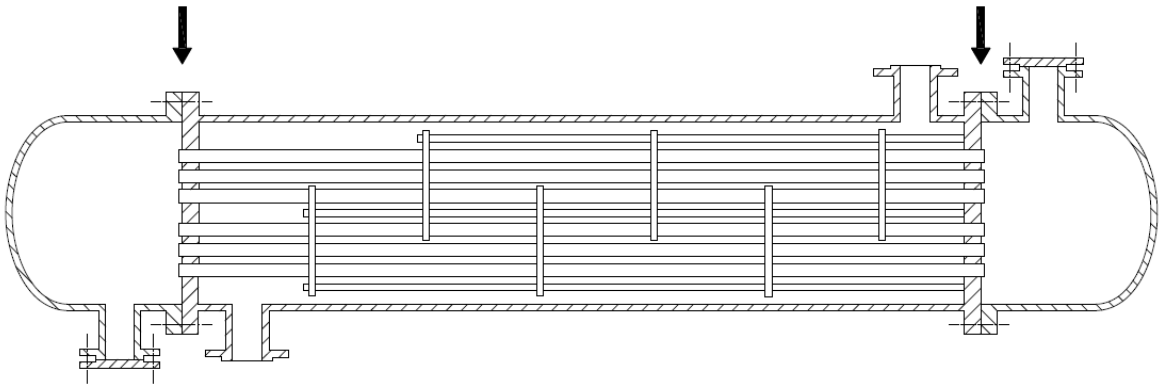


Figure A.6.2-Head Cover Test

NOTES:
1) These heat exchangers may or may not have expansion joints and support lugs.
2) The arrows indicate the places where possible leaks are to be inspected.

Figure A.6 – Testing of Heat Exchanger with Fixed Tubesheets

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