

MECHANICAL DESIGN OF SHELL-AND-TUBE HEAT EXCHANGER

Procedure

This Standard replaces and cancels the previous revision.

The Responsible CONTEC Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is fully responsible for adopting and applying the clauses thereof.

CONTEC

Comissão de Normas
Técnicas

Technical Requirement: a provision established as being the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("nonconformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by the verb forms "shall", "it is necessary...", "is required to...", "it is required that...", "is to...", "has to...", "only ... is permitted", and other equivalent expressions having an imperative nature.

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 particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by the verbal form "should" and equivalent expressions such as "it is recommended that..." and "ought to..." (verbs of a nonmandatory nature). It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "nonconformity" to this Standard that may contribute to the improvement thereof shall be submitted to the Responsible CONTEC Subcommittee.

SC - 02

Tanks and Vessels

Proposed revisions to this Standard shall be submitted to the Responsible CONTEC Subcommittee, indicating the alphanumeric identification and revision of the Standard, the clause(s) to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

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Foreword

PETROBRAS technical standards are prepared by Working Groups - GTs (consisting of PETROBRAS specialists and specialists from PETROBRAS Subsidiaries), are commented by Local Representatives (representatives of the Industrial Units, Engineering Projects, Technical Divisions and PETROBRAS Subsidiaries), are approved by the Responsible Subcommittees - SCs (consisting of specialists belonging to the same specialty, representing the various PETROBRAS Departments and PETROBRAS Subsidiaries), and approved by the CONTEC General Assembly (consisting of representatives of the Superintendencies of the PETROBRAS Departments and PETROBRAS Subsidiaries that use PETROBRAS technical standards). A PETROBRAS technical standard is subjected to revision at any time by the Responsible Subcommittee and must be reviewed every 5 years to be revalidated, revised or cancelled. PETROBRAS technical standards are prepared in accordance with standard PETROBRAS N-1. For complete information about PETROBRAS standards see PETROBRAS Technical Standards Catalog.

1 SCOPE

1.1 This Standard establishes the requirements for the mechanical design of shell-and-tube heat exchangers. This Standard complements standard PETROBRAS [N-253](#).

1.2 For purposes of this Standard the designation “shell-and-tube heat exchanger” covers heat exchangers in general, and heaters, coolers, reboilers and other shell-and-tube heat exchanging equipment.

1.3 This Standard is applied to heat exchangers designed beginning with its date of issuance.

1.4 This Standard contains only Technical Requirements.

2 SUPPLEMENTARY DOCUMENTS

The documents listed below are mentioned in the text and contain valid requirements for the present Standard.

PETROBRAS N-133	- Welding;
PETROBRAS N-253	- Pressure Vessel Design;
PETROBRAS N-266	- Pressure Vessel Design Presentation;
PETROBRAS N-2159	- Acessórios de Permutador de Calor;
ABNT NBR 6405	- Rugosidade das Superfícies;
API STD 660	- Shell-and-Tube Heat Exchangers for General Refinery Services;
ASME Section II A SA-450/ SA-450M	- Specification for General Requirements for Carbon, Ferritic Alloy and Austenic Alloy Steel Tubes;
ASME Boiler and Pressure Vessel Code - Section VIII - Division 1	(see Note 2);
BSI BS 5500	- Unfired Fusion Welded Pressure Vessels;
TEMA	- Standards of Tubular Exchanger Manufacturers Association.

- Notes:
- 1) For documents for which only the Portuguese version is available, the PETROBRAS department that uses this Standard should be consulted for any information required for the specific application.
 - 2) The parts mentioned in this Standard are from the ASME Section VIII - Division 1 - July 1, 1999, which usually have its indications unchanged. In case of happening any alteration it will be issued Amendment for this Standard with the new indications.

3 GENERAL REQUIREMENTS

3.1 Technical Requirements for Presentation of Proposals and Design

The technical requirements for presentation of proposals and design of heat exchangers shall be in accordance with standard PETROBRAS [N-266](#).

3.2 Designer's Responsibility

3.2.1 The designer's responsibilities are defined at standard PETROBRAS [N-253](#).

3.2.2 In those cases where PETROBRAS provides Data Sheets, basic drawing showing the arrangement and general dimensions, technical specification or other specific document for the heat exchanger, the mechanical design shall fully comply with those documents, that prevail over this Standard. Any discrepancies or alternatives suggested will only be accepted after being expressly approved by PETROBRAS.

3.3 Types of Heat Exchangers

3.3.1 Except as otherwise expressly specified by PETROBRAS, all shell-and-tube heat exchangers shall be in accordance with one of the types indicated in the standard TEMA.

3.3.2 For any heat exchanger that does not precisely correspond to any of the standardized types referred to in the preceding item, a description and drawings giving complete details, shall be prepared.

3.4 Mechanical Design

3.4.1 The mechanical design of the heat exchangers shall be done in strict compliance with the standards and other requirements of standard PETROBRAS [N-253](#).

3.4.2 The design shall also strictly comply with the latest edition of the standard TEMA. As a general rule, "Section R" of the standard TEMA shall be followed and the design may be in accordance with Sections "B"/"C" only when expressly specified or accepted by PETROBRAS.

4 DESIGN CRITERIA

4.1 Pressure

4.1.1 The design pressure shall be determined in accordance with the standard TEMA.

4.1.2 Except as expressly accepted by PETROBRAS, no part of the exchanger may be designed for differential pressure.

4.1.2.1 Where the heat exchanger is designed for differential pressure, provision shall be made for a safety system ensuring this design condition for components subject to pressure at the same time on both the shell side and the tube side.

4.1.2.2 A warning plate shall be used in heat exchangers designed for differential pressure. The design indication for differential pressure shall be recorded also in the tag plate of the heat exchanger, as by standard PETROBRAS [N-2159](#).

4.2 Temperature

4.2.1 The design temperature shall be determined in accordance with the standard TEMA.

4.2.2 The temperature for determining the allowable stress on bolts, studs, nuts and gaskets shall be the same as that of the respective flange. For flanges used for connecting the channel to the shell (or the channel to the tubesheet and shell) the temperature for determining the allowable stress shall be the highest temperature between the shell flange and the channel flange.

4.2.3 For heat exchangers with more than a single shell in series, different design temperatures shall be established for each shell, in accordance with the operating temperatures of each one. That criterion need not be observed when the temperature differences between the various shells do not entail the use of different materials, do not entail different allowable stresses, or do not entail the use of expansion joint.

4.3 Other Criteria

4.3.1 In the mechanical design of heat exchangers with more than one shell directly connected to the other, the additional stresses due to the weights and stresses resulting from differential expansion between shells shall always be taken into account.

4.3.2 Heat exchangers that are identical or of the same type, shall contain the largest possible number of exchangeable parts. In particular, the tube bundle and test ring shall be exchangeable with other equipment whenever this is economically viable.

5 MATERIALS

5.1 For all parts in contact with both fluids (e.g. tubes, tubesheets and floating head) material selection shall be based on the corrosiveness of both fluids and on the following temperature criteria:

- a) both fluids having a minimum design temperature exceeding 15 °C: the temperature for material selection is based on the temperature of the hottest fluid;
- b) one of the fluids having a minimum design temperature equal to or less than 15 °C: the temperature for material selection is based on the temperature of the coldest fluid;
- c) the temperature for material selection is based on the design temperature of the component determined in accordance with standard TEMA.

5.2 The material of tubes shall be compatible with the material of tubesheets, so as to avoid formation of a galvanic cell.

5.3 Bimetallic tubes may be used, provided they are accepted by PETROBRAS.

5.4 For shell fluids that are electrolyte, the material of baffles, tie-rods and spacers of the tube bundle shall be compatible with the material of the tubes, so as to avoid formation of a galvanic cell. These parts may be made of commercial quality materials.

5.5 For service in which the exchanger is classified as of class equal or greater than ASME 600, it shall be used seamless tube (e. g.: in carbon steel ASTM A 179).

5.6 It is obligatorily used seamless tube when the connection tube x tubesheet is by strength welding, as standard ASME Section VIII - Division 1, UW-20.

5.6.1 In this case, tubes must be submitted to a hydrostatic test by the tubes manufacturer, as standard ASME Section II A SA - 450 / SA - 450M.

5.6.2 The hydrostatic test pressure of the tubes shall be the greatest value between:

- a) hydrostatic test pressure given by standard ASME Section II A SA - 450 / SA - 450M;
- b) hydrostatic test pressure given by standard ASME Section VIII, Divisions 1 or 2 (pursuant the design).

Note: In any of the cases, a) or b), the tube wall stress, determined by standard ASME Section II A SA - 450 / SA - 450M, shall not surpass 80 % yield strength of the tube material.

5.7 Welded carbon steel tubes (ASTM specification A 214), when used for corrosive services or for temperatures over 200 °C shall be subjected, as an additional requirement, to the following tests:

- a) test for local corrosion-susceptibility of welded tubes;
- b) hydrostatic test or Eddy Current test.

5.8 Non-metallic anti-corrosive coating, inside the shell, may only be used in exceptional circumstances, when expressly authorized by PETROBRAS.

5.9 Tubesheets may only be provided with anti-corrosive coating (including clad-plate construction) on the tube side, i.e., on the side where the tube ends are expanded or welded. The anti-corrosive coating on the shell side is only allowed when expressly authorized by PETROBRAS.

5.10 For tubesheets with anti-corrosive metal coatings, only the clad plate construction (in accordance with specifications ASTM A 263, A 264 or A 265) is allowed without PETROBRAS prior approval. Any other type of coating shall be subject to the express approval of PETROBRAS in every case.

5.11 No corrosion allowance shall be added to heat exchanger tubes, made of any material.

5.12 Corrosion allowances may not be less than the minimum values required by the standard TEMA.

5.13 The specified corrosion allowance shall be added to the female faces (male and female flanges) and to grooves (tongue and groove flanges).

5.14 Internal bolts, studs and nuts (e.g. for floating head) shall be made of material assuredly resistant to corrosion by the shell side fluid. If stress corrosion is possible in carbon steel bolts, the hardness control with heat treatment, if necessary, shall be specified.

5.15 weld consumables shall be in conformity with standard PETROBRAS [N-133](#). Consumable shall be qualified by the Certification System of FBTS (Fundação Brasileira de Tecnologia de Soldagem).

6 SHELL AND CHANNEL

6.1 Shell welds shall be ground on the inside to facilitate the removal of the tube bundle.

6.2 When there is a difference in thickness between shell plates or between the shell and the cover, the plates shall be aligned by the inside surface.

6.3 For heat exchangers with a coated channel, the channel cover shall also be coated. The anti-corrosive coating shall extend all the way around the insertion slots of the pass partitions and the entire seating area of the gasket.

6.4 Whenever there is anti-corrosive lining in the shell or the weight of the tube bundle is greater than 29.5 kN (3 000 kgf), it is necessary to place slide bars in the tube bundle and tracks in the shell, to allow the removal of the tube bundle without damaging the coating. These bars and tracks shall be made of material resistant to corrosion by the shell fluid.

7 GIRTH FLANGES

Girth flanges refer to flanges of the channel, shell, shell cover and floating head cover that do not belong to nozzles.

7.1 Types of Girth Flanges

Girth flanges shall be in accordance with the types shown in this item.

7.1.1 Welding Neck Flange

The forged steel welding neck flange may be used for any rating and diameter.

7.1.2 Slip-on Flange

Slip-on flange, forged steel, may be used for ratings 150 and 300 and any standard diameter, but limited to 400 °C. Slip-on flange shall not be used when the corrosion allowance is greater than 3 mm.

7.1.3 Ring-Type Flange

Ring-type flanges, forged steel, hot-rolled, seamless, or those made of plate or bar shall be selected according to the design pressure in accordance with this item.

7.1.3.1 For a design pressure up to and including 2 000 kPa (290 psi), regardless of the fabrication, ring-type flanges shall comply with one of the Figures 2-4 (7), (8), (8a), (9), (9a), (10), (10a) or (11) of ASME Code, Section VIII, Division 1, since the corrosion allowance is less than 3.0 mm.

7.1.3.2 For design pressure over 2 000 kPa (290 psi), regardless of the fabrication, ring-type flanges shall comply with one of Figures 2-4 (7) or (11) of ASME Code, Section VIII, Division 1.

7.2 Flange Calculation

7.2.1 Forged steel flanges having all their dimensions (including hole circle, number and diameter of bolts) exactly in accordance with ASME B.16.5 or ASME B16.47, are accepted for working pressures and temperatures up to the limits established in this Standard, without the need for special calculations.

7.2.2 Flanges of any other dimensions or construction systems shall obligatorily be calculated in accordance with ASME Code, Section VIII, Div. 1, and the calculations shall be available at any time to PETROBRAS for examination, whenever so requested.

7.3 Fabrication

7.3.1 Welding neck flange obtained by machining a forged ring is only allowed in exceptional cases and with PETROBRAS approval. In this case, it shall be made a 3 directions traction test.

7.3.2 Ring-type flanges made of bar or plate of any rating shall be obtained from rolled or forged rings, having not more than 2 fully radiographed butt welds. These flanges shall be heat treated as required in ASME Code Section VIII, Division 1, and the surfaces of the original plate shall be parallel to the axis of the finished flange. These flanges are only allowed with PETROBRAS approval.

7.4 Types of Facing and Joints

The types of facing and joints for girth flanges shall be selected according to FIGURE A-1 and to the TABLE A-1 of the ANNEX A.

7.5 Bolts and Holes of Flanges

The minimum diameter of flange bolts shall be 3/4". All threads shall be according to ASME B1.1 Class 2A, except as otherwise specified. Bolt holes are Class 2B and shall be drilled and the seating surfaces of nuts in flanges shall be machined to a minimum finish having an average roughness of not more than 0.003 mm (0.000125 in). Flange holes shall be symmetric to design directions N-S or E-W or to the vertical direction.

8 FLANGE OF FLOATING HEAD COVER

The flange of the floating head cover shall be preferably in accordance with Figure 1-6 (d) of ASME Code Section VIII, Division 1.

9 TUBESHEETS

9.1 Tubesheets may be of forged construction or be made of plate, with forged construction being adopted whenever possible. If the tubesheet is made of welded plates, the weld shall be fully radiographed or ultrasonically inspected.

9.2 Tubesheets welded to the shell (or to the channel) shall comply with one of the following figures in ASME Code Section VIII, Division 1: UW. 13.2 (i), UW. 13.2 (j), UW 13.2 (k) and UW. 13.3 (all types). Tubesheets with welds as shown in figures UW. 13.2 (h) and UW 13.2 (l) are not acceptable. Tubesheets in accordance with any of the types shown in Figures UW 13.3 shall in all cases be of forged construction, regardless of the diameter and material used.

9.3 The attachment details for fixed tubesheets shall be in accordance with FIGURE A-2 of the ANNEX A.

9.4 As a general rule, tubes shall be expanded and broached in the holes of tubesheets. The tube ends shall exceed by 3 mm the surface of the tubesheet except in the case of vertical heat exchangers where the tube end must face the surface of the top tubesheet. There shall be at least 2 expansion slots, on the base metal in each hole of the tubesheet, approximately 3 mm wide and 0.4 mm deep. In case of clad tubesheet it must have 1 more expansion slot, made in the clad.

9.5 For tube-to-tubesheet connection by expansion, the metallic coating shall be at least 9 mm thick so as to fully contain the 3^o expansion slot of the tubes. The minimum distance between the edge of the slot and the outer face of the coating shall be 3 mm.

9.6 Broaching shall not be used in the following cases:

- a) service rating equal or greater than ASME 600;
- b) service with lethal fluid, in only one of the sides (shell side or tubes side), with operation pressure superior to operation pressure of the other fluid;
- c) service whose leakage is inadmissible (e. g.: H₂ and H₂S), in only one of the sides (shell side or tubes side), with operation pressure superior to operation pressure of the other fluid (service).

9.7 The connection tube-to-tubesheet shall be by total strength welding as ASME Code Section VIII, Division 1, item UW-20 (a) (1), in the cases mentioned in item 9.6. In these cases, it is only permitted another kind of connection tube-to-tubesheet when explicitly permitted by PETROBRAS. Always the strength welding is used, the tube shall be expanded inside the hole.

9.8 For tubesheets with anti-corrosive metallic coating, the anti-corrosive coating shall extend all the way around the insertion slots of pass partitions and the entire seating area of the gasket.

9.9 If the tube-to-clad connection is obtained by a seal weld, the minimum thickness of the clad shall be 3 mm.

9.10 The minimum distance between the edge of the tube holes and the groove for the peripheral, gasket shall be 1.5 mm in the case of tubes expanded in the tubesheet, and, 3.0 mm for tubes welded to the tubesheet.

10 TUBE BUNDLE

10.1 The maximum recommended weight for the tube bundle is 98.1 kN (10 000 kgf). Weights exceeding this value shall be approved by PETROBRAS, and in this case, the manufacturer user shall supply the exchanger with an own device to allow the removal and assembly of tube bundle.

10.2 The thickness of tube bundle baffles shall not be less than twice the corrosion allowance adopted for the shell. Wherever necessary, transverse baffles shall be slotted to allow complete drainage of the shell.

10.3 For tubesheets fitted with "U" tube bundle, the following minimum values shall be observed for the mean radius of curvature of the tubes:

- a) 3/4" outside diameter tubes: 35 mm;
- b) 1" outside diameter tubes: 40 mm.

- Notes:
- 1) "U" bends shall in all cases be one-piece tubes, and circumferential joints will not be accepted.
 - 2) The manufacturer shall evaluate the need for heat treatment for residual stress relief after bending.

10.4 Equipment with type A or B front-end head shall be fitted with a special test ring (companion flange) to permit pressurization of the shell, for testing, with the tubesheet in place and the head removed. Alternatively, the outside diameter of the tubesheet may be the same as that of shell flanges.

10.5 The tube bundle of vertical heat exchangers shall be removable from the upper part.

11 FLOATING HEAD COVER

11.1 The floating head cover shall have one of the configurations shown in FIGURE A-3 of the ANNEX A.

11.2 Bolts of the floating head cover shall be easily accessible with the shell cover removed.

12 EXPANSION JOINT

12.1 General

12.1.1 Expansion joint may only be used when specified or authorized by PETROBRAS, its adoption being forbidden in the following cases:

- a) lethal fluid service;
- b) equipment operating with gas at pressure above value to be given as by the design.

12.1.2 The supplier shall take into account not only the specified external movements to be absorbed by the expansion joint but also those resulting from the geometry of the joint itself. Possible interferences between the internal sleeve of the joint and the body due to rotating movements shall be checked by the supplier.

12.1.3 All joints shall be designed for at least 5 000 coinciding design pressure and temperature cycles.

12.1.4 The expansion joint shall have an internal sleeve welded to the end upstream from the flow so as to minimize deposits and erosion on the bellows.

12.1.5 The expansion joint may be pre-stressed on assembly so as to minimize stresses in the joint, when the heat exchanger starts operating. Design displacements shall be based on the temperature of the hottest fluid. Pre-stressing shall be carried out at the supplier's works before transportation.

12.1.6 All welds in the body (shell and head) shall be butt-welded joints. The inspection shall be 100 % radiographic (X rays or gamma rays) 100 % magnetic particle or liquid penetrant, including welds joining the bellows to the body.

12.1.7 All welds of the bellows shall be 100 % inspected by liquid penetrant and 100 % radiographed, before the pipe conformation to form the bellows, and 100 % inspected by liquid penetrant after conformation.

12.2 External Expansion Joint

12.2.1 Bellows shall be fitted with an external removable protection box for containing the fluid, in the case of leakage, with a warning signal being sounded in the control room. Provision shall also be made for drainage space. This external bulkhead shall not be thermally insulated, and shall also be used in the transportation of the joint, so as to protect the bellows.

12.2.2 Provision is to be made for a system of additional support for the equipment, or positioning of the joint so that it is not subject to additional loads other than those due to pressure, deadweight and displacements due to expansion to be absorbed.

12.3 Internal Expansion Joint

12.3.1 When an expansion joint is required for heat exchangers with a single pass in the tubes, it shall be located internally between the floating head cover and the shell cover (see FIGURE A-4 of the ANNEX A).

12.3.2 The internal expansion joint shall be designed for the total internal and external pressure values, applied independently.

13 NOZZLES

Nozzles shall be in accordance with standard PETROBRAS [N-253](#) and standard TEMA.

14 OTHER DETAILS

14.1 Jack screws shall be placed at all connections with girth flanges.

14.2 Lifting lugs shall be placed on the channel, channel cover, shell cover and floating head, in accordance with standard PETROBRAS [N-2159](#). Wherever insulation is used, the lugs shall be long enough to avoid interference with the insulation. Lugs shall be placed in such a position that the respective parts can be hoisted plumb vertical.

14.3 Provision shall also be made for threaded holes on the tubesheets of tube bundles, to allow insertion of eyebolts for the removal of the bundle. On tubesheets with anti-corrosive coating, these holes shall be located on the periphery, beyond the coating.

14.4 Except in special cases subject to prior approval by PETROBRAS, connections with prisoner bolts are not allowed in the shell, channel or tubesheets.

14.5 In heat exchangers with two-phase flux on the shell side and in the other cases specified by TEMA, the impingement baffle in the inlet nozzle of the shell should have 2 plates with staggered slots, as shown in FIGURE A-5 of the ANNEX A. The slots shall not be located in line with the tube.

14.6 All external bolts shall have surplus threaded length equal to the thickness of the nut, after being tightened up. The surplus threaded length allows the use of bolt tensor device while the bolt is being tightened up.

15 SUPPORTS

Supports shall be in accordance with standard PETROBRAS [N-2159](#).

16 TAGPLATE

All heat exchangers shall be fitted with a tagplate in accordance with standard PETROBRAS [N-2159](#).

/ANNEX A

ANNEX A - FIGURES AND TABLE

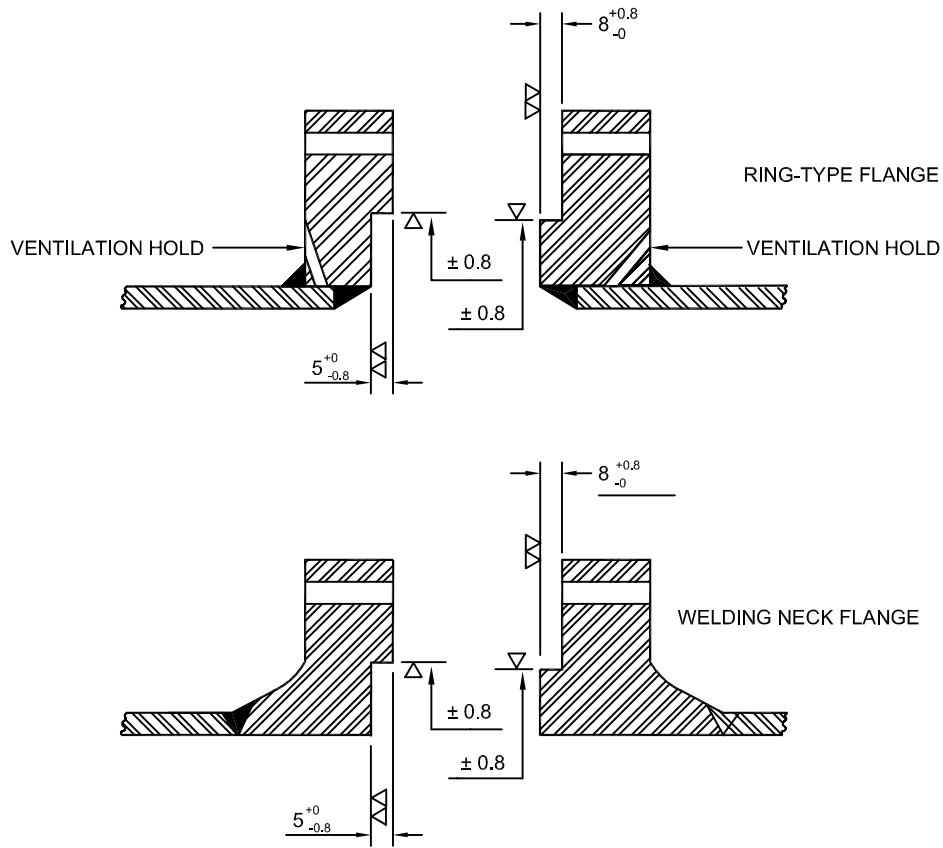


FIGURE A-1.1 - "Male/Female" Type

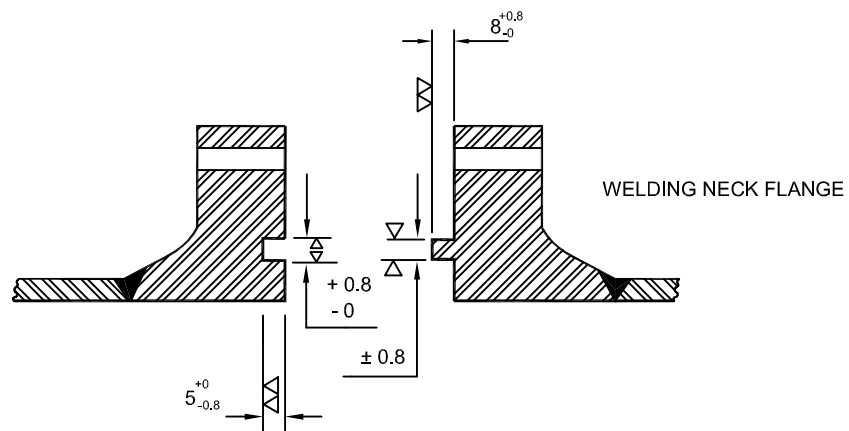


FIGURE A-1.2 - "Tongue/Groove" Type

FIGURE A-1 - TYPES OF FACING FOR GIRTH FLANGES

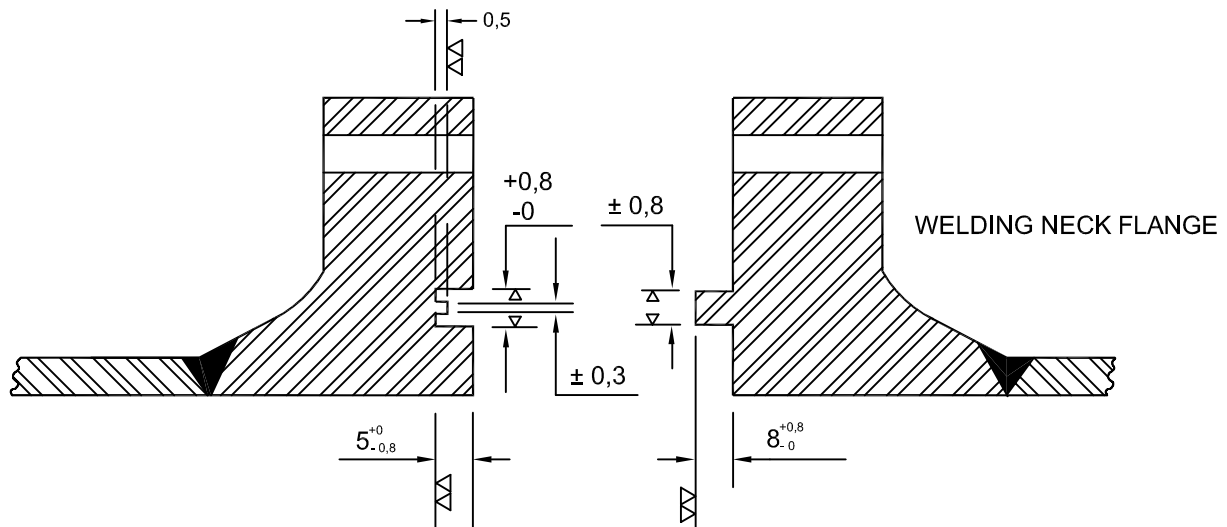
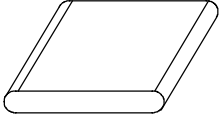



FIGURE A-1.3 - "Tongue/Groove with Nubbin"

- NOTES: 1) GIRTH FLANGES SHALL BE FOR STANDARD CONFINED JOINT CONSTRUCTION, UNLESS OTHERWISE SPECIFIED. WHEN THESE FLANGES HAVE A TONGUE AND GROOVE FACING, THE GROOVES SHALL BE DONE IN THE FIXED TUBESHEET AND ON THE CHANNEL COVER.
- 2) FOR FLAT DOUBLE JACKETED ASBESTOS FILLED OR SOLID METAL GASKETS, FLANGES SHALL HAVE A SMOOTH FINISH WITH A MEAN ROUGHNESS (Ra - AS PER STANDARD ABNT NBR 6405) OF NOT MORE THAN 0.0015 mm (0.000063 in = ∇).
- 3) USE MEAN ROUGHNESS FINISH (Ra - AS PER STANDARD ABNT NBR 6405) OF NOT MORE THAN 0.003 mm (0.000125 in) WHERE ∇ IS INDICATED.

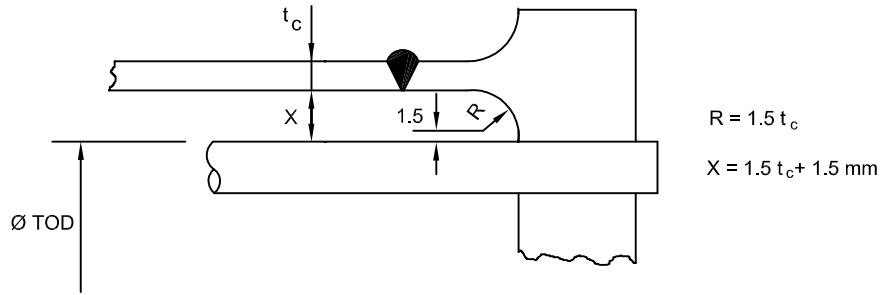
FIGURE A-1 - TYPES OF FACING FOR GIRTH FLANGES

TABLE A-1 - TYPE OF GASKETS FOR GIRTH FLANGES

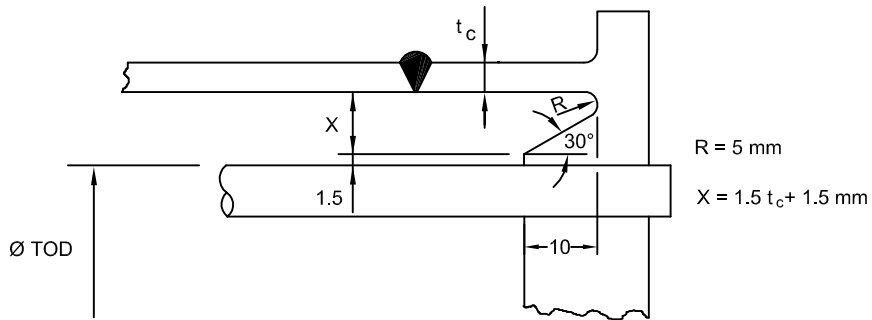
Type of Gasket	Material	Factor m	Stress γ (psi)	Scheme
Flat Double Jacketed Asbestos or Flexible Graphite Filled	ALUMINUM	3.25	5 500	
	COPPER OR BRASS	3.50	6 500	
	CARBON STEEL	3.75	7 600	
	MONEL®	3.50	8 000	
	4-6 % CHROMIUM	3.75	9 000	
	STAINLESS STEEL	3.75	9 000	
Solid Metal	ALUMINUM	4.00	8 600	
	COPPER OR BRASS	4.75	13 000	
	CARBON STEEL	5.50	18 000	
	MONEL® OR 4-6% CHROMIUM	6.00	21 800	
	STAINLESS STEEL	6.50	26 000	

- Notes:
- 1) TABLE A-1 is in agreement with ASME Section VIII, Division 1.
 - 2) Except as otherwise specified, gaskets for all girth flanges of heat exchangers shall be selected as follows:
 - a) for ratings 150 # and 300 #, with a design temperature between 0 °C and 250 °C: flat double jacketed carbon steel asbestos or flexible graphite filled gasket with male/female type facing;
 - b) for ratings 150 # and 300 #, with design temperature below 15 °C or above 250 °C, or ratings 400 # and 600 # for any design temperature: flat double jacketed austenitic stainless steel asbestos or flexible graphite filled gasket for flanges with male/female facing;
 - c) for ratings 600 # operating gas or vapor or ratings 900 # or higher for any design temperature: solid metal gasket for flanges with tongue and groove facing or tongue and groove with nubbin; in this case the gasket material shall not form a galvanic cell with the flange and its hardness shall be 30 Brinell below the hardness of the flange facing, the following maximum hardness values being indicated according to the gasket material:
 - gasket material: carbon steel maximum hardness: 90 HB;
 - gasket material: alloy steel 1 @ 5 % Cr maximum hardness: 130 HB;
 - gasket material: stainless steel 304 or 316 maximum hardness: 130 HB;
 - gasket material: stainless steel 304l or 316l maximum hardness: 110 HB;
 - d) in any type of specified gasket the nature of the fluid in contact with it shall be taken into account when the material is specified.

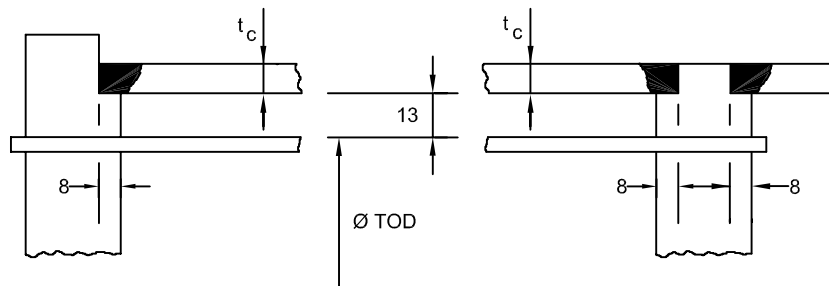
¹ MONEL® (MONEL Metal): Material of property of International Nickel Corp. This information is given to help the users of this Standard and does not mean an obligatory utilization of the mentioned product. It is possible to use equivalent product, since it carries to an equal result.


DETAIL 1

GROOVE ATTACHMENT IN THE TUBESHEET, IN THE SHELL WELDING REGION (PER ASME SECTION VIII).


DETAIL 2

GROOVE ATTACHMENT IN THE TUBESHEET, IN THE SHELL WELDING REGION (PER ASME SECTION VIII).


DETAIL 3

TUBESHEET WELDED DIRECTLY TO SHELL (PER ASME SECTION VIII).

NOTE: ALL DIMENSIONS IN MILLIMETERS.

FIGURE A-2 - FIXED TUBESHEET ATTACHMENT DETAILS

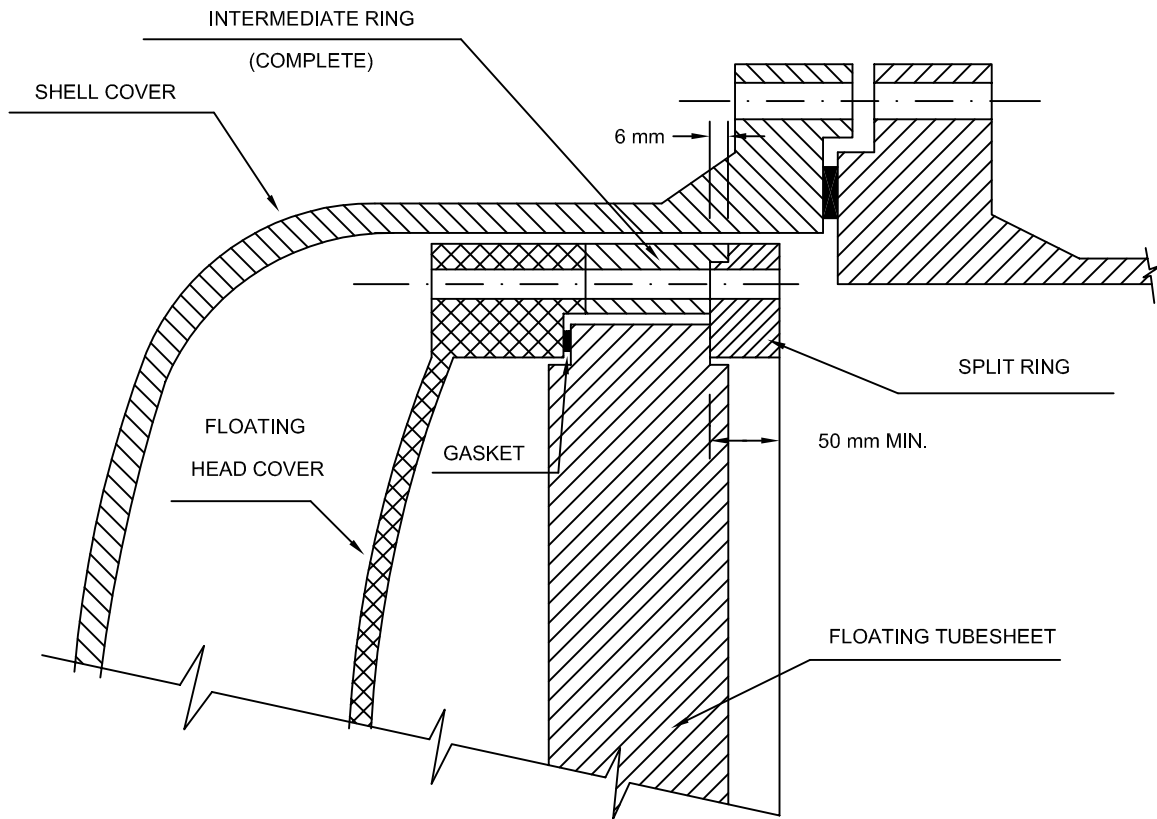
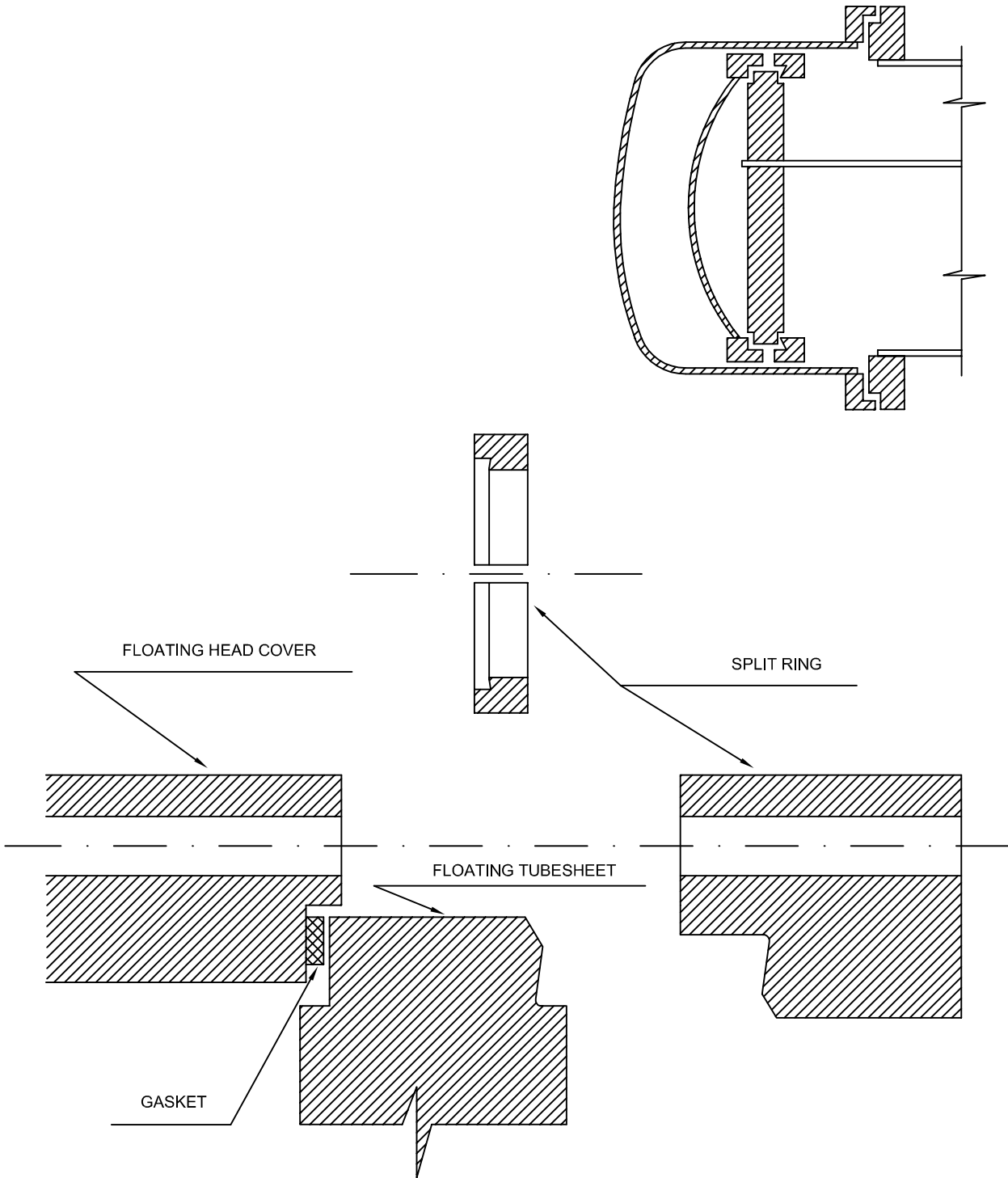


FIGURE A-3.1 - Configuration 1

FIGURE A-3 - ASSEMBLY OF FLOATING HEAD COVER



NOTE: CALCULATION FOR THIS CONFIGURATION 2 MUST BE AS BY STANDARD BS 5500 - ENQUIRE CASE 36.

FIGURE A-3.2 - Configuration 2

FIGURE A-3 - ASSEMBLY OF FLOATING HEAD COVER

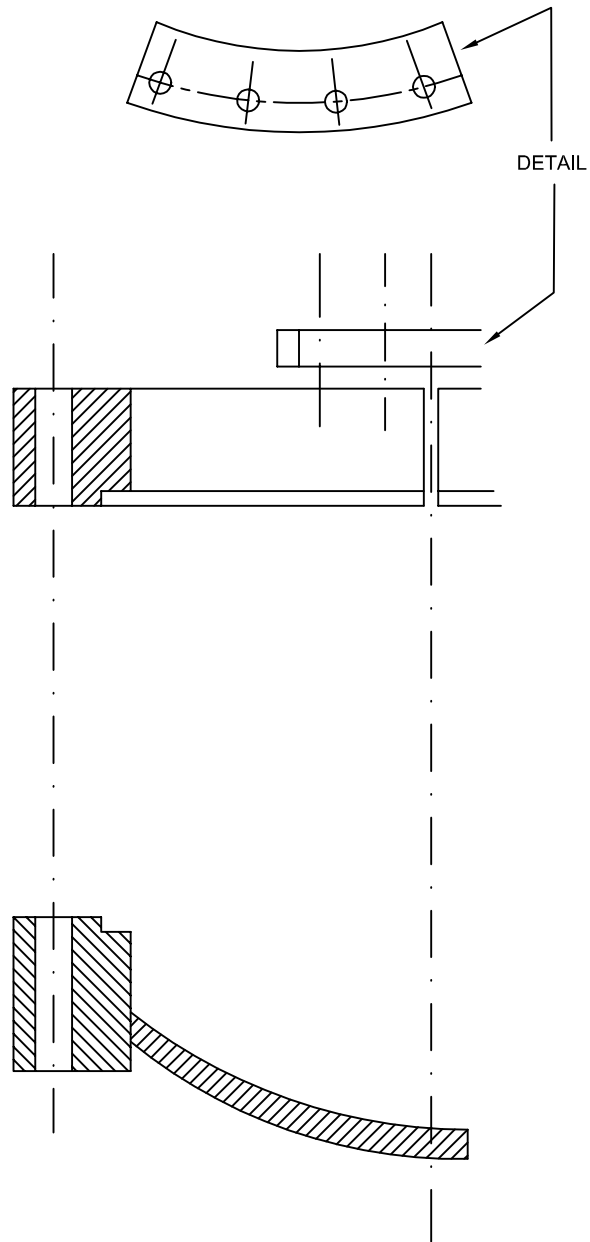


FIGURE A-3.3 - Splice Plate For the Configurations 1 and 2

FIGURE A-3 - ASSEMBLY OF FLOATING HEAD COVER

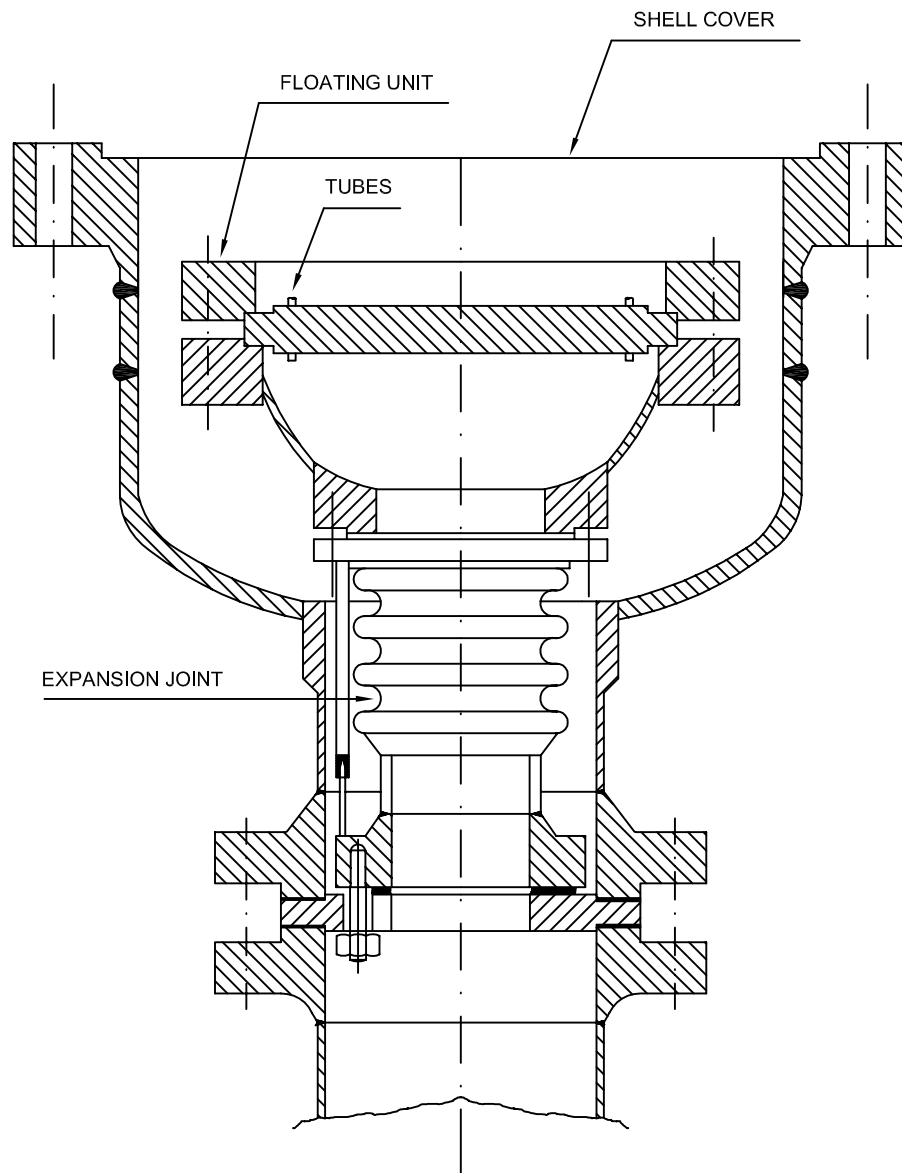
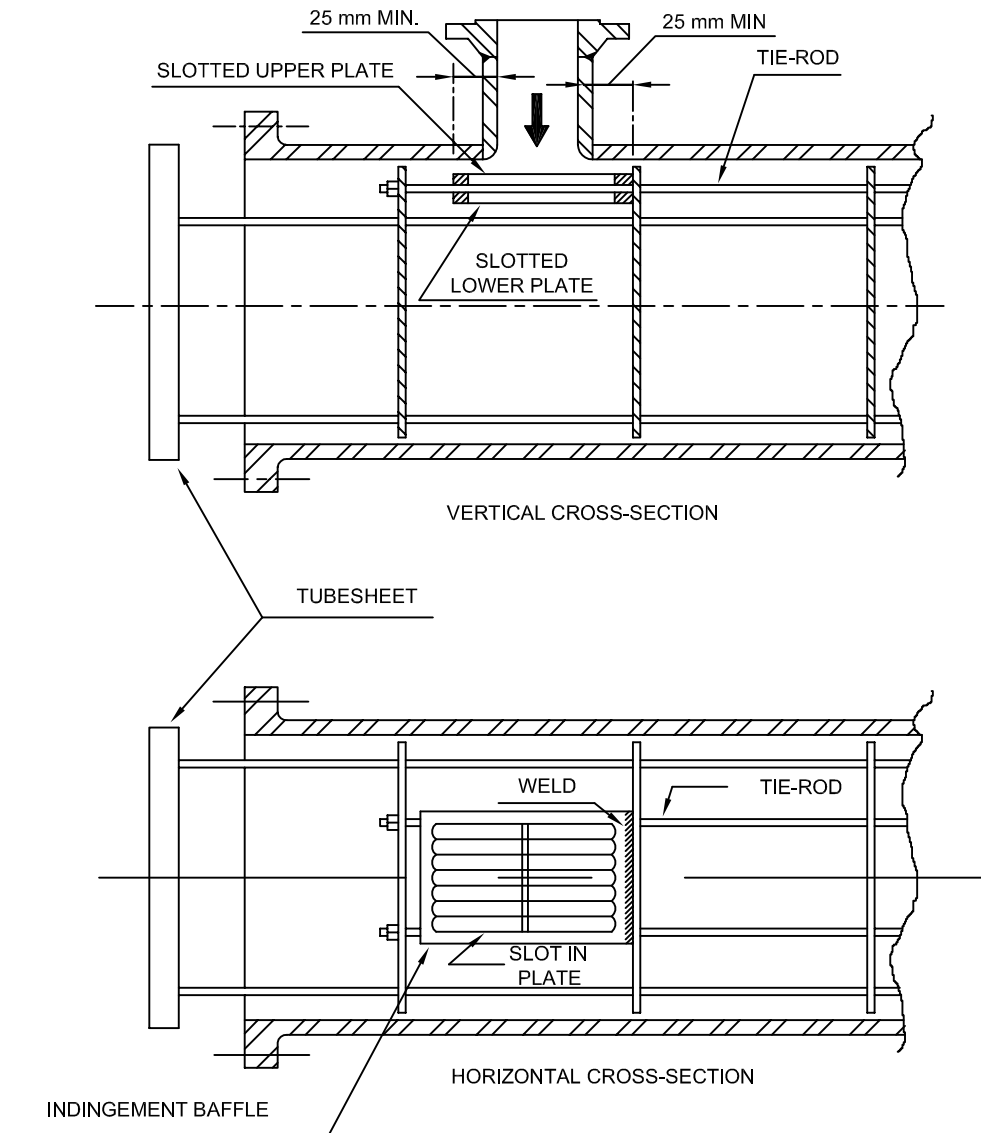


FIGURE A-4 - INTERNAL EXPANSION JOINT



- NOTES: 1) SLOTS ON BOTH PLATES SHALL BE STAGGERED.
 2) TOTAL AREA OF SLOTS IN EACH PLATE SHALL BE EQUAL TO THE NOZZLE INLET AREA.

FIGURE A-5 - IMPINGEMENT BAFFLE FOR TWO PHASES FLUID

