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1 Subject of specification

This specification and other documents referenced herein establish the minimum requirements for the design , manufacture, erection, inspection and tests for shell and tube heat exchangers being operated on Grupa LOTOS S.A. plant.

2 Scope of validity

This specification applies to preparation of inquires and contracts for newly planned investment or modernisation projects of Grupa LOTOS S.A.

It is also serves as the base for preparation of detailed specifications and inquires for individual and package delivery.

2.1 Deviations

Any deviation from this specification and the relevant specifications, standards and related documents including proposals, which the bidder claims to be economically and / or technically superior solutions must be submitted in writing for review and approval by Grupa LOTOS S.A. Non-approved exceptions are not acceptable by Grupa LOTOS S.A.

The supplier must report in writing any ambiguity in this or any other specifications of Grupa LOTOS S.A. or non-compliance with the referred documents / standards and obtain a written explanation from Grupa LOTOS S.A.

3 General

3.1 Scope

This specification, used in conjunction with the purchase documents, data sheets and/or drawings establishes the minimum requirements for the mechanical design, fabrication, inspection and testing of shell and tube, double pipe and multi-tube hairpin heat exchangers.

In this specification only the term "heat exchanger(s)" which includes condensers, coolers, reboilers, double pipe and multi-tube hairpin type will be used.

This Specification is based on the ASME Boiler and Pressure Vessel codes and referenced standards and specifications.

The heat exchangers to be designed, manufactured and supplied in accordance with Pressure Equipment Directive (97 / 23 / EC) and marked with “CE” mark.

3.2 Order of Precedence

In case of conflicts exististing between this specification and other documents, the following order of precedence shall govern:

- The current Polish legislation
- Terms of purchase order / contract and other requirements agreed in writing Grupa LOTOS S.A.

- Data Sheets approved by Grupa LOTOS S.A.
- This specification
- Other Specifications
- Drawings and other documents
- Standards

4 Design Criteria

4.1 General Requirements

The design, construction and inspection of heat exchangers shall, as a minimum, meet the requirements of TEMA standard Class R (for process media), Class C (for utility media - safe, non-flammable) and ASME Section VIII, Division 1, or Division 2 as applicable and as indicated on the drawings/data sheets and referenced specifications.

Preferred shall be horizontal heat exchangers with a floating head and a square (45° or 90°) pitch of tubes to allow for mechanical cleaning of intertube space.

For water coolers and condensers, cooling water should flow through the tubes. Water cooler design should allow for tube cleaning without dismantling of water pipelines (channel type A according to TEMA classification).

The heat transfer surface shown in the drawing and in the nameplate is defined as the external surface of tubes with length between internal surfaces of the tubesheets. For U-tube heat exchanger this surface is defined as the external surface of tubes with length form internal surface of tubesheet to the end of straight length of tubes.

The location of heat exchangers on the plant must allow for using of the bundle extractor. Free space of 0.5 m below of the lower edge of the main flange has to be kept.

4.2 Design Conditions

Manufacturer shall be responsible for the design of the heat exchanger shown in Grupa LOTOS heat exchanger specifications, drawings and/or data sheets.

In special cases manufacturer shall also be responsible for the process design in accordance with Grupa LOTOS S.A. data sheet.

If the Manufacturer does process design, pressure drop and fouling factor shall be chosen such that continuous operation of at least three years is guaranteed.

In case of fixed tubesheet heat exchanger, it is absolutely necessary to calculate stress caused by thermal expansion between shell and tubes. If results show that allowable stress is exceeded, a flexible element (an expansion bellow) shall be specified. Should the applicable Code not contain any specification to this effect, the manufacturer has to provide an additional stress analysis according to TEMA Class R for fixed tubesheet exchangers with an outside diameter of up to and including 1500 mm. When outside diameters are exceeding 1500 mm, an additional analysis has to be agreed upon with Grupa LOTOS S.A.

When dimensioning the saddles (anchor points) for heat exchangers with removable tube bundles, the design shall consider the horizontal forces resulting from pulling the tube bundles by allowing for 1.5 x bundle weight. This provision shall apply to stacked heat exchangers in particular.

For tubesheets with protruding flange edges, the protruding edge shall have a thickness h_f of 60% of the counter flange's plate thickness.

Flat channel covers that are provided with pass partition plates, shall be designed that the maximum deflection is not higher than:

- 0.762 mm for DN up to 600 mm (DN = nominal diameter of the channel)
- 0.125% of DN for DN above 600 mm

in accordance with TEMA section 5 item RCB 9.21

4.3 Stresses

The basic allowable stress for pressure parts shall be the values specified in the applicable code.

The basic allowable stresses for non-pressure parts, except as listed below, shall be 33-1/3 percent of the ultimate tensile strength, 66-2/3 percent of the yield strength, or that producing a creep rate of 1 percent in 10000 hours, whichever is lower.

4.4 Design Pressure and Temperature

Heat exchangers shall be designed to the design pressure and design temperature specified in the heat exchanger drawings/data sheets.

In case several pressure-temperature combinations are specified all of them shall be taken into account.

For external bolting and for components exposed to both shell-side and tube-side fluids, the design temperature shall be the more severe of the shell-side or tube-side. Shells, tubes, floating heads and tubesheets shall be designed for full design pressure on either side, with atmospheric pressure or specified vacuum on the other side.

The pressure compartments (shell side and tube side) are to be designed separately for the appropriate maximum permissible design pressure. In both cases, the higher maximum permissible design temperature shall be used for calculating the connecting elements between two pressure spaces.

4.5 Corrosion allowances

Corrosion allowance shall be per TEMA. Heat exchanger class (R, C or B) will be specified in drawing / data sheets or in purchase order specification.

Bundle tubes shall have no corrosion allowance unless specifically stated.

Internal covers shall have the corrosion allowance on both sides; the same applies to tubesheets.

For grooved tubesheets and for grooved flat covers, the groove can be considered as corrosion allowance equal to groove depth.

Girth flanges' sealing faces shall have minimum 2 mm extra thickness to allow facings regeneration during repairs.

No corrosion allowance shall be added to flange sealing faces.

The backing device connecting plate shall have no corrosion allowance.

Tie rods, spacers, transverse baffles, support plates, pass partition plates and similar parts shall have no corrosion allowance, unless stated otherwise.

When clad plate or weld overlay cladding is specified, the cladding or weld overlay thickness shall not be included in stress calculations, unless otherwise noted on the heat exchanger drawings / data sheet.

The specified minimum thickness (depth) of the cladding or weld overlay shall have complete chemical analysis and shall meet the chemical requirements of the specified stainless steel grade or other special alloy.

Weld overlay cladded surfaces shall be checked 100 % by dye penetrant examination,

4.6 Loads

If required in the technical requisition, wind loads have to be included in the design in accordance with applicable regulations agreed with Grupa LOTOS. Process induced loads must always be taken into account.

4.7 Shells, Heads and Covers

Shells and heads shall have the same inside diameter. Diameter steps of 50 mm are possible.

The minimum nominal thickness for shells, heads and for tubesheets shall be in accordance with the TEMA Standards.

All weld seams shall be located to clear saddle supports, brackets, etc.

Longitudinal and circumferential seams in cylindrical and conical shells and in heads shall be located to clear openings and their reinforcement by min 3 x wall thickness or 50mm, whichever is greater.

If reinforcing pads for nozzles and other attachments are located over longitudinal and circumferential weld joints, the welded joint shall be ground smooth and radiographed for its entire covered length, plus 25 mm on each sideAttachments (for example insulation supports) shall be located to clear seams by at least one plate thickness.

Dished heads shall be of seamless construction. However, dished ends with one chordal seam and 100 % radiographed are acceptable.

Semi-ellipsoidal heads with a 2:1 ratio of major to minor axis and hemispherical heads shall be used.

Shells for double pipe heat exchangers shall be of one-piece construction whenever practical and shall be fabricated of pipe. Carbon steel pipe components shall be seamless.

All floating head heat exchangers are to be provided with flat covers on the channel side, unless otherwise specified in Grupa LOTOS S.A. drawing or/and data sheets. Exceptions are to be agreed with Grupa LOTOS S.A.

4.8 Expansion Joints

Where expansion joints are required or specified the expansion shall be calculated with metal temperatures based on operating conditions.

The specific data for the expansion joints are given in the guide drawing or data sheets. The welding ends are to be of the same thickness and material as the adjacent equipment shell. The connection of the expansion joint bellow to the welding end must be produced without gap.

The expansion joints are to be designed under the assumption of 1500 load cycles if no specific data are given in the guide drawing or data sheet. The number of expansion joint convulsions is to be decided by the manufacturer.

When it is necessary to locate the expansion joint in a baffled area of the tube bundle, the expansion joint shall be provided with an internal sleeve to prevent by-passing. The inside diameter of the sleeve shall be identical to the inside diameter of the shell.

On horizontal heat exchangers with an expansion joint, its location shall be near the sliding support, which allows movement.

Shell expansion joints shall be ventable and drainable in the operating position.

The expansion joint bellows are to be made of austenitic material if no contrary information is given in guide drawing or data sheet.

All heat exchangers with expansion joints in the shell are to be provided with stiffening device for shipment.

4.9 Reinforcement of Openings

The reinforcement of openings in the shell and heads shall be designed in accordance with the applicable code for the design pressure and temperature. Each reinforcing pad or segment thereof shall be provided with a ¼ inch diameter NPT threaded "telltale" hole.

Integral reinforcement of openings shall be used when any of the following conditions exist:

- Process requirements state the service is cyclic or the service involves rapid thermal transients
- Shell or channel wall thickness exceeds 50 mm
- Design temperature exceeds 400 °C

4.10 Reinforcement for Nozzle Loads

Nozzle reinforcement shall be checked for piping loads (forces and moments) as specified in the technical requisition or drawing.Verification of nozzles under additional loads:

The manufacturer shall make the following calculations to verify that the design is adequate for the additional nozzle forces and moments:

A. Stresses due to external forces and moments

- British Standard Institution, Published Document (BSI PD) 5500 Appendix G

or

- Welding Research Council Bulletin;

:537 + Errata (WRCB 537) Local stresses in spherical and cylindrical shells due to external loads.

B. Stresses due to internal pressure *

BSI PD 5500, Unfired fusion welded pressure vessels, Appendix G, G.2.3.6.2 *)

* The internal pressure shall be the design pressure at the design temperature

The total combined stress due to A and B above shall be calculated according to BSI PD 5500, Appendix G, at all the eight investigated points, with due consideration to directions and signs before the total stress intensity at each point is derived.

All nozzles with reinforcing pads shall be calculated for the stresses occurring at the perimeter of the reinforcing pad and at the nozzle as described in BSI PD 5500, Appendix G.

4.11 Nozzles

All nozzles and connections shall be flush inside, unless otherwise specified.

Minimum nozzle necks thickness, including up to 3 mm (1/8") corrosion allowance shall be Sch. XS for carbon steel and for stainless steel shall be Sch. 40S.

Unless otherwise specified on the drawings or / and data sheets, flanges for all external nozzles 24 inch nominal size and less shall be in accordance with ASME B16.5 with respect to class and flange facing type and for nominal size of 26 through 60 inch shall be in accordance with ASME B16.47, Series A flanges and checked per ASME, Section VIII, Div.1, Appendices 2 and S.

The finish of the gasket contact surface of nozzle flange facing shall conform to ASME B16.5, unless otherwise specified. When a "raised face" (RF) is specified, the gasket contact surface roughness shall be 1,6 to 3,2 µm Ra to ISO 4287 (63 to 125 µinch AARH) unless otherwise specified.

Nozzles necks shall be of seamless pipe. Nozzle necks may be of rolled plate when the nozzle size is NPS 16 or larger for carbon steel and NPS 8 and above for other materials.

All rolled plate nozzle necks shall be 100% radiographed.

The drilling of nozzle flanges shall straddle the natural axis of the heat exchanger.

All threaded connections shall conform to ASME B1.20.1

4.12 Vent and Drain Nozzles

Vent and drain nozzles are to be arranged in all heat exchangers at places where they function perfectly in service position. An appropriate number of such nozzles is to be provided where compartments are formed by partition plates.

The inlet and outlet nozzles on the shell and tube side shall be fitted with side nozzles $1^1/_2$" WN 600 with blind flanges for pressure tests.

Vertical heat exchangers shall be vented and drained on the shell side.

Heat exchangers with floating head shall have vent and drain nozzles located in the shell cover.

4.13 Flanges and Gaskets

Flanges for girth joints shall be of the forged welding-neck type. Slip-on flanges or other types of forged welding flanges may only be used if allowed by Grupa LOTOS S.A. in writing.

All girth joints shall be of through-bolted construction.

Forged weld neck flanges (WN) or long weld neck flanges (LWN) shall be used.

Slip-on type flanges shall not be used for class 300 and higher or for design temperature above 250 °C and also when the service is designated to be hydrogen, hydrogen sulphide, sour water, cyclic or corrosion allowance is more than 3 mm.

Lap joint, studded connections or threaded are permitted only if specified in requirements or after a special permission granted by Grupa LOTOS S.A. in writing.

All facings shall be adequately protected against damage during fabrication, storage and/or heat treatment.

Oval type gaskets shall be used with ring joint flanges.

Flanges shall have the same inside bore as the nozzle pipe.

All gaskets are to be made of one piece.

The minimum dimensions for gaskets of girth flanges are the following:

Heat exchanger nominal size	Gasket width (mm)	Web width for pass partition plate in channel and floating head (mm)
≤ 550	10	10
600 – 900	13	10
950 – 1150	16	10
≥ 1200	19	10

If the actual stress acting on the gasket exceeds the allowable stress than the gasket width has to be changed.

4.14 The Tube Bundle Design

4.14.1 General

Shell and tube heat exchangers with dirty service on the shell side are to be provided with removable bundle.

Maximum diameter of tube bundle shall not exceed 1500mm and the maximum weight – 15000kg.

Manufacturer shall carry out vibrations analysis for all operating cases and guarantee that the supplied heat exchanger is vibration free.

Heat exchangers with extended shell (e.g. Kettle type) are to be equipped with spacers, guide rails and skids.

Exceptions for special heat exchangers are shown on the guide drawing of tubesheet layout.

4.14.2 Tubesheets

The outside diameter of stationary tubesheets must be smaller than the bolt circle diameter reduced by bolthole diameter.

The outside diameter of the floating head tubesheet shall be chosen such that easy bundle removal from the shell is ensured.

Grooves are to be provided in the tubesheets where gasket webs exist. The transitions between groove and circumferential gasket face shall be plane and free of steps.

The flange welded to the fixed tubesheet may have the same wall thickness as the shell unless the following limits are exceeded:

- Di ≤ 1100 mm and p_B ≤ 30 bar E ≤ 85 %
- Di > 1100 mm and p_B- ≤ 10 bar

In both cases, heat treatment is only required when specified in the ASME Code.

The minimum tubesheet thickness minus corrosion allowance shall be equal to the tube outside diameter.

4.14.3 Tubes

Condition as supplied

In general, seamless steel tubes shall be specified. If stainless steel is used, the tubes may be welded, however, this is subject to Grupa LOTOS S.A. written approval. Tubes shall have no circumferential welds.

Tube Dimensions

Carbon steel and low alloy steel			Stainless steels and high alloy steel		
Tube O.D. [mm]	Min. wall thickness [mm]	Pitch [mm]	Tube O.D. [mm]	Min. wall thickness [mm]	Pitch [mm]
20	2,11	26	20	1,65	26
25	2,77	32	25	2,0	32

The above specified dimensions shall be used unless other dimensions are specified in Grupa LOTOS S.A. guide drawings or data sheets. Other tubes may be used after obtaining written permission from Grupa LOTOS S.A.

The above mentioned tubes shall preferably have a length of 6000 mm. Intermediate sizes between 2000 mm and 5000 mm are possible with a 100 mm step after agreed with Grupa LOTOS S.A.

For U-tube construction, the required tube gauge based on pressure or other considerations shall be increased by at least one (1) gauge number to allow for thinning of the tube at the U-bend.

U-tubes shall be allowed only if mechanical cleaning inside the tubes is not required. Girth welding of U-tubes along their length is not allowed. The minimum radius of bend for U-tubes R = $1.5D_z$. The wall thickness thinning must not exceed TEMA RCB-2.31 allowance.

4.14.4 Tube-to-tubesheet Joints

There are following tube-to-tubesheet joints:

- Steel tubes attached to tubesheets in accordance with DIN 8558 part 2
- for protruding tubes , type: C10.1 and C10.2,
- for let in tube , type: C10.4,
- for tube without protruding , type: C10.3,

- Steels tubes attached to tubesheets in accordance with DIN 28187

1. Expanding method
- expanding without grooves, item 3.2.1
- expanding with 1 or 2 grooves, item 3.2.1
- hydraulic expanding, item 3.2.2
- explosive expanding, item 3.2.3

2. Combined methods
- light expanding and welding, item 3.3.1

- welding and light expanding, item 3.3.2
- expanding and welding, item 3.3.3
- welding and expanding, item 3.3.4
- light expanding, welding and expanding, item 3.3.5

Detail requirements for tube-to-tubesheet joints and choosing of joint types are given in mentioned above standards.

The manufacturer shall obtain a written permission from Grupa LOTOS S.A. for using one of the above mentioned methods or use own method of attaching tubes, prior submitting it for acceptance.

The design diameters of boreholes are to be provided according to DIN 28182 with a tolerance of ± 0.05 mm.

The boreholes must be smooth (peak-to-valley height 30 μm) and must have no sharp edges at the ends. The tube ends must be free of grease.

The supplier shall furnish on request a representative sample of the tube-to-tubesheet weld to Grupa LOTOS S.A. for review before commencing fabrication.

For shell-side clad tubesheets, the tubes shall be expanded to seal against the cladding material. Clad shall be thick enough to meet requirements of TEMA, RB-7.311. Manufacturer has to prepare a procedure for such a joint and submit to Grupa LOTOS S.A for approval before fabrication.

4.14.5 Transverse Baffles

The outside diameters of transverse baffles are to be machined only after the actual shell inside diameter has been determined. They must be turned on the outside and shall be free of burs at the edges and in the tube holes. Transverse baffles shall be designed in compliance with TEMA sandard.

No transverse baffle-to-shell clearances greater than indicated in Table RCB-4.3 of the TEMA Standards shall be used unless specifically approved by Grupa LOTOS S.A.

The boreholes in the transverse baffles are to be made according to DIN 28182 Tab 3 or TEMA standard, section 5, item RCB 4.2.

For heat exchanger with Duroplast coating on the shell side, the borehole diameter must be agreed with Grupa LOTOS S.A. PTFE sleeves are to be provided in the boreholes. All parts shall be coated prior to assembly.

4.14.6 Tie rods, sealing strips

The minimum number and size of tie rods shall be determined according to TEMA Std.

For heat exchangers with Duroplast coating on the shell side, tie rods shall be welded to the transverse baffles without spacers.

Sealing strips shall not be provided for heat exchangers, where on the shell side exists isothermal condensing or isothermal boiling or/and in kettle type shell.

Seals strips are required when the radial clearance between shell and the outer tubes exceeds 16mm.

Exchangers with vertical cut baffles (baffle cut parallel to shell side nozzle centerline) shall have seal strips installed to seal the bypass areas caused by omission of tubes. Dummy tubes, rods, or seal strips shall be provided for any pass partition lanes that are parallel to the shell side flow. Seal strips thickness shall not be less than greater of 75% of baffle thickness or 6mm. For vertical cut baffles

(baffle cut parallel to shell side nozzle centerline), seal strips shall not extend into the inlet or outlet baffle spaces.

For horizontal cut baffles (baffle cut perpendicular to shell side nozzle centerline), seal strips shall extend from the front or stationary tubesheet to the last baffle or support plate. One pair of seal strips or one dummy tube shall be provided for each five (5) tube rows between baffle cuts. Minor adjustment may be made to suit actual tube layout.

Bypass seal strips shall be attached to the transverse baffles by continuous welds on one side of each baffle.

Peripheral bypass seal strips shall not restrict the bundle inlet or outlet flows.

All removable bundles weighting more than 1000 kg shall be provided with skid bars for bundle removal. If skid bars are used, they shall be welded to the transverse baffles and support plates to form a continuous sliding surface.

Seal strips may be used as skid bars, which shall protrude 0.8 mm beyond the outside diameter of baffle and support plates.

4.14.7 Pass partition plates in channel and floating head

The pass partition plates must be welded tightly into the channels or bonnets.

The sealing faces of pass partition plates are to be set back by 0.1 mm + 0.1 / -0 from the ring sealing faces.

The thickness for carbon steels is 10 mm for a nominal heat exchanger diameter up to and including 600 mm and 12 mm for greater nominal diameters. A reduction to 8 mm must be provided at the sealing face. The thickness for high-alloy materials is 8 mm for a nominal heat exchanger diameter up to and including 600 mm and 10 mm for greater nominal diameter. A reduction to 8 mm must be provided at the sealing face.

Each horizontal pass partition plate shall have a drain hole of 5 mm diameter, located about 30 mm from the front edge, vertical plates with an 5 mm diameter hole at the lowest and at the highest point if no special vent or drain is provided.

4.14.8 Longitudinal baffle sealing

If two-pass flow is intended on the shell side, the longitudinal baffle seal must be provided.

Therefore, the longitudinal baffle is to be tightly welded to the tubesheet, the transverse baffles are to be tacked to the longitudinal baffle.

The longitudinal baffle seal shall only be fixed prior to final heat exchanger assembly; it must not be pre-bent under any circumstances. The sealing strips will bend automatically when the bundle is inserted into the shell. Selection of sealing strips plate material shall enable repeated assembly and disassembly of tube bundle without destroying them.

The longitudinal baffle must be at least 8 mm thick.

4.14.9 Impingement plates

The use and design of impingement plates at the shell side inlet of heat exchangers according to guide drawing/data sheet. They may be bolted or welded to tie rods or sliding rails.

They shall be arranged such that a free cross section equivalent to the nozzle cross section is ensured. Perforated plates are not acceptable.

4.15 Supports and External Attachments

For heat exchangers built of solid alloy steels, and supported on saddles, brackets or legs, the carbon steel supports shall not be welded directly to the shell. Alloy wear plates shall be used between the shell and the carbon steel support. Wear plate shall be made of the same material as the shell, except that for all grades of austenitic stainless steel shells, the wear plate may be of ASME SA-240 304L stainless steel. The wear plate thickness shall be the same material grade as the shell to which it is attached, extending 50 mm all around the support unless shell reinforcement calculations call for greater thickness and/or width, and shall be continuously welded to the shell. A ¼ inch NPT diameter vent hole shall be provided in each wear plate.

Lifting lugs shall be provided for all channels, removable channel covers, floating head covers and removable shell covers and other removable parts over 25 kg. The lifting lug shall be designed for a load at least twice the component weight.

The lower shells of stacked removable-bundle heat exchangers shall be designed to carry the superimposed load without suffering distortion that could cause binding of the tube bundles.

Saddles for horizontal equipment shall be in accordance with DIN 28080.

Where horizontal heat exchanger is installed on a concrete foundation, the sliding plate shall be used under the sliding saddle.

Brackets for vertical equipment shall be in accordance with DIN 28083.

All heat exchanger supports shall be provided with at least two (2) earthing lugs, one at each saddle (for horizontal equipment)

Lifting lugs for vertical and horizontal equipment shall be designed according to:

- Trunnions DIN 28085 or heat exchanger manufacturer's standard agreed with Grupa LOTOS S.A.
- Lugs DIN 28086 or heat exchanger manufacturer's standard agreed with Grupa LOTOS S.A.

Lifting devices shall be designed to enable lifting of heat exchanger in any possible position

Insulation clips shall be provided for insulated vertical heat exchangers.

Flanges of heat exchangers, including the flanges of floating heads shall be provided with at least two jack screws for convenient gasket dismantling.

Two eyebolts according to DIN 580 are to be provided at the front of the stationary tubesheet for bundle removal. Exceptions are heat exchangers with cladding or Duroplast coating on the tubesheet. In this case, two lifting lugs similar to DIN 28086 of austenitic material or of the same material as the cladding are to be provided. If this is not possible for space reasons, two threaded holes (minimum M 20) are to be provided for the attachment of two eyebolts on the circumference of the tubesheet. Eyebolts and lifting lugs shall be designed for a pulling force of at least 150 percent of the bundle weight. Each tapped hole shall be fitted with a threaded plug of the same materials as the tubesheet face. The eyebolts, lifting lugs, threaded plugs shall be included in the scope of supplies.

5 Design Requirements

5.1 Materials

Materials used for pressure retaining parts shall meet Pressure Equipment Directive (97 / 23 / EC) requirements.

Materials shall be selected based on the service and the design temperature as well as the Minimum Design Metal Temperature (MDMT) and shall be in accordance with any of the applicable specifications listed in the ASME Code, Section II but shall be limited to those that are permitted in ASME, Section VIII.

Carbon steel shall be killed for pressure parts and components welded to the pressure parts. Carbon content shall not exceed:

- 0,23 % for plates and pipes
- 0,25 % for forgings

and carbon equivalent describe with the following formula:

CEV=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 shall not exceed 0,43 %.

Plates 50 mm thick and above shall be 100 % ultrasonic tested per ASTM A 435 in steel work.

Clad plates shall be 100 % ultrasonic tested per ASTM A 578 (in accordance with SA-263, SA-264 and SA-265 additional requirements S12) – acceptance level class 3 (in accordance with SA-263, SA-264, SA-265) and shall pass shear test. Minimum shear strength of the alloy cladding and base metals shall be 140 N/mm^2.

After forming, heads made of clad plate shall be ultrasonic tested per ASTM A 578 – additional requirement S12 in accordance with SA-263, SA-264, SA-265 acceptance level class 3.

Main components materials shall comply with those specified in the data sheets / drawing.

Structural shapes if specified inside the shell shall be fabricated from the same material P number as the shell to which are attached.

Only seamless tubes shall be used for both carbon steel and stainless steel material. If welded tubes are specified in Grupa LOTOS S.A. drawings / data sheets, they shall be subjected to a non-destructive electric test (eddy current test) over the total tube length at the mill as described in the applicable ASME code. Tubes shall have no circumferential welds.

Internal and external non-pressure parts as welded to pressure retaining parts shall be of the same material grade or the same P number as the pressure plate, unless noted otherwise. For these parts non-impact tested materials are acceptable.

For bolts and nuts the process of manufacture, heat treatment, chemical and mechanical requirements, coatings and marking shall be in accordance with the requirements of applicable codes and specifications. The applicable "Identification Symbol" shall be stamped on bolts and nuts as required by the material codes and specifications. Material and test data sheets shall be provided to Grupa LOTOS S.A. upon request.

Gaskets shall be of asbestos free material suitable for the process and service conditions.

Baffles, support plates, tie rods and spacers may be of commercial quality materials, of the specified nominal analysis. Baffles and support plates material shall be of a nominal analysis similar to the tube material.

All materials shall be new and unused.

Heat exchangers specified to be of alloy or non-ferrous material may be quoted alternatively if the use of another form of the material (e.g. solid plate, integrally bonded clad plate, weld overlay or combination of these) will result in a more economical construction.

The mechanical properties of materials shall be determined on test specimens prepared from each plate, pipe or forging (or lot*) in the specified heat-treated condition.

** A lot is defined as material of the same heat whose thickness is within plus or minus 20 % (however no more than 12,5 mm) of the specified thickness and which is simultaneously heat treated.*

All plates, forgings, and pressure parts shall be stamped in a permanent and legible manner with the steel supplier's heat, slab, and serial number designating the part. Light die marking shall be used on 6 mm (1/4 inch) and thinner steel and alloy steel and on 13 mm (1/2 inch) and thinner non-ferrous plates and forgings. All other provisions shall be as specified in the applicable ASME code.

Supplementary requirements will be specified in the purchase order documents.

Resistance to intergranular corrosion of stainless steel in an oxidizing service of sulphuric acid, nitric acid shall be checked per ASTM A262. A report shall be provided.

Material substitutions prior heat exchanger fabrication commence or during fabrication shall be approved in writing by Grupa LOTOS S.A..

Manufacturer shall submit for approval, the complete description of the chemical and mechanical properties of all material substitutions proposed prior to purchase.

5.2 Bolts and Gaskets

External pressure bolting for girth and nozzle flange connections or blind flanges shall be stud bolts threaded full length with two hex nuts each. The strength of studs shall be based on the cross-section of the smallest diameter.

Stud bolts should protrude two (2) threads beyond nuts.

Bolt sizes and threads shall conform to ASME/ANSI B1.1, Class 2A (external thread) or Class 2B (internal thread):

- Bolts in 1 inch diameter and smaller shall be coarse threads series (UNC).
- Bolts over 1 inch diameter shall be 8 thread series (8UN).

In case of bolts of a diameter bigger than 1½ inch the location of the bolts and the design of the joint must permit use of hydraulic bolt tensioners. Also the plant plot plan shall include sufficient access for bolt tensioner operation.

Manufacturer shall define the torque and the procedure of tightening the bolts of the main joints of the heat exchanger.

All internal bolting shall be of the same material type as the heat exchanger inside.

The threads of external studs and nuts shall be coated with a suitable thread lubricant (e.g. containing molybdenum disulphide) to prevent galling.

Gaskets shall be as specified on the heat exchanger drawing/data sheet.

Gaskets for ring joint flanges shall be of the oval type conforming to the requirements of ASME B16.20. The Brinell hardness of metal gaskets and metal-jacketed gaskets shall be about 25 HB lower than that of the flange facing material. Gasket materials shall generally be as follows for the indicated flange, flange lining, or flange cladding material.

- Carbon and carbon 1/2 percent Mo steels: low carbon iron or low carbon steel with a maximum Brinell hardness of 120
- 1/2 to 10 percent Cr-Mo and 11 to 13 percent Cr steels: 5 percent Cr - 1/2 percent Mo steel with a maximum Brinell hardness of 130
- ASME type 304, 321, and 347 steels: ASME type 304 steel with a max. Brinell hardness of 160
- ASME type 316 steels: ASME type 316 steel with a maximum Brinell hardness of 160

Except for ring joint gaskets, two spare gaskets and 10 % bolts with nuts (min. 1 bolt with nuts per bolt size and per material grade) shall be furnished for each flanged connection with installed gasket.

All gaskets furnished shall be new and shall be installed before the heat exchanger is shipped. Gaskets used for shop test purposes shall be replaced with new materials (excluding ring joint type gaskets).

Gaskets and bolts for nozzle flange connections shall be in accordance in the piping specifications.

5.3 Fabrication and Workmanship

Heat exchangers stacked in service shall be assembled in the shop and inspected for alignment of mating flanged connections and supports. Required shims between supports shall be installed and tack welded to supports.

If heat exchangers are arranged on top of each other or on other equipment (heat exchangers group) or if reboilers are flanged to columns, the bolts, nuts and gaskets for connecting flanges as well as the connecting elements and shims for the supporting structure shall be included in the scope of supplies of the manufacturer who provides the equipment to be connected. Shims shall have thickness of 1, 2, 3, 4 and 5 mm.

All weld procedures including non-pressure welds shall be identified by number and shall be referenced in weld details on fabrication drawings.

5.4 Welding

Welding preparation shall be conducted in accordance with the applicable codes and standards.

All welded joints should be made by arc welding.

Covered electrodes shall comply with the relevant AWS-ASME specifications, and the electrode covering shall be basic type. Low-hydrogen electrodes shall be used to avoid cold cracking (hydrogen cracking).

Nozzles and their reinforcements shall be connected with the shell by full penetration welds.

If post welding heat treatment (PWHT) is required, all welding must be completed prior to PWHT.

If heat treatment is required than all welding has to be finished earlier. In case of clad material, plate shall be 100 % ultrasonic tested to check cladding adherence to the base material. Weld overlay shall be checked with liquid penetrant. If 100 % weld overlayed surface was checked with penetrant before heat treatment than after heat treatment the surface shall be randomly tested, however not less than 10 %.

For low-alloy steels Cr-Mo verification of hardness after heat treatment in the weld area and in the area subjected to treatment is required. Hardness shall not exceed:

- 215 HB for steel of Cr content < 2%

- 240 HB for steel of Cr content > 2%

When austenitic stainless steel is welded to carbon steel or low alloy steel, if working temperature is less than 350 °C welding consumables 309(L) or 309Mo(L) (for austenitic steel with Molybdenum for example 316L) shall be used. For higher working temperature a nickel based electrodes should be used for example ENiCrFe-3.

Welding of equipment parts made of carbon steel to stainless steel needs every time Grupa LOTOS S.A. permission in writing.

In heat exchangers with removable bundles, all welds are to be ground flush to the shell inside.

5.5 Heat Treatment

The mandatory requirements of the ASME code shall be interpreted as minimum requirements.

Post forming heat treatment shall be performed for carbon steel, carbon manganese steel and low alloy steel as follows:

- Hot formed material, if it was heated above normalising temperature, shall be normalised;
- Cold formed material shall be stress relieved when required by code;

This heat treatment shall be performed after final forming.

Pressure parts made of austenitic stainless steel, formed at temperature less that solution annealing temperature shall be subject to solution annealing in accordance with ASME Section VIII, UHA-44.

Brinell hardness readings shall be taken on the inside (except in alloy lined portion of vessels) of the vessel for each longitudinal and circumferential weld, nozzle weld, and Heat Affected Zone (HAZ). The readings shall be taken after final heat treatment, No reading shall exceed the limits given in the code / specifications.

Special consideration shall be given to the forming temperature to avoid possibility of “hot cracking” when hot forming is proposed for austenitic materials.

All materials shall be mechanically certified in the final heat treated condition.

Ordered material shall have 3 cycles of heat treatment simulation. Mechanical properties of materials tested after a simulated PWHT shall meet the minimum strength requirements for the material grade.

After PWHT of heat exchanger no welding, hammering, grinding or deformation shall be permitted. On two sides of the vessel shell shall be painted in 75 mm high letters in Polish or English language: "POST WELD HEAT TREATED, DO NOT HAMMER OR WELD ON THIS VESSEL". (PODDANY OBROBCE CIEPLNEJ. SPAWANIE I UDERZANIE ZABRONIONE).

Local heat treatment is not permitted without Grupa LOTOS S.A. written approval.

Channels and bonnets of heat exchangers with four and more tube passes and floating head covers shall be post weld heat treated (PWHT).

The heat treatment must be made prior to the machining of sealing faces.

Flange faces and other machined surfaces shall be suitably protected against oxidation during heat treatment and shall be checked after treatment for warpage and distortion.

Under stress corrosion conditions, bends of carbon steel U-tubes shall be subject to annealing. Bends of austenitic stainless steel U-tubes shall be subject to stress relief or other stabilizing treatment.

5.6 Tolerances

Tolerances shall conform to the requirements of the TEMA standards but nominally identical parts shall be interchangeable.

The flatness of tubesheet gasket contact surfaces shall be measured after the tubes are expanded or welded to the tubesheet.

The tolerance on the thickness specified for the alloy cladding on integrally clad plate shall be as follows:

- Specified nominal thickness: minus 0.4 mm; plus 1.6 mm
- Specified minimum thickness: minus 0 mm; plus 1.6 mm

6 Inspection and Testing

6.1 Testing

Radiographic examination shall be in accordance with the ASME code.

When 100% radiography is specified, the root passes and the finished fillet welds of all nozzle attachment welds shall be inspected by magnetic particle, liquid penetrant or ultrasonic method approved by Grupa LOTOS S.A. Welds may be grinded only when necessary to effect proper interpretation of the radiograph.

A dye-penetration test shall be carried out on the tube to tubesheet welding. This test shall be made after the first layer has been welded and again after the second layer. Test results shall be recorded in the examination report.

When practicable, all heat exchangers shall be subjected to a hydrostatic test in accordance with the code. Hydraulic test pressure shall be maintained for at least 1 hour.

Equipment shall be hydrostatically tested in accordance with PED requirements.

Stainless steel and/or high nickel alloy, including clad materials shall be tested with low chloride water.

If not stated otherwise, content of chloride in test water shall not exceed:

- Carbon steel < 500 ppm
- Austenitic stainless steel and high nickel alloy material < 25 ppm

The shell-side hydrotest shall be performed with bonnet and channel removed.

The bundle must be removed or inserted only in the presence of the Grupa LOTOS S.A. inspector. Exceptions are subject to written approval of Grupa LOTOS S.A.

Stacked equipment units must be trial-assembled in the workshop to ensure perfect fit. The pressure test shall be performed at the same time.

No tubes or tube holes shall be plugged without Grupa LOTOS S.A. written approval for the method and procedure of plugging.

All reinforcing pads shall be given an air and bubble solution pressure test before the test of the pressure vessel. The test pressure shall be at 30÷50 kPa g, The test holes in pads shall be left open for use as telltale holes. They shall be filled with corrosion inhibiting grease after testing of vessel. .

Service gaskets and service bolting shall be used for shop tests. Any materials damaged during the tests shall be replaced by the Manufacturer with new material.

6.2 Pressure Test Rings

The tube bundle pressure test rings shall be supplied for each heat exchanger, regardless number of the same heat exchangers. For heat exchangers with floating head there are required test flange fixing stationary tubesheet and test ring closing shell from floating head side together with packing gland for floating tubesheet. For U-tube heat exchangers there is sufficient one test flange for fixing tubesheet. Test rings / flanges shall be permanently marked with a tag number of heat exchanger in 10 mm high characters.

6.3 Inspection

The Inspection and Test Plan (ITP) shall be completed and sent to Grupa LOTOS S.A. for fixing the notification, review, witness and hold points.

All mandatory inspection requirements of applicable national, regional, local laws and regulations for the area of installation or as furnished by Grupa LOTOS S.A. have to be observed.

A visual and dimensional spot check by Grupa LOTOS S.A. authorised representative will be carried out prior to the hydraulic test and/or heat treatment or coating of the heat exchanger..

The Manufacturer shall notify in writing (by e-mail and/or fax) Grupa LOTOS at least 10 working days in advance when the heat exchanger will be ready for inspection.

Inspection by Grupa LOTOS S.A. shall in no way relieve the Manufacturer from the responsibility to meet the requirements of the purchase documents.

Grupa LOTOS S.A. authorised representative shall have the right to inspect all work in progress, to insure that proper workmanship, orientation, welding, testing, painting, etc. are being obtained.

Grupa LOTOS reserves the right to make preliminary intermediate and final inspection.

The heat exchangers as made available for the inspection shall be free from slag, dirt, oil, welding spatter and other foreign matter.

The heat exchangers presented for the inspection shall be subjected to a previous dimensional check by the manufacturer. The manufacturer shall prepare a dimensional record indicating the actual dimensions for each heat exchanger (including out of roundness; offset in welded joints, deviations from true alignment) and submit it to the Grupa LOTOS S.A. authorised representative. Any deviation from the specified tolerances shall be clearly marked in this record.

All loose components included in the scope of supply of the heat exchangers shall be kept ready for the inspection.

If the heat exchangers or heat exchangers' components to be inspected are not ready to the expected extent or in the specified quality at the scheduled date, the manufacturer shall bear all additional costs arising from subsequent inspections.

After specified hold points have been reached, Manufacturer shall not proceed with performing the activity until authorization is received from Grupa LOTOS S.A.

Inspection of torquing (or tightening) on main flanges bolts has to be done after installing of the exchanger on the plant. If inspected values are different from the project ones, then the manufacturer or contractor of the exchanger is obliged to supply exchanger to Grupa LOTOS S.A. with a proper torquing (tightening) values. Then the manufacturer (contractor) of the exchanger must perform a pressure test.

In case of the following problems, Grupa LOTOS shall be informed in writing without any delay:

- Deviations from the standard
- Rejected or insufficient test results
- Objections raised in connection with the checking of drawings
- Failure to comply with the specified tolerances
- Fabrication defects / repairs
- All events resulting in fabrication delays and thus jeopardising the delivery date.

6.4 Documents Required During Inspection

Grupa LOTOS S.A. authorized representatives at the time quality surveillance activities are being conducted at Manufacturer premises shall have available a complete set of below listed documents related to the purchase order:

- Confirmed purchase orders for materials
- Material certificates together with part list for which they will be used
- Welding procedures approved by Notified Body
- Welder's qualification records
- Weld map
- Certificates of performed tests of welds
- Certificates of heat treatment
- Plan of marking of materials on the equipment (main pressure parts
- Certificates of manufacturer's pressure tests
- Certificates of first pressure tests issued by Notified Body
- Manufacturer's dimensional check record
- Manufacturer's certificate of conformity, that equipment was manufactured in accordance with:

- relevant code agreed in purchase order and PED 97/23/EC
- standards
- technical documentation

- Notified Body certificate of conformity, that equipment was manufactured in accordance with relevant code and PED 97/23/EC.

6.5 Rejection

Equipment or parts thereof and materials entering therein, indicating irremediable or injurious defect, improper fabrication, excessive repairs, or that they are not in accordance with the requirements of this specification shall be subject to rejection. They shall be subject to rejection at any time or place by the Grupa LOTOS S.A. authorised representative if such conditions are discovered after acceptance of the items at the supplier's plant.

7 Nameplates

Completed heat exchangers shall have a nameplate in Polish language or Polish and English language, in accordance with TEMA and PED 97/23/EC. Nameplates shall be made of corrosion resistant material installed on a nameplate bracket by solid stainless steel rivets. Inscriptions on the nameplate shall be engraved. The nameplate on horizontal heat exchangers shall be located above the fixed saddle support.

8 Painting, Marking, Packing

8.1 Painting

Painting shall be in accordance with Grupa LOTOS specification No.: 1190.

Unless otherwise noted on the drawings, shop fabricated equipment shall be painted on outside surfaces only.

Shop painting shall not be applied within 150 mm (6 inches) of any weld before Grupa LOTOS S.A. inspection.

Stainless steel and high nickel alloy (inconel, hastelloy, etc.) are not to be painted, unless noted otherwise. Only stainless steel brushes, clean, iron free sand or stainless grit shall be used for cleaning alloy surfaces. All welding flux shall be completely removed. Solvents used to clean or remove scale or oil shall be free of organic and inorganic chlorides.

Derusting, painting as well as preservation of the pressure equipment shall be carried out after hydrostatic testing and the inspection by Grupa LOTOS S.A.

Exposed machined parts for example: flange facing, threads shall be protected during fabrication/ blasting and painting.

Stainless steel equipment, which does not require painting, shall have the outside surface pickled and passivated.

8.2 Marking

The heat exchanger shall be marked with the item number. (Character height about 200 mm)

Removable heat exchanger components such as covers, bundles, floating heads, test rings, glands etc. shall be durably marked with the technological number of the heat exchanger.

Care shall be taken to ensure that water insoluble ink or paint is used for markings.

When austenitic and high nickel alloy (inconel, hastelloy, etc.) steels are to be marked with fabrication or shipping information, the marking shall be done with water insoluble ink that does not contain sulphur, chlorides or metallic pigments.

Parts to be supplied loose such as spare parts shall be identified by means of a tag indicating the relevant part number as per the workshop drawing as well as the item number.

8.3 Packing

All openings shall be sealed watertight and in such a way as to avoid damage to the connecting faces and preclude access to the inside of the heat exchanger for strangers.

Telltale and vent holes in saddles and reinforcing plates shall be filled with corrosion-inhibiting grease.

Loose small elements and spare parts included in the scope of supply shall be separately packed and shipped together with the heat exchanger.

Further information on packing and transport are included in the packing and shipping instructions.

Unless otherwise specified the heat exchanger interior shall be thoroughly cleaned and dried.

If specified in relevant purchase order documents; stainless steel heat exchangers (including stainless steel clad heat exchangers) shall be filled with nitrogen and provided with nitrogen cylinder, 3-way valve, gauge and stainless steel shroud. The required overpressure shall be written on the shroud. Nozzles for welding on site shall be bevelled and protected with steel or plastic caps.

9 Manufacturer's Qualification

Upon request, the Manufacturer shall furnish evidence that he is able to fulfil the requirements for fabrication, testing and inspection of heat exchangers as specified in the relevant codes and regulations.

Should valid qualification records for the welding procedures and welders not be available at time of the bid or should the qualification records available fail to cover one or several criteria to be met, this has to be indicated in the bid. Any difficult fabrication activities or special manufacturing cases shall be considered.

Before fabrication, any welding procedure and welder's qualification records required shall be duly checked and approved by third party as required by PED 97/23/WE and purchase order.

10 Guarantees

All materials, design and construction shall be subject to the conditions and guarantees required by the purchase order.

The heat exchanger manufacturer shall guarantee that the equipment designed by him, will meet the conditions specified in the purchase order. In case the equipment does not fulfil the specified conditions the heat exchanger manufacturer shall, without cost to Grupa LOTOS S.A. furnish such new equipment or redesign, and rebuild the equipment furnished, so that the specified conditions will be met.

Drawings review, intermediate and final inspections of heat exchangers carried out by Grupa LOTOS S.A., and also Release Note do not relieve manufacturer from his responsibility to fulfill requirements of purchase order.

11 Relavant documents

Any "Technical Specification" issued by Grupa LOTOS S.A. listed in Contract Files.

12 Codes and standards

Codes and standards listed below form part of this specification. Each publication shall be the latest revision and addendum in effect at the Contract award, unless otherwise specified:

- 97/23/WE (PED) Directive of the European Parliament and of the Council on the approximation of the law of the Member States concerning pressure equipment
- 2009/105/EC Directive of the European Parliament and of the Council relating to simple pressure vessels (replaces Directive 87/404/EEC of 25 June 1987)
- ASME BPVC ASME Boiler & Pressure Vessels Code – Sections I through X
- ASME B16.5 Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24
- ASME B16.47 Large Diameter Steel Flanges NPS 26 Through NPS 60
- ASME B16.20 Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral-Wound, and Jacketed
- ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges
- ASME B 1.1 Unified Inch Screw Threads (UN and UNR Thread Form)
- TEMA (Tubular Exchanger Manufacturers Association) Standards
- ASTM A 435 Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
- ASTM A 578 Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- ASTM A 262 Standard practice for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steel
- ASTM A 263 Standard Specification for Stainless Chromium Steel-Clad Plate
- ASTM A 264 Standard Specification for Stainless Chromium-Nickel Steel-Clad Plate
- ASTM A 265 Standard Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate
- British Standard BS 5500, Appendix G
- PN-EN-10204 Metallic products - Types of inspection documents
- Welding Research Council (WRC) Bulletin:
    - WRC Bulletin 537
- Stresses in Large horizontal cylindrical pressure Vessels on 2 saddled supports by L.P. Zick
- DIN 580 Eye bolts
- DIN 8558 Part 2 Design and workmanship of welded joints. Steel vessels and apparatus used in the chemical industry
- DIN 28080 Saddle supports for horizontal cylindrical vessels
- DIN 28083 Bracket supports, Part 1 and 2
- DIN 28085 Lifting lugs on apparatus for mounting
- DIN 28086 Lugs on vessels for use in process engineering

- DIN 28182 Tubular heat exchangers; tube pitches, diameter of bores in tubesheets, baffles and support plates

13 Record of changes

No.	Date	Description	Introduced by
0		This specification entirely replaces the former Grupa LOTOS S.A. standard No. PR 07 231 with the same title.	B. Kowalewski
1	14.11.2006.	In the point 4.14.3. changed min. wall thickness of the tubes.	B. Kowalewski
2	09-05-2011	Changed points 4.1, 5.2, 6.3.	S. Zajączkowski
3	30-11-2013 (rev.3)	Review, update, standardize and changes to the Standard within scope of order No. OK/990/2012	Editorial board coordinated by T.Wróbel
-	31-08-2015	Page layout corrections, no contents changes.	T. Wróbel