



TECHNICAL REQUIREMENTS

MECHANICAL

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SHELL AND TUBE HEAT EXCHANGERS

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1. SCOPE

- 1.1 This Specification, together with applicable job specifications, covers the minimum requirements for shell and tube exchangers used in general refinery and petrochemical services.
- 1.2 This Specification does not cover double pipe exchangers, tank heaters or tubular exchangers associated with Mechanical equipment normally furnished by the supplier of that equipment.

2. REFERENCES

The latest editions of the following publications are to be used with this Specification as applicable:

2.1 Standards of Tubular Exchanger Manufacturers Association (TEMA), Class "R"

NOTE: Unless otherwise specified in individual heat exchanger Material Requisition.

2.2 American Petroleum Institute (API) Standards

API Std. 660/ISO 16812 *Shell-and-Tube Heat Exchangers for General Refinery Services*

2.3 European Standards

EN 13445 (all parts) *Unfired pressure vessels*

2.4 American Society of Mechanical Engineers (ASME) Standards

ASME B16.5 *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24*

ASME B16.11 *Forged Steel Fittings, Socket Welding and Threaded*

ASME B16.20 *Metallic Gaskets for Pipe Flanges*

ASME B16.47 *Large Diameter Steel Flanges NPS 26 Through NPS 60 (Series "B" if not otherwise indicated)*

ASME SEC VIII D1 *BPVC Section VIII - Rules for Construction of Pressure Vessels - Division 1*

ASME SEC VIII D2 *BPVC Section VIII - Rules for Construction of Pressure Vessels - Division 2 Alternative Rules*

ASME SEC IX *BPVC Section IX - Welding, Brazing, and Fusing Qualifications*

ASME SEC II A *BPVC Section II A - Ferrous Material Specification*

ASME SEC II B *BPVC Section II B - Non-Ferrous Material Specifications*

ASME SEC II D *BPVC Section II D - Material Properties*

2.5 American Society of Testing and Materials (ASTM) Specifications:

ASTM A 193/A 193M *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service*

ASTM A 320/A 320M *Standard Specification for Alloy/Steel Bolting Materials for Low-Temperature Service*

2.6 Standards of Expansion Joint Manufacturers Association (EJMA)

2.7 National Association of Corrosion Engineers (NACE) Standards

NACE MR0103 *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

2.8 OL Specifications

OL-TR-GR-000 *General Requirements*

OL-TR-CR-002 *Civil. Heat Insulation*

OL-TR-CR-011 *Civil. Corrosion Protection and Lining. Painting*

OL-TR-CR-012 *Civil. Corrosion Protection and Lining. Lining for Piping and Pressure Vessels*

OL-TR-MR-000 *Mechanical. General*

OL-TR-MR-001 *Mechanical. General Welding, Fabrication and Inspection*

OL-TR-MR-002 *Mechanical. Positive Material Identification*

OL-TR-MVR-001 *Mechanical. Unfired Pressure Vessels*

2.9 Local, State, National Codes and Legislations

Legislation of the Republic of Lithuanian *Law on the Supervision of Potentially Dangerous Equipment No. I-1324 („Lietuvos Respublikos Potencialiai pavojingų įrenginių priežiūros įstatymas Nr. I-1324 (aktuali redakcija nuo 2011 -07-19)“)*

Legislation of the Republic of Lithuanian *Law on Assessment of Conformity VIII-870 („Atitikties įvertinimo įstatymas VIII-870“)*

Legislation of the Republic of Lithuanian *Technical Regulation on Pressure Equipment (Slėginių įrenginių techninis reglamentas)*

Legislation of the Republic of Lithuanian *Technical Regulations for Equipment and Protection Systems Used in Potentially Explosive Atmosphere („Įrangos ir apsaugos sistemų, naudojamų potencialiai sprogoje aplinkoje, techninis reglamentas“)*

STR 1, 2 (Legislation of the Republic of Lithuanian) *Technical regalement's of construction*

2.10 Others

Equipment shall comply also with the following:

2.10.1 Pressure equipment, as defined in Pressure Equipment Directive (P.E.D.) 97/23/CE article 1, shall fully satisfy the P.E.D. essential safety requirements. In particular, design and construction shall be carried out by Manufacturer according to ASME or EN code, as amended under the supervision and approval of the nominated Notified Body, to fulfill P.E.D. requirements.

2.10.2 Equipment and Protection Systems intended for use in Potentially Explosive Atmospheres, shall be in full compliance with Directive 94/9/CE (ATEX) requirements.

NOTES:

(1) Detailed information relevant to Area Classification, Group, Ignition Temperature etc., shall be as indicated on individual Material Requisition.

(2) Manufacturer shall affix the CE marking and shall prepare a declaration of conformity for the Equipment. Nomination of a Notified Body shall be made as needed.

2.10.3 Compliance with European Directives includes all needed/requested CE nameplates, marking, declaration of conformity, operating instruction manuals etc.

3. TERMS AND DEFINITIONS

For terms and definitions see:

- Section 3 of API Std. 660/ISO 16812;

NOTE: Addition to Section 3 of API Std. 660/ISO 16812: Effective surface - the area associated with tube bends in U-tube bundles shall be considered as effective heat transfer surface in kettle-type reboilers only.

4. REQUIREMENTS

4.1 Shell and tube heat exchangers covered by this Specification shall be designed, fabricated, inspected, tested and stamped in accordance with TEMA except as modified in API Standard 660, this Specification, a job specification and individual data sheets listing specific operating conditions and special requirements. The order of precedence is:

- a) Data Sheet (see Annex A), doc. no. OL-TR-MER-DS1 (acc. to TEMA);
- b) Job Specification;
- c) This Specification;
- d) API Standard 660;
- e) TEMA.

4.2 The Vendor's proposal shall include, for each heat exchanger unit, completed data sheets such as given doc. no OL-TR-MER-DS1 (latest rev.).

4.3 The surface area, when shown by OL on individual data sheets at the inquiry stage, is given for preliminary plot plan and general information purposes only. The Manufacturer shall be responsible for thermal, hydraulic, Mechanical and vibration free design.

4.4 A manufacturer may offer his standard design as an alternate unit, provided the alternate design covers a construction which is suitable for and guaranteed to meet the

operating conditions specific and all deviations from this Specification are listed in the Vendor's proposal.

- 4.5 Test rings for floating head exchangers having removable shell covers shall be included.
- 4.6 The exchanger must comply with all local, state and national codes. Where conflicts occurs, the applicability of local, state and national codes, regulations, ordinances or rules shall be mutually agreed upon by the OL and vendor.
- 4.7 Paragraph and section numbers referenced in this Specification refer to numbers in TEMA unless otherwise specified.

5. DESIGN

5.1 General

- 5.1.1 Continuous longitudinal baffles which form two pass shells (TEMA Type F) may be considered only when they provide significant thermal and Mechanical design advantages, and then only when specific approval is given by the OL.
- 5.1.2 Where single pass floating head design is required and approved by OL, a bellows type internal expansion joint shall be used for the floating head nozzle connection.
- 5.1.3 Multiple shell units of the same size design and material shall have interchangeable parts insofar as is practical.
- 5.1.4 Outside packed floating heads (TEMA Type P) are not to be used.
- 5.1.5 The U-bend area is not admissible as effective area for sensible heat service on single pass shell designs with shell side fouling factor greater than 0.0016, regardless of nozzle locations. The U-bend area in a kettle reboiler may be admissible as effective area.
- 5.1.6 When TEMA "H" is specified for isothermal boiling of fluid on shell side, the long baffles shall be perforated with 6mm (1/4") diameter holes at 12mm (1/2") pitch. The maximum baffle length should extend 150mm (6") on each side of tube support.

5.2 Design Conditions

- 5.2.1 Physical properties of petroleum fractions will be as specified on individual data sheets or TEMA Section 8. Viscosities and specific heats of fluids other than petroleum fractions, where not specified on individual data sheets, will be calculated by the vendor from data given and from recognized sources of engineering literature.
- 5.2.2 Water flow on tube side of exchangers shall be designed for a velocity range of 1 to 2.5m/s. Vendor is to advise if allowable pressure drop is not compatible with economical design and these water velocity limits.
- 5.2.3 Differential of tube-side/shell-side design pressure shall not be used for the calculation of thickness of tubes, tube sheets, flanges, floating-heads, etc. without the written approval of OL.

5.3 Materials

- 5.3.1** Materials shall be as stated on the data sheet. Ferritic material selected from the ASME Code shall not be used below -29°C (-20°F) design temperature unless it passes the impact tests in accordance with Paragraph UG-84 of the ASME Code.
- 5.3.2** Bessemer quality steel, other than deoxidized acid Bessemer steel, shall not be used for parts to be welded or formed.
- 5.3.3** Minimum thickness of carbon steel shells, channels and bonnets in Paragraph RCB-3.13, R-9.11, and CB-9.11 will apply to low alloy materials not exceeding 9% chromium.
- 5.3.4** Purchaser shall specify if the service is sour in accordance with NACE MR0103 (i.e., sulfide stress cracking is possible), in which case all materials in contact with the process fluid shall meet the requirements of NACE MR0103.
- 5.3.5** Floating head flange joint bolting of ferritic material shall be ASTM A 193/A 193M Grade B7M if the shell side service has been specified to contain wet H₂S, caustic solution in concentrations which would require PWHT, or amines. Due to the lower yield strength of B7M studs (when compared to B7/B16 studs), controlled tightening of the floating head should be considered.
- 5.3.6** If the shell side corrosion allowance is greater than 3mm (1/8"), floating head flange bolting shall be either 12 chrome conforming to ASTM A 193/A 193M Grade B6 or 18 chrome 8 nickel conforming to ASTM A 320/A 320M Grade B8, strain hardened.
- 5.4 Alloy Protective Linings**
- 5.4.1** Where non-ferrous shell, channel or tube sheets are specified in the individual data sheets and solid is not specified, the vendor may offer either solid or clad type. Cladding shall be explosive bonded, roll bonded or weld overlay. When clad is used it must meet Paragraph RB-7.6 and C-7.6. Fabrication, inspection and testing procedures shall comply with OL Specification OL-TR-MR-001, General Welding, Fabrication and Inspection.
- 5.4.2** The specified minimum thickness of corrosion-resistant lining or cladding shall be applicable to all exposed surfaces including sides and bottom of partition and other gasket grooves.
- 5.4.3** Sleeve lining or strip lining is prohibited without written approval of OL.
- 5.5 Shells, Channels and Covers**
- 5.5.1** Modify API Standard 660, Paragraph 7.8.2 to read: Shell and channel girth flanges are to be of forged steel, weld neck type, faced for confined gaskets. For design pressures less than 10bar(g) (150psi(g)), the girth flanges shall be designed for 10bar(g) (150psi(g)) minimum. Slip-on welding flanges shall not be used.
- 5.5.2** Modify Paragraph G-7.11 to incorporate the following: The fixed shell support and anchor bolt size are to be designed to withstand a longitudinal force twice the bundle weight. Minimum anchor bolt size is M24.
- 5.5.3** Add to API Standard 660, Paragraph 7.3.3: The corrosion allowance shall be deducted before investigating such external loading.
- 5.5.4** The boiling water side of steam generators shall also comply with ASME Code Section I unless noted differently on the data sheet.

5.5.5 Process nozzles in the corroded condition shall be capable of withstanding the moments and forces in Table 1 below. The forces act as shown in figure RGP-RCB-10.6. Calculations are to be made in accordance with WRC-107 at the nozzle to shell intersection (pipe O.D.). Other methods require OL approval. None of the individual stresses (circumferential, longitudinal, shear or combined) may exceed 2.5Sa at pipe O.D. for nozzle without pad or 1Sa at pipe O.D. for nozzle with pad. Stresses shall be checked at nozzle O.D. and pad O.D. In some cases, added shell thickness may be required.

Table 1. Maximum Allowable Nozzle Loads

Nozzle Size DN (In.)	Forces N (lbf)			Moments N-m (lbf-ft)		
	P	V ₁	V _c	M _r	M ₁	M _c
80 (3")	2669 (600)	2669 (600)	2669 (600)	813 (600)	813 (600)	813 (600)
100 (4")	4448 (1000)	4448 (1000)	4448 (1000)	1627 (1200)	1356 (1000)	1356 (1000)
150 (6")	8007 (1800)	6672 (1500)	6672 (1500)	4067 (3000)	3661 (2700)	3661 (2700)
200 (8")	13345 (3000)	10676 (2400)	10676 (2400)	8135 (6000)	6101 (4500)	6101 (4500)
250 (10")	17793 (4000)	13345 (3000)	13345 (3000)	8135 (6000)	7457 (5500)	6779 (5000)
300 (12")	20017 (4500)	17793 (4000)	17793 (4000)	8135 (6000)	9491 (7000)	8135 (6000)
350 (14")	22241 (5000)	22241 (5000)	22241 (5000)	9491 (7000)	10847 (8000)	9491 (7000)
400 (16")	25800 (5800)	25800 (5800)	25800 (5800)	10169 (7500)	12202 (9000)	11524 (8500)
450 (18")	28913 (6500)	28913 (6500)	28913 (6500)	11253 (8300)	13287 (9800)	12609 (9300)
500 (20")	31138 (7000)	31138 (7000)	31138 (7000)	12474 (9200)	14236 (10500)	13829 (10200)
600 (24")	34251 (7700)	34251 (7700)	34251 (7700)	14236 (10500)	16948 (12500)	16134 (11900)

5.6 Tube Bundle

5.6.1 Tube wall thickness calculations shall take into consideration thinning at U-bend. If required, the inner tube row(s) gage may be increased.

5.6.2 Add to API Standard 660 Paragraph 9.6.2:

- Stress relieve u-bends of all carbon steel, low alloys steel, copper alloys and monel;
- Stress relieve u-bends of 12% Cr, and 17% Cr stainless steel;
- Stress relieve u-bends of austenitic stainless steel after bending at 1020 to 1100°C;
- Stress relieve u-bends of austenitic stainless steel after bending at 1020 to 1100°C;
- Stress relieve u-bends of austenitic-ferritic (duplex) stainless steel in case a heat treatment is required for process reasons or for manufacturer practice (quench annealing at 1050 to 1100°C).

5.7 Bolts – Gaskets

5.7.1 Bolts between connecting nozzles of stacked exchangers will be provided by the Vendor and are to be removable without moving the exchangers.

5.7.2 Nozzles gaskets shall be in accordance with the Table 2 below.

Table 2. Gaskets

Flange Facing	Face Finish	Gasket Type	Dimensional Code
RF & FF	Stock	1.5mm soft ring	ASME B 16.21
RF	Stock	Spiral Wound	ASME B 16.20
RF	Very Smooth	Metal Jacketed	ASME B 16.20
RJ	Very Smooth	Oval Ring	ASME B 16.20

5.8 Connections, Miscellaneous

5.8.1 Nozzle necks shall have minimum thickness not less than the requirement of the Code, using design temperature, design pressure and corrosion allowance as specified on the Material Requisition.

5.8.2 Modify TEMA Paragraphs RB-10.33 and C-10.33 to read: Thermowell connections shall be DN25 (1") nominal pipe size NPT in cooling water service and for all other services. Projection shall be 152mm (6") from face of flange to O.D. nozzle.

5.8.3 When RTJ nozzle flanges are specified, vents and drains in Paragraph RCB-10.31 shall be DN25 (1") flanged RTJ and pressure gauge and thermowell connections in Paragraphs R-10.32, C-10.32, B-10.32, RB-10.33, and C-10.33 shall be omitted.

5.8.4 Nozzles and couplings shall be installed so that their ends match smoothly with the inside surface of the shell, channel, or head to which they are attached.

5.8.5 Shims, spacers, bolts, nuts, washers and gaskets (for interconnecting nozzles) shall be furnished for stacked exchangers.

5.8.6 Modify TEMA paragraphs R-10.32, C-10.32 and B-10.32 to read: Pressure gauge connections shall be DN20 (3/4") nominal pipe size for all nozzle sizes unless noted otherwise on data sheets. When flanged connections are specified, they shall be DN25 (1") LWN flanges.

5.8.7 All flanged auxiliary connections shall be furnished with blind flange.

6. FABRICATION

6.1 When requested in the OL purchase order, welding procedures shall be submitted for OL approval within 10 days after receipt of an order. No welding shall be done prior to OL's final written acceptance of the procedures. Welding procedures shall comply with the requirements of OL Specification OL-TR-MR-001, General Welding, Fabrication and Inspection.

6.2 FCAW and FCAW/SMAW welding procedures on materials in the P-1 through P-4 groups are not acceptable.

6.3 Oxyacetylene welding will not be used on fabrication of heat exchangers. Any other ASME or EN Code approved method may be used.

- 6.4 Stress relief of an austenitic (300 series) stainless steel bellows or any part of a single pass floating head assembly is prohibited.
- 6.5 When strength or seal welding of tubes is specified the manufacturer shall submit a procedure for the tube installation, welding and testing for approval. The procedure shall incorporate the following steps at a minimum:
- a) Chamfer all tube holes on tubeside;
 - b) Clean tube ends, tubesheet face and tube holes;
 - c) Insert tubes and lightly roll to hold in place;
 - d) Weld tubes to tubesheet;
 - e) Air and soap test welds;
 - f) After test, expand tubes to proper amount;
 - g) Liquid penetrant test seal welds;
 - h) Hydrostatic test per ASME or EN code.

7. DOCUMENTS

- 7.1 API Standard 660 Section 6 is supplemented by OL's Vendor Data Requirements. Nozzle load calculations shall be submitted to OL for record.
- 7.2 Additional engineering information required from the vendor and quantities of Vendor Data to be supplied are listed on OL Vendor Data Requirement Forms and/or related OL Specifications *OL-TR-MR-000*, *OL-TR-GR-000* etc.

8. WARRANTY AND GUARANTEES

TEMA paragraph G-5 is supplemented by OL's Terms and Conditions. Manufacturer is responsible for thermal, hydraulic, Mechanical and vibration free design.

9. INSPECTION AND TESTING

- 9.1 API Standard 660 Section 10 is supplemented by OL's Inspection Matrix and the requirements of OL Specifications *OL-TR-MR-001* and *OL-TR-MR-002*. Exchangers with design pressures equal to or greater than 34bar(g) (500psi(g)) shall be 100% radiographed.
- 9.2 All welded tube-to-tubesheet joints shall have the tube weld integrity verified (before final expansion) by pneumatic test from the shellside at a minimum gauge pressure of 1bar (15psi), using a soap-water solution to reveal leaks.
- 9.3 The shellside hydrostatic test shall be conducted with the bonnet or channel cover removed unless otherwise specified by Purchaser.
- 9.4 An optional shellside helium leak test shall be provided when specified by Purchaser for welded tube-to-tubesheet joints prior to final expansion.
- 9.5 A supplemental helium flange leak test shall be provided when specified by Purchaser.

10. PREPARATION FOR SHIPMENT

- 10.1 All external surfaces shall be cleaned and primed in accordance with OL Specification *OL-TR-CR-011*.

- 10.2** All exchangers shall be dried to ambient dew point. Exchangers shipped over the ocean shall be purged with nitrogen prior to closing for shipment. Exchangers shipped overland shall have a desiccant, such as silica gel, placed inside the nozzles.
- 10.3** Threaded connections shall be plugged with solid bar stock plugs of the same nominal chemical composition as the connection.
- 10.4** Test holes in reinforcing pads shall be plugged with grease or plastic sealant prior to shipment.

ANNEX A. (INFORMATIVE) DATA SHEET

This annex includes data sheet for the following items:

- Shell and Tube Heat Exchanger Data Sheet:
doc. no. *OL-TR-MER-DS1*, 1 page.