

DEP SPECIFICATION

SHELL AND TUBE HEAT EXCHANGERS
(AMENDMENTS/SUPPLEMENTS TO ISO 16812:2007)

DEP 31.21.01.30-Gen.

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ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



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These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

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The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

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- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

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TABLE OF CONTENTS

PART I	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES	6
1.6	COMMENTS ON THIS DEP	6
1.7	DUAL UNITS.....	6
PART II	GENERAL.....	7
1.	DESIGN SPECIFICATIONS	7
1.1	THERMAL DESIGN AND RATING	7
1.2	MATERIALS SPECIFICATIONS	8
2.	ORDERING.....	8
2.1	SCOPE OF SUPPLY	8
3.	DESIGN RULES	8
PART III	AMENDMENTS/SUPPLEMENTS TO ISO 16812.....	10
3.	Terms and definitions.....	10
4.	General.....	10
5.	Proposals.....	11
6.	Drawings and other required data	11
6.1	Outline drawings and other supporting data	11
6.2	Information required after outline drawings are reviewed	11
6.3	Reports and records.....	12
7.	Design	13
7.1	Design temperature (and pressure)	13
7.2	Cladding for corrosion allowance	13
7.3	Shell supports	14
7.4	Stationary head	15
7.5	Floating head.....	16
7.6	Tube bundle.....	17
7.7	Nozzles and other connections	27
7.8	Flanged external girth joints.....	29
7.9	Expansion joints	32
7.10	Gaskets	33
7.11	Handling devices	35
7.13	Carbon steel in wet hydrogen sulfide service	35
7.14	Kettle-type reboilers and evaporators	36
7.15	Embaffle™ heat exchangers	37
7.16	Transitions.....	38
8.	Materials.....	38
8.1	General.....	38
8.2	Gaskets	38
8.3	Tubes.....	39
8.4	External bolting	39
8.5	Cathodic protection	40
9.	Fabrication.....	40
9.1	Shells.....	40
9.2	Pass-partition plates.....	40
9.5	Welding	41
9.6	Heat treatment.....	41
9.7	Dimensional tolerances.....	43

9.8	Gasket contact surfaces other than nozzle-flange facings	43
9.9	Tube holes	44
9.10	Tube-to-tubesheet joints	44
9.11	Assembly	44
9.12	Insulation supports	45
10.	Inspection and testing	45
10.1	Quality assurance	45
10.2	Quality control	45
10.3	Pressure testing	46
10.4	Nameplates and stampings	47
10.5	Test ring and test flange	47
10.6	Repairs	48
11.	Preparation for shipment	48
11.1	Protection	48
11.2	Identification	49
12.	Supplemental requirements	49
12.1	General	49
12.2	Design	49
Annex A	Recommended practices	50
Annex B	Shell and tube heat exchanger checklist	50
Annex C	Shell and tube heat exchanger data sheets	50
PART IV	REFERENCES	51

APPENDICES

APPENDIX 1	MATERIALS FOR USE IN SHELL AND TUBE HEAT EXCHANGERS	54
APPENDIX 2	METHOD OF DETECTION OF HARMFUL OXIDE FILMS ON COPPER-NICKEL ALLOY TUBES	64
APPENDIX 3	DRAWINGS	66

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design and construction of shell and tube heat exchangers having a bare tube surface area of greater than 0.5 m² (5.4 ft²). This DEP is not intended for hairpin type heat exchangers or for pressurized water-cooled (or glycol-cooled) seal-oil coolers, lube-oil coolers, jacket water coolers for rotating equipment, vacuum-operated steam surface condensers, feed water heaters, or alkylation contactor bundles of proprietary design.

Part III of this DEP is written in the form of amendments and supplements to ISO 16812:2007. Part III follows the clause numbering of ISO 16812 for easy reference.

All clauses of ISO 16812 not modified by this DEP remain valid as written.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated September 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

NOTE: The terms Supplier and Manufacturer as used in this DEP are synonymous with the term **Vendor** (as used in ISO 16812:2007) depending on the context in which the term is used.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

NOTE: The term Principal as used in this DEP is synonymous with the term **Purchaser** (as used in ISO 16812:2007).

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (Part IV).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a minor revision of the DEP of the same number dated September 2013. The following are the main, non-editorial changes.

Section/Clause	Change
Part III, 7.3.9	Deleted first sentence of clause.
Part III, 7.5.12.1	Revised clause in its entirety.
Part III, 7.5.12.4	Deleted clause. Renumbered remaining clause.
Part III, Table 9	Modified gasket stress table.
Part IV	Deleted standard drawing reference S 21.017.
Part IV	Added standard drawing reference S 21.085.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II GENERAL

(Part III) of this DEP is written as amendments and supplements to ISO 16812:2007. Wherever reference is made to ISO 16812, it shall be understood to mean ISO 16812:2007 as amended/supplemented by this DEP.

For ease of reference, the clause numbering of ISO 16812 has been used throughout (Part III) of this DEP.

Clauses in ISO 16812, which are not mentioned in this DEP, shall remain valid as written.

This document is intended primarily for use by the Supplier and shall be included in the purchase requisition along with the heat exchanger data/requisition sheet (DEP 31.21.00.93-Gen., or equivalent), supplementary technical requirements, project specifications, and any other DEPs required to provide a complete set of design, materials, fabrication, inspection and testing instructions to the Supplier.

1. DESIGN SPECIFICATIONS

1.1 THERMAL DESIGN AND RATING

1.1.1 The TEMA type and other details of the design including tube count, tube diameter, tube thickness, tube length, number of tube passes, tube layout angle, tube pitch, number of shellside cross-passes, baffle spacing, baffle cut and orientation shall be as specified on the data/requisition sheet (DEP 31.21.00.93-Gen., or equivalent) by the Contractor. The Supplier may propose an alternate design for consideration, provided the proposal includes the base design specified by the Contractor.

1.1.2 The Supplier shall provide a mechanical and thermal performance guarantee, regardless of the party who completes the initial thermal design or rating, unless otherwise agreed by the Principal. In the case of a proprietary design, the Contractor shall contact the Principal to agree on the calculation method and responsibility.

1.1.3 Designs with helical baffles, rod-baffles, EMBaffles™, twisted tubes, low-finned tubes or other enhanced tube types (including tube inserts) may only be used with the agreement of the Principal. This requirement is not intended to impede the application of enhanced heat transfer technology; the intention is to assist in improving the likelihood of successful applications.

1.1.4 Floating head exchangers with a nozzle connection to the floating head cover, commonly referred to as a "tail-pipe" nozzle, with expansion joint, and fixed tubesheet exchangers shall be designed to accommodate normal operating cases in accordance with (Part III clause 7.9.2.c).

The Contractor SHALL [PS] also provide steady state and any applicable transient details for predictable upset cases (e.g., loss of flow, loss of upstream wash water injection, etc.), start-up and shut-down cases (including steam-out). Flow rates, inlet pressures, inlet temperatures, physical properties, and heating curves (where applicable) for both the hot and cold streams, shall be provided for each case. An expansion joint design checklist (per ISO 16812, Annex C, or equivalent) shall be provided with the data/requisition sheet by the Contractor.

Shell-and-tube metal temperatures for analysis of thermal stresses SHALL [PS] be those that produce the most adverse differential expansion conditions that can occur, including the effects with only one (1) side fouled. The minimum number of cycles for each case, other than the normal operating case, shall be specified by the Contractor based on 10 times the number of cycles expected in a ten year period.

If the data provided by the Contractor is considered to be insufficient for checking purposes, it is the responsibility of the Supplier to request further information from the Contractor.

The materials and Supplier of thin-wall bellows expansion joints shall be approved by the Principal.

- 1.1.5** All exchangers SHALL [PS] be analyzed for flow induced mechanical vibration. All exchangers with single phase gas service and two-phase flow services with more than 95 % vapour (by mass) at the shell side inlet, shall also be analyzed for acoustic vibration noise.

For exchangers with vapour or two-phase flow on the shell side, or for those with baffle cuts which are parallel to the inlet/outlet nozzle centrelines, the vibration analysis SHALL [PS] be verified based on the actual tube bundle design details provided in the Supplier's general arrangement or detailed drawings (actual baffle locations, actual shell entrance and exit areas, actual tube layout) rather than the tube bundle details assumed or specified by the Contractor on the data/requisition sheet at the enquiry stage.

In the event of disagreements about tube vibration, the HTRI Xist program shall be used as a basis for assessing tube vibration. The use of the HTRI Xvib program shall only be used with the approval of the Principal.

- 1.1.6** Prior to completing the design, the Contractor shall determine all restrictions on bundle size (diameter, length, weight) and any other special provisions for bundle maintenance based on the bundle pulling, handling, or cleaning equipment used at the operating site considering applicable economic considerations for exchanger foundations, structures, and required maintenance access.

- 1.1.7** The checklist referenced in ISO 16812, Annex B, which is replaced by DEP 31.21.01.83-Gen., shall be completed for each project and included with the requisition documents in order to properly use this DEP as part of purchase requisition.

1.2 MATERIALS SPECIFICATIONS

(Appendix 1) provides a summary of material specifications and supplemental requirements for a number of generalised service conditions specific to the tube side (tube bundle, channel, floating head, etc.).

It is the responsibility of the Contractor to specify the materials for all pressure components (including pass partition plates, bolting and gaskets) and non-pressure components (including baffles, impingement devices, tie rods and sealing devices) on the data/requisition sheet.

2. ORDERING

2.1 SCOPE OF SUPPLY

The Supplier shall provide the complete heat exchanger including:

- a) Bolts, nuts and gaskets for the interconnecting nozzles of directly flanged stacked heat exchangers;
- b) Shims and bolting for the interconnecting supports of stacked heat exchangers,
- c) The number of spare sets of gaskets and bolting for construction and start up spares. These shall be identified by the Contractor.

The Contractor shall specify when the Supplier is expected to install or provide insulation clips, platform clips and other similar types of field scope or construction interfaces.

Excluded from the scope of supply are foundations, the erection of the supporting structure, instruments, insulation, and fireproofing of saddles or structural support steel.

3. DESIGN RULES

In case of conflict between documents relating to an order, the following hierarchy shall normally apply:

- a) Equipment data sheets and drawings;
- b) The purchase requisition;

- c) This DEP
- d) Other referenced DEPs;
- e) ISO 16812:2007.

In the event of a conflict, the Principal shall be consulted.

PART III AMENDMENTS/SUPPLEMENTS TO ISO 16812**3. Terms and definitions**

Add new terms:

3.14 hydrogen service

services in which the hydrogen partial pressure is greater than 700 kPa absolute (100 psia) at any temperature

3.15 wet hydrogen sulphide service

service which normally contains dissolved H₂S in a free water phase and can result in environmental cracking of carbon steel materials

3.16 very toxic service

service containing substances that are very hazardous for the environment or human health.

NOTE: The Contractor shall indicate on the data/requisition sheet when the shell and/or tube side of the heat exchanger is in hydrogen, wet hydrogen sulphide service or very toxic service.

4. General**4.1** *Replace this clause with:*

Shell and tube heat exchangers shall comply with the specified pressure design code. The Contractor shall specify the applicable pressure design code on the data/requisition sheets.

ASME Section VIII, Division 1 shall be applied for all heat exchangers unless approved otherwise by the Principal.

Where another pressure design code is applicable, the Contractor shall indicate the code.

ASME Part UHX, with the applicable allowable stresses, shall be applied regardless of the pressure design code that is applied.

Heat exchangers shall comply with the applicable requirements in DEP 31.22.00.31-Gen., based on the specified vessel category. The vessel category shall be specified in accordance with DEP 31.22.00.30-Gen.

4.2 *Replace this clause with:*

Heat-exchanger construction shall conform to TEMA (latest edition), Class R, unless otherwise specified on the data/requisition sheet. The Recommended Good Practice section of TEMA shall also be applied, where applicable.

4.3 *Add to this clause:*

Exchangers shall be registered in accordance with the applicable regulations. Where the applicable regulations have no requirements for pressure vessel registration, the exchangers shall be registered with the U.S. National Board of Boiler and Pressure Vessel Inspectors, if specified by the Contractor.

Add new clause:

4.8 When designed to the ASME code, heat exchangers shall be ASME Code stamped, unless otherwise specified.

5. Proposals

5.1 *Replace this clause with:*

The Supplier's proposal shall include submission of a datasheet, containing all of the pertinent design information specified on the Contractor's data/requisition sheet.

When a tube count-shell diameter combination has been specified on the Contractor's data sheet and cannot be met, the following shall apply:

- For shells fabricated from rolled plate, the shell inside diameter shall be increased over that specified on the Purchaser's data sheet, as required, to meet the specified tube count and all other requirements which affect the tube layout, and shell and bundle entrance areas in TEMA, ISO 16812 and this DEP;
- For shells fabricated from pipe, the supplier shall state the maximum tube count obtainable for the specified shell diameter. Adequacy of the Suppliers tube count will be determined on a case-by-case basis.

5.2 *Add to this clause:*

This includes special flow distributors, expansion joints, and floating head tailpipes and/or flange details.

5.3 *Add to this clause:*

The use of distributor belts shall be approved by the Principal.

5.5 *Add to this clause:*

If the Supplier has no exceptions, there shall be a statement to this effect in the proposal.

6. Drawings and other required data

6.1 Outline drawings and other supporting data

6.1.1 j) *Add to this clause:*

Corrosion allowance shall also be included when a value is specified separately for internal components (i.e., tubes, bellows-type expansion joints, etc.). If no corrosion allowance has been specified for the tubes, the available tube corrosion allowance based on original tube outside diameter shall be calculated and shown on the outline drawing;

Add new clauses:

- w) Heat exchangers that have titanium components shall have the following statement on the outline drawing: "Titanium Equipment – Do not perform hot work without approval of the Principal."
- x) Heat exchanger foundation loads due to empty, operating, and hydrotest weights, wind and earthquake loads, and bundle pulling loads.

6.1.2 *Replace this clause with:*

The Supplier shall submit the results of the flow-induced vibration analysis, based on the actual details of the design proposed, including the clearance between the shellside inlet and outlet nozzles and the tube bundle, and the actual inlet, outlet and central baffle spacing.

6.2 Information required after outline drawings are reviewed

6.2.2 *Replace this clause with:*

Weld maps, all proposed welding procedures and qualifications (including tube-to-tubesheet welding procedures and qualifications), and all supporting test results such as impact tests, hardness tests, corrosion tests, as applicable, shall be submitted for approval, prior to fabrication.

6.2.3 *Add new clauses:*

- n) Location of and notation of sub-supplier's component identification number;
- o) Vacuum ratings;
- p) Stress relieving requirements for U-tubes shall be included in the U-tube bend schedule drawing;
- q) Requirements for spring washers, if applicable.
- r) Special handling, special hydrotest requirements, shipping or storage requirements.

6.2.4 *a) Add to this clause:*

- i. Actual and allowable tube-to-tubesheet loadings for fixed tubesheet exchangers;
- ii. Pass partition plate and longitudinal baffle thickness calculations;
- iii. Expansion joint calculations;
- iv. Maximum allowable pressure (MAP) new (inclusive of corrosion allowance) and cold and the maximum allowable working pressure (MAWP) hot and corroded. The limiting component shall be identified.
- v. The static head due to the liquid level in vertical exchangers shall be included in the thickness calculations for design pressure at the coincident design temperature. The exchanger shall be assumed to be completely filled with process fluid, or water, whichever has the higher density.

b) Add to this clause:

Design calculations based on wind, seismic and transportation loads shall be provided, when defined by the Contractor. The loading conditions shall not be less than those specified in DEP 31.22.00.31-Gen.;

c) Add to this clause:

The Supplier shall provide a tabulation of required bolt loadings (bolt torque, bolt stress, and axial force values) for exchanger girth flange, channel cover flange, and floating head flange bolting on the drawings;

Add new clauses:

- e) The Supplier shall submit the Inspection and Test Plan (ITP) for review and approval. Surveillance requirements identified by the Contractor shall be incorporated into the Supplier's ITP;
- f) The Supplier shall submit materials handling and segregation procedures for all stainless steel and alloy materials.

6.2.5 *Replace this clause with:*

Design calculations for heat exchanger supports, lifting devices, and pulling devices shall be submitted. The documents provided shall include a table of foundation loads in all operating cases (considering wind and seismic effects), the hydrotest case and the bundle pulling case (for each bundle in stacked units).

6.3 **Reports and records***Add new clauses:*

- n) Tube expansion/tube wall reduction values be recorded on a tube layout drawing and included in the Manufacturer's data book;
- o) The wall thickness of six (6) randomly selected tubes shall be measured at a distance of approximately 25 mm (1 in) behind the shell side face of the stationary tubesheet. The thickness of each tubesheet shall be measured at one position. The

thicknesses shall be recorded on a tube layout drawing and included in the Manufacturer's data book.

7. Design

7.1 Design temperature (and pressure)

The design temperature for both shell and tube side shall be provided on the data/requisition sheet by the Contractor. However, after the maximum allowable working pressure is established, the Supplier shall apply the highest possible design temperature where reduction in allowable stress of the pressure components is not incurred, provided the flange rating or vacuum rating is not limiting. The design temperature shall not be increased beyond the value specified on the data/requisition sheet for floating head type exchangers with a single tubepass, fixed tubesheet type exchangers, or for any exchangers in hydrogen service.

7.1.3 *Replace this clause with:*

For floating head exchangers with a single tubepass and tailpipe, and for all fixed tubesheet exchangers, the need for an expansion joint shall be determined by the Supplier based on the operating cases specified on the equipment data/requisition sheet. In addition, all alternate and upset operating cases specified by the Contractor in the Expansion Joint Design Checklist shall be assessed.

Add new clause:

7.1.4 Where thermal and pressure cyclic loading has been specified, the Supplier shall demonstrate, by a calculation method approved by the Principal, that the heat exchanger will be able to sustain the specified loading for the duration of its service life. The Contractor shall specify the pressure and/or temperature loading cycles and the required service life for fatigue analysis.

Add new clause:

7.1.5 Design pressures (including any applicable vacuum ratings) for the shell and tube sides shall be specified separately by the Contractor. The most unfavourable combination of design pressures on the shell and tube side shall be used in the design and calculations for components including tubes, tubesheets, floating heads, tailpipes and internal bellows.

Add new clause:

7.1.6 Where a differential design pressure between the tube side and shell side is specified on the data/requisition sheet, a warning sign, stating the maximum differential design pressure and the maximum differential test pressure, shall be located next to the nameplate. The use of differential design pressure shall not be applied, unless approved by the Principal.

7.2 Cladding for corrosion allowance

7.2.1 *Replace this clause with:*

The full thickness of the corrosion resistant cladding (including weld overlay) shall be used as corrosion allowance, including the thickness of the weld overlay used to restore cladding at welded joints. Where corrosion-resistant cladding (or weld overlay) is specified, it SHALL [PS] apply to all wetted surfaces, including gasket grooves. Non-integral bonded liners shall not be used unless approved by the Principal.

Pass partition plates shall be of the same alloy as the cladding to which they are welded. The minimum cladding thickness at locations where the pass partition plates are welded shall be 5 mm (3/16 in), when the base material requires post-weld heat treatment for either Code or service reasons.

7.2.2 *Replace this clause with:*

Weld overlays applied for corrosion protection shall have sufficient thickness to provide the specified chemical composition to a depth of at least 2.5 mm (3/32 in), unless otherwise specified on the data/requisition sheet.

The minimum cladding (or weld overlay) thickness at the tube side tubesheet face shall not be less than 6 mm (1/4 in) to permit welding of the tube ends to the tubesheet cladding.

When the shell side face of a tubesheet is specified with cladding (or weld overlay) the thickness of the cladding shall not be less than 10 mm (3/8 in). Rolling shall extend to within 3 mm (1/8 in) of the shell side clad or weld overlay face to provide a seal between the tubes and the cladding or weld overlay.

*Add new clause:***7.2.3** Non-bonded alloy liners shall not be used on manway or channel covers, unless approved by the Principal.**7.3 Shell supports****7.3.1** *Add to this clause:*

The Supplier shall verify that number and size of anchor bolts are adequate for the bundle pulling load, based on ASME SA 307 Grade M material or equivalent, unless otherwise specified by the Contractor.

For stacked exchangers the fixed shell support and anchor bolts of the lower exchanger shall be designed to withstand the longitudinal force applied at the centreline of the upper heat exchanger bundle.

7.3.2 *Add to this clause:*

- g) The sliding plate underneath the sliding support saddle shall be in accordance with Standard Drawing S 22.003.
- h) Saddles shall protrude beyond the bottom nozzles, including the drain nozzle with blind flange, by at least 50 mm (2 in) to prevent damage to flange facings during transport, storage and maintenance.

7.3.3 *Add to this clause:*

The saddle of the lower exchanger shall be configured as shown in Figure 1 below when the lower shell has a nominal diameter of 1000 mm (40 in) or greater. The outer gusset ribs shall extend at least 50 mm (2 in) beyond the outside diameter of lower shell. Exchanger shells shall not be stacked in combinations of more than two (2), unless approved by the Principal.

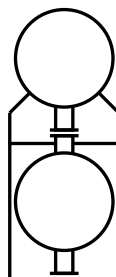


Figure 1 Saddle for stacked heat exchangers

7.3.5 *Replace last sentence of this clause with:*

The total length of the slots shall be equal to the anchor bolt diameter, plus twice the theoretical thermal expansion of the shell (based on the shell side design temperature) plus 8 mm (5/16 in.).

Add new clause:

- 7.3.6** Flange bolting on connections between stacked shells shall be removable from one side of the flange without removing the upper shell.

Add new clause:

- 7.3.7** Horizontal exchangers shall have supports designed in accordance with the revised L. P. Zick analysis (Pressure Vessel and Piping; Design and Analysis, ASME, 1982).

Add new clause:

- 7.3.8** Support design shall comply with UG-54 and Appendix G of the ASME Code. Exchanger supports shall be continuously welded to the shell.

Add new clause:

- 7.3.9** The Supplier shall verify that the support design is suitable for all defined loadings including wind, seismic, and super-imposed external nozzle loads.

Add new clause:

- 7.3.10** When skirts are used to support vertical exchangers, they shall be in accordance Standard Drawing S 20.001 and with the additional requirements specified in DEP 31.22.00.31-Gen.

Add new clause:

- 7.3.11** A grounding lug shall be welded to one (1) of the exchanger supports in accordance with Standard Drawing S 68.004.

Add new clause:

- 7.3.12** Stresses on exchanger supports resulting from nozzle external loads and different thermal growth rates of stacked exchangers shall be included as super-imposed loads in designing the supports, as applicable. Exchanger support reactions shall include these applicable loads, and be shown on the drawings.

7.4 Stationary head

7.4.2 *Replace this clause with:*

Pass partition plates (in both stationary heads and the floating heads) shall be designed, per TEMA paragraph RCB-9.132, without corrosion allowance, to accommodate at least three (3) times the maximum calculated clean pressure differential across each pass partition plate.

In no case shall the minimum thickness be less than the value specified in TEMA paragraph RCB-9.131. The use of rods, bars, etc. to stiffen pass partition plates is acceptable. Calculations of the maximum allowable differential pressure across the pass partition plate shall be submitted with the mechanical design calculations.

Add new clause:

- 7.4.3** For TEMA 'B' type bonnets, tubesheets shall extend to the same diameter as the connecting flange and allow for independent hydrostatic test of both the shell and tube sides, without the use of a test ring.

Add new clause:

- 7.4.4** When an axial nozzle is used on stationary heads, the minimum distance from the intersection of the nozzle centreline and the head, to the tubesheet shall be equal to $(0.6) \times$ (inside bonnet [or channel] radius - inside nozzle radius). This supersedes TEMA RCB 9-12.

The velocity head in the inlet nozzle shall not be greater than 15 % of the pressure drop in the tubes, otherwise a conical enlarging/reducing transition shall be provided with an included angle not exceeding 30 degrees. For TEMA style N or C heads, a straight section of 200 mm (8 in) minimum length shall be provided at the tubesheet to facilitate peripheral tube cleaning and/or inspection.

Add new clause:

- 7.4.5** Channel covers used with clad or weld overlayed channels shall also be clad or weld overlayed. Loose-lined covers or solid alloy covers shall not be used unless approved by the Principal.

Add new clause:

- 7.4.6** Strongbacks shall not be used on flat channel covers to meet deflection limits in TEMA RCB-9.21.

7.5 Floating head

- 7.5.4** *Replace second sentence of this clause with:*

Floating heads shall be in accordance with Figure 1 (a) or (b) of ISO 16812, with full penetration welds used to connect the flange ring to the dished head.

- 7.5.5** *Add to this clause:*

Except for clad or weld overlayed construction, floating head flanges shall be provided with 3 mm (1/8 in) additional thickness to provide a future machining allowance on the gasket contact seating surface. The additional thickness shall not be used in the calculation of the maximum allowable working pressure.

Add new clause:

- 7.5.6** Floating heads shall be through-bolted. Use of bolts which are threaded into tapped holes in the floating tubesheet is not permitted.

Add new clause:

- 7.5.7** Divided floating heads shall not be used.

Add new clause:

- 7.5.8** The backing ring for split ring floating heads shall conform to TEMA Figure RCB 5.141, style A.

Add new clause:

- 7.5.9** Integral shell covers shall be used on all sizes of U-tube and multi-tubepass pull-through floating head exchangers.

Add new clause:

- 7.5.10** When an axial nozzle is used on the floating head, the minimum distance from the intersection of the nozzle centreline and the head, to the tubesheet, shall be equal to $[(0.6) \times (\text{inside floating head radius} - \text{inside nozzle radius})]$. This supersedes TEMA R-5.11.

When the tube side inlet nozzle is located at the floating head, the velocity head in the inlet nozzle shall not be greater than 15 % of the pressure drop in the tubes, otherwise the floating head shall be configured as a conical transition with an included angle not exceeding 30 degrees.

Add new clause:

7.5.12 Floating head tail-pipes

- 7.5.12.1** Where single pass floating head style exchangers are to be used, the tailpipe-to-shell cover seal shall be of the "flanged" or "packed" type. Use of the packed-type joint is limited to non toxic services with non-flammable liquids and gases below 150°C (300°F) and 1035 kPag (150 psig) on the shell side and shall be approved by the Principal. Where flanged style floating head tailpipe joints are used, the type shall be as indicated by the Contractor from standard drawing S 21.085 "Acceptable single pass floating design heads". Where no type has been specified by the Contractor, the Supplier shall indicate the type selected in the proposal for approval by the Principal. Alternate designs not indicated in drawing S 21.085 may only be used with the approval of the Principal.

7.5.12.2 The external tail-pipe connections shall be provided with an ASME B16.5 or ASME B16.47 flange for attachment to the adjoining pipe, except when the tailpipe is connected to another tailpipe of a stacked exchanger in series. In the latter case, the interconnecting pipe spool assembly shall be furnished by the Supplier, with all resulting loads (including thermal) incorporated in the design.

7.5.12.3 Floating head tail-pipes incorporating expansion joints shall be provided with the necessary lugs on the floating head cover and tail-pipe, and retaining rods (which shall also act as guide bars). The retaining rods shall be designed for hydrotesting of the bundle outside of the shell.

7.5.12.4 The Supplier shall provide a tail-pipe and expansion joint drawing with the proposal.

7.6 Tube bundle

7.6.1 Tubes

7.6.1.1 *Add to this clause:*

15.9 mm (5/8 in) outside tube diameter may be used only when approved by the Principal.

7.6.1.2 *Replace this clause with:*

Table 1 below shows the outside tube diameters and minimum required tube gauges for bare tubes of copper alloys, carbon steel, low alloy steel, aluminium and high alloys. The actual thickness provided shall be suitable for both internal and external design pressure, any vacuum conditions, design temperature, tube thinning in U-bends, and any specified corrosion allowance for the tubes.

Table 1 Minimum wall thickness of tubes

Tube material	Nominal tube outside diameter		Tube gauge (SWG)	Tube wall thickness (Note 4)	
	mm	(in)		mm	(in)
Copper alloys	15.88	(5/8)	16	1.63	(0.064)
	19.05	(3/4)	16	1.63	(0.064)
	25.40	(1)	16	1.63	(0.064)
	31.75	(1-1/4)	14	2.03	(0.080)
	38.10	(1-1/2)	14	2.03	(0.080)
	50.80	(2)	12	2.64	(0.104)
Carbon steel, low alloy steels, and aluminium alloys	15.88	(5/8)	14	2.03	(0.080)
	19.05	(3/4)	14	2.03	(0.080)
	25.40	(1)	14	2.03	(0.080)
	31.75	(1-1/4)	14	2.03	(0.080)
	38.10	(1-1/2)	12	2.64	(0.104)
	50.80	(2)	12	2.64	(0.104)
High alloys (defined in ISO 16812)	15.87	(5/8)	16	1.63	(0.064)
	19.05	(3/4)	16	1.63	(0.064)
	25.40	(1)	16	1.63	(0.064)
	31.75	(1-1/4)	14	2.03	(0.080)
	38.10	(1-1/2)	14	2.03	(0.080)

	50.80	(2)	14	2.03	(0.080)
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- NOTES:
1. Values in this table are based on Standard Wire Gauge (SWG). Birmingham Wire Gauge (BWG) may also be selected with the same gauge number. The Standard used shall be specified on the data/requisition sheet.
 2. For special materials (e.g., titanium tubes) the minimum wall thickness shall be 18 SWG.
 3. For low fin tubing, the wall thickness shall be at the root diameter. Titanium low-finned tubes shall have a minimum bare end wall thickness of 16 SWG so that the minimum thickness under the fins is not less than 0.9 mm (0.035 in).
 4. Tubes shall be supplied as minimum wall, except that high alloys (as defined in ISO 16812) may be supplied as average wall.

Where the tube thickness is specified as minimum wall, the tube thickness used for thermal design and pressure drop calculation purposes shall be 1.1 times the minimum wall thickness.

7.6.1.3 Add to this clause:

In services that are specified on the data/requisition sheet to require mechanical cleaning on the tube side, the mean radius of U-bends shall not be less than 75 mm (3 in) for tubes of an outside diameter less than 25.4 mm (1 in) or two (2) times the nominal outside diameter of the tube for tube diameters greater than or equal to 25.4 mm (1 in).

Where titanium U-tubes are specified, the minimum bend radius shall be two times the nominal outside tube diameter for tube diameters less than 25.4 mm (1 in), and 3.3 times the nominal tube diameter for tube diameters greater than or equal to 25.4 mm (1 in), unless a larger bend radius is required for mechanical cleaning.

Where standard duplex stainless steel (e.g., S31803 or S32205) U-tubes are specified, regardless of the need for mechanical cleaning, the minimum bend radius shall not be less than 3.3 times the nominal outside diameter of the tube for all tube diameters. For benign services (e.g., non sour or wet H₂S), consideration may be given to using a minimum bend radius of two times the nominal tube diameter when approved by the Principal.

Where super duplex stainless steel (e.g., S32750) is used, U-tubes may be provided with a minimum bend radius of two times the nominal outside diameter of the tube regardless of service and tube diameter.

Add new clause:

7.6.1.4 The tube side pressure drop may be calculated using smooth tube friction factors for stainless steel and other high alloy tubes, where corrosion is not expected. Commercial pipe friction factors shall be used for carbon and low alloy steel tubes.

Add new clause:

7.6.1.5 Where possible, the number of tubes in any pass shall not be greater than 10 % above or below the average number of tubes per pass. If this cannot be accommodated, the Supplier shall indicate this in the proposal. The tube velocity shall be reported on the data/requisition sheet for each tubepass.

Add new clause:

7.6.1.6 Tubes shall be designed for design pressure on either side, with atmospheric pressure or vacuum, if specified, on the other side unless otherwise specified or approved by the purchaser.

Add new clause:

7.6.1.7 Where welded tubes are used, re-dressing or "scarfing" of the weld seam is required when an expanded only tube-to-tube sheet joint is specified. The Contractor shall specify any additional testing requirements for welded tubes.

Add new clause:

7.6.1.8 For circumferential low finned tubes, the fin density shall have not exceed 1181 fins per metre (30 fins per inch), except that finned tubes in titanium materials may have up to 1417 fins per metre (36 fins per inch). Longitudinally-finned or high-finned tubes shall not be used.

7.6.2 Tubesheets

7.6.2.1 *Replace second sentence of this clause with:*

Where collar bolts are used, at least four (4) shall be provided and their location shall be identified on the drawings and by stamped markings on the OD of the tubesheet and on both ends of the studs. One (1) end of the collar bolt shall be machined with a standard size hex head.

7.6.2.4 *Replace second sentence of this clause with:*

Single or two-piece collar type studs shall be supplied for 25 % of the bolt holes in the stationary tubesheet in order to maintain the gasket in its position during the removal of the bonnet. The extended portion of the tubesheet shall be designed for hydrotesting of the shellside or tubeside independently, with the respective bonnet or shell removed, and with the full complement of bolting installed. Removable bundle units with 'A' type heads need not have full diameter tubesheets.

Add new clause:

7.6.2.5 Regardless of the pressure design code that is applied, the tubesheet thickness shall not be less than that required by either TEMA clause R-7.11 or ASME Section VIII, Div.1, Part UHX, except where a thin flexible tubesheet design is specified on the data/requisition sheet.

Add new clause:

7.6.2.6 Stationary tubesheets for removable bundles with bonnet stationary heads shall be through-bolted. The holes shall not be threaded.

Add new clause:

7.6.2.7 The welded connections between a tubesheet and the adjacent cylinder shall be in accordance with ASME Code Figure UW-13.3, Type (a) (b) or (c) or equivalent configurations. Figure UW-13.2 Type (a), (b), (c), (i), (j), (k), or equivalent, may only be used in non-cyclic service where the design pressure is less than 6.9 MPa (1000 psig) and the design temperature is less than 400 °C (750 °F).

Add new clause:

7.6.2.8 Tubesheets with applied cladding (or weld overlay) shall meet the following requirements:

- The cladding shall be integrally and continuously bonded to the base material. Brazing shall not be used to bond the cladding to the tubesheet.
- Integrally clad tubesheets and tubesheets with applied weld overlay shall be ultrasonically tested to check the integrity of the bonding in accordance with ASTM A 578, with an acceptance standard level C.

Add new clause:

7.6.2.9 Except for clad or weld overlayed construction, gasketed tubesheets shall be provided with 3 mm (1/8 in) additional thickness to provide a future machining allowance on all gasket contact seating surfaces (including the pass partition). The additional base material thickness shall not be used in the calculation of the maximum allowable working pressure.

7.6.3 Baffles and support plates

7.6.3.1 *Add to this clause:*

For titanium tubes, the baffle/support plates shall have a thickness in accordance with TEMA; however, the minimum thickness shall not be less than 5 mm (3/16 in).

7.6.3.2 *Replace this clause with:*

To facilitate draining of heat exchanger shells, all transverse baffles and support plates, which extend to the bottom of the shell, shall have V-notches that are 10 mm (3/8 in) high for shell inside diameters of 1000 mm (40 in) or less. For larger shell diameters, the V-notches shall be 16 mm (5/8 in) high and 19 mm (3/4 in) wide at the lowest point.

*Add new clause:***7.6.3.4** The unsupported tube span shall not exceed 80 % of the value indicated in TEMA Table RCB-4.52, except that it shall not exceed 60 % in the following cases:

- For titanium tubes and applications with similar tube wall thickness and elastic modulus combinations;
- For tubes in kettle-type reboilers, evaporators, and steam generators.

*Add new clause:***7.6.3.5** A reduction in the baffle to shell diametric clearances given in TEMA Table RCB-4.3 may be considered in some cases to reduce leakage between the baffles and shell, with approval of the Principal. In such cases, the Supplier shall verify that the reduced clearance is possible considering fabrication tolerances, bundle insertion, etc.*Add new clause:***7.6.3.6** When a full support baffle at the tangent line of U-bends is specified on the data/requisition sheet for TEMA types other than G, H, X and J shells, the full support shall have cut-outs to allow fluid circulation through the U-bend area. These cuts shall be located above/below the upper/lower rows of tubes to fully support the tubes, but in no case shall the height of the cut out exceed 5% of the nominal shell diameter.

For TEMA types G, H, X and J shells, a full support baffle, without cut-outs, shall be provided at the U-bend. This support baffle shall be provided with notches, as per (7.6.3.2), on the top and bottom for venting and draining purposes only.

*Add new clause:***7.6.3.7** A full support baffle shall be provided at the centreline of the shell inlet/exit nozzles for TEMA shell types G and H and at the centreline of the central nozzle for TEMA shell type J.

A full support shall be provided at the centreline of each shell side nozzle in TEMA Type X shells. This full support, as well as any other tube supports in an X shell, shall be cut 3 mm (1/8 in) above and below the top and bottom tube rows, respectively, so as to fully support these tubes.

*Add new clause:***7.6.3.8** Floating heads in shells with removable shell covers shall be supported by a doughnut baffle with a thickness that is 3 mm (1/8 in) greater than the tube support baffles. Unless otherwise required for anchoring seal strips, a doughnut baffle shall not be provided in shells with integral shell covers.*Add new clause:***7.6.3.9** Where vertically cut transverse baffles (either single or double segmental) are used in combination with vertically oriented nozzles, a partial tube support which fully covers a minimum of four (4) tube rows shall be provided, unless the vibration analysis dictates that a larger number of rows must be supported. The partial support shall be located at the nozzle centreline at the entrance or exit of the shell, and is required in addition to any impingement protection. The partial support shall not cause excessive flow restriction in the end baffle space.*Add new clause:***7.6.3.10** Unless otherwise specified on the data/requisition sheet, vertical cut double segmental baffle designs shall consist of an even number of cross-passes, with the centre baffle type installed as the first and last baffle. As an alternative to installation of partial supports per