

DEP SPECIFICATION

**SHELL AND TUBE HEAT EXCHANGERS
(AMENDMENTS/SUPPLEMENTS TO API STD 660)**

DEP 31.21.01.30-Gen.

February 2017

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



© 2017 Shell Group of companies

All rights reserved. No part of this document may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

This document contains information that is classified as EAR99 and, as a consequence, can neither be exported nor re-exported to any country which is under an embargo of the U.S. government pursuant to Part 746 of the Export Administration Regulations (15 C.F.R. Part 746) nor can be made available to any national of such country. In addition, the information in this document cannot be exported nor re-exported to an end-user or for an end-use that is prohibited by Part 744 of the Export Administration Regulations (15 C.F.R. Part 744).

This document has been supplied under license by Shell to:
UOP Honeywell ted.fuger@honeywell.com 19/01/2018 02:53:36

AVA Documents
Document Sharing Hub

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

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.

The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

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.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is typically granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 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.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

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	7
1.7	DUAL UNITS.....	7
1.8	NON NORMATIVE TEXT (COMMENTARY).....	7
PART II	GENERAL.....	8
1	GENERAL.....	8
2	MATERIALS SPECIFICATIONS.....	8
PART III	AMENDMENTS/SUPPLEMENTS TO API STD 660.....	9
3	Terms and Definitions	9
3.16	very toxic (substances)	9
4	General.....	9
4.1	9	
4.2	9	
4.9	9	
4.10	9	
4.13	9	
5	Proposal Information Required	10
5.1	10	
5.2	10	
6	Drawings and Other Required Data	10
6.1	Outline Drawings and Other Supporting Data	10
6.2	Information Required After Outline Drawings Are Reviewed.....	10
6.3	Reports and Records.....	11
7	Design	11
7.2	Cladding for Corrosion Allowance.....	11
7.3	Shell Supports.....	12
7.4	Stationary and Floating Heads	13
7.5	Tube Bundle	14
7.6	Nozzles and Other Connections.....	22
7.7	Flanged External Girth Joints.....	24
7.8	Girth Flange Joint Supplementary Design Requirements	24
7.9	Expansion Joints	25
7.10	Gaskets	26
7.11	Handling Devices	28
7.12	Requirements for Hydrogen Service	28
7.13	Kettle-Type Reboilers and Evaporators	29
8	Materials.....	29
8.1	General.....	29
8.2	Requirements for Carbon Steel in Sour or Wet Hydrogen Sulfide Service	30
8.3	Gaskets	30
8.4	Tubes.....	30
8.5	Cathodic Protection.....	32
9	Fabrication.....	32
9.1	Shells.....	32
9.2	Pass-Partition Plates	32
9.3	Connection Junctions	32

9.4	Tubes.....	33
9.5	Welding	33
9.6	Heat Treatment.....	34
9.7	Dimensional Tolerances.....	35
9.9	Tube Holes.....	35
9.10	Tube-to-Tubesheet Joints	36
9.11	Assembly	36
9.12	Insulation Supports	36
10	Inspection and Testing.....	37
10.1	Quality Control	37
10.2	Pressure Testing.....	37
10.3	Nameplates and Stampings.....	39
11	Preparation for Shipment.....	39
11.1	Protection	39
11.2	Identification	40
12	Supplemental Requirements	40
12.1	General	40
12.2	Design	41
Annex A (informative)	Recommended Practices	41
Annex B (informative)	Shell-and-Tube Heat Exchanger Checklist	41
Annex C (informative)	Shell-and-Tube Heat Exchanger Data Sheets.....	41
PART IV	REFERENCES	42

APPENDICES

APPENDIX 1	MATERIALS FOR USE IN SHELL AND TUBE HEAT EXCHANGERS	45
APPENDIX 2	METHOD OF DETECTION OF HARMFUL OXIDE FILMS ON COPPER-NICKEL ALLOY TUBES	56
APPENDIX 3	DRAWINGS.....	58

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.

This DEP is based on API STD 660, Ninth Edition.

This DEP is primarily intended for use by the Manufacturer/Supplier.

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 February 2014; 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.

In API STD 660, the term **Purchaser** is used. In this DEP, the term **Purchaser** shall be understood to mean the **Contractor**.

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

In API STD 660, the term **Vendor** is used. In this DEP, the term **Vendor** shall be understood to mean the **Manufacturer/Supplier**.

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.

The word **shall** indicates a requirement.

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

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Data/ Requisition Sheet	Data/requisition sheet DEP 31.21.00.93-Gen. or Principal-approved equivalent.

1.3.3 Abbreviations

Term	Definition
KCl	potassium chloride
NTIW	No Tube in Window
PTFE	Polytetrafluoroethylene

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 full revision of the DEP of the same number dated February 2014, addressing changes to the API STD 660 and extensively revising to reduce the volume and complexity of content. The changes are too numerous to summarize but the following DEM1 changes are noted:

Section/Clause	Change
Part II, 1.1.4	DEM1 requirement deleted
Part II, 1.1.5	DEM1 requirement deleted
Part III, 7.2.1	DEM1 requirement deleted
Part III, 7.6.4.8	DEM1 requirement deleted
Part III, 12.1	DEM1 requirement deleted
Part III, 12.2.2	DEM1 requirement deleted
Part III, 12.2.3	DEM1 aspect of requirement deleted
Part III, 12.2.4	DEM1 requirement deleted

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://www.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.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

PART II GENERAL

1 GENERAL

(Part III) of this DEP is written as amendments and supplements to API STD 660. Wherever reference is made to API STD 660, it shall be understood to mean API STD 660, Ninth edition, March 2015 as amended/supplemented by this DEP.

For ease of reference, the clause numbering of API STD 660 has been used throughout (PART III) of this DEP.

1. Clauses in API STD 660 which are not mentioned in this DEP shall remain valid as written.
2. This document is intended primarily for use by the Manufacturer/Supplier and should be included in the purchase requisition along with the following:
 - a. heat exchanger data/requisition sheet (DEP 31.21.00.93-Gen., or equivalent);
 - b. supplementary technical requirements;
 - c. shell and tube exchanger checklist (DEP 31.21.01.83-Gen.);
 - d. project specifications.

2 MATERIALS SPECIFICATIONS

(Appendix 1) provides a summary of material specifications and supplemental requirements for a number of materials for general service.

1. The Contractor shall separately specify on the data/requisition sheet the materials for all of the following for both shell and tube sides of the heat exchanger:
 - a. pressure components (including pass partition plates, bolting and gaskets);
 - b. non-pressure components (including baffles, impingement devices, tie rods and sealing devices).
2. The Contractor may specify the applicable materials group and allow the Manufacturer to choose the applicable specification based on product type.
 - a. Alternatively, the Contractor may specify the applicable ASTM (or equivalent) specification for specific components or product types.
3. The Contractor shall indicate any special material supply or testing requirements that may be applicable based on service or project requirements.

PART III AMENDMENTS/SUPPLEMENTS TO API STD 660**3 Terms and Definitions**

Add new term:

3.16 very toxic (substances)

Substances that are very hazardous for the environment or human health. For this DEP the term “very toxic” includes very toxic – acute, chronic, and environment categories unless otherwise specified.

Very toxic service is not equivalent to lethal service as defined by ASME.

Refer to DEP 01.00.01.30 Gen. Part III for further information regarding toxic fluid classification.

4 General**4.1**

Add the following to this clause:

1. Heat exchangers shall comply with the applicable requirements in DEP 31.22.00.31-Gen., based on the specified vessel category, where requirements are not otherwise specified in this DEP.
2. The vessel category shall be specified for the shell and tube sides independently.

4.2

Add the following to this clause:

1. The “shall” statements in the Recommended Good Practice section of TEMA shall be considered as normative requirements, where applicable.

4.9

Add the following to this clause:

1. Refer to DEP 31.22.00.31-Gen. clause 5.8 to determine the need for a fatigue analysis, and the method of analysis to be applied.

4.10

Replace this clause with the following:

1. Heat exchangers identified by the Contractor to be in sour or wet hydrogen sulphide service shall comply with the applicable requirements of all of the following:
 - a. API STD 660 Annex A.2.2.6;
 - b. DEP 31.22.00.31-Gen.;
 - c. DEP 30.10.02.17-Gen. or DEP 39.01.10.12-Gen. as applicable.

Add the following new clauses:

4.13

1. Refer to DEP 31.22.00.31-Gen. clause 5.9 to determine the need for a creep analysis, and the method of analysis to be applied.

5 Proposal Information Required

5.1

Replace this clause with the following:

1. The Manufacturer's/Supplier's proposal shall include submission of a datasheet, containing all of the design information specified on the Contractor's data/requisition sheet.
2. If the Manufacturer/Supplier cannot meet any tube count-shell diameter combination that has been specified on the data/requisition sheet, the following shall apply.
 - a. For shells fabricated from rolled plate, increase the shell inside diameter over that specified on the data/requisition sheet to meet the specified tube count and all other requirements which affect the tube layout, and shell and bundle entrance areas in TEMA, API STD 660 and this DEP.
 - b. For shells fabricated from pipe, state the maximum tube count obtainable for the specified shell diameter.

The adequacy of the Manufacturer's tube count will be determined on a case-by-case basis.

5.2

Add the following to bullet d):

1. The Manufacturer/Supplier shall advise if the conditions provided for the exchanger design are too severe to comply with the requirements of (7.9.1).

6 Drawings and Other Required Data

6.1 Outline Drawings and Other Supporting Data

6.1.1

Add the following to this clause:

- w. The available tube corrosion allowance based on original tube outside diameter.
- x. Heat exchanger foundation loads due to empty, operating, and hydrotest weights, wind and earthquake loads, and bundle pulling loads.
- y. Tabulation of required bolt loadings (bolt torque with assumed nut factors or bolt elongations for bolts which are tensioned) along with any requirements for spring washers for girth flanges, channel covers, and floating head flanges.

6.2 Information Required After Outline Drawings Are Reviewed

6.2.2

Replace this clause with the following:

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

6.2.4

Add the following to this clause:

- f. Pass partition plate and longitudinal baffle thickness calculations.

- g. Calculations to determine the following:
 - i. maximum allowable pressure (MAP) new (inclusive of corrosion allowance) and cold
 - ii. maximum allowable working pressure (MAWP) hot and corroded.
- h. Inspection and Test Plan (ITP).
- i. Fabrication procedures (including head forming, U-bend forming, tube end joining, surface preparation and coating);
- j. heat treatment procedures (including stress relieving requirements for U-tubes);
- k. non-destructive examination procedures;
- l. testing procedures;
- m. special handling requirements;
- n. special hydrotest requirements;
- o. shipping or storage requirements.

6.2.5

Add the following after "and pulling devices" in this clause:

- 1. and verification of anchor bolt sizes.

Add the following to the end of this clause:

- 2. The anchor bolt material to be considered in the calculations shall be specified by the Contractor.

6.3 Reports and Records

Add the following to this clause:

- o. For carbon and low alloy steel materials, as-built wall thicknesses shall be taken as specified in DEP 31.22.00.31-Gen. clause 7.4.1.6 along with the following additional component thicknesses and locations.
 - i. The wall thickness of six randomly selected tubes shall be measured at a distance of approximately 25 mm (1 in) behind the shell side face of the stationary tubesheet.
 - ii. The thickness of each tubesheet shall be measured at one position.
 - iii. The as-built thicknesses and locations shall be recorded in the Manufacturer's data book.

7 Design

7.2 Cladding for Corrosion Allowance

7.2.1

Add the following to this clause:

- 1. The use of non-integrally bonded liners shall be subject to approval by the Principal.

7.2.2

Replace this clause with the following:

- 1. Weld overlays shall have sufficient thickness to provide the specified chemical composition to a depth of at least 2.5 mm (3/32 in).

2. In no case shall the total applied thickness of weld overlay for corrosion protection be less than 3 mm (1/8 in).

7.2.3

Replace this clause with the following:

1. 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.

Add the following new clauses:

7.2.6

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

7.2.7

1. Channel covers used with clad or weld overlay channels shall also be clad or weld overlaid.
2. Loose-lined covers or solid alloy covers shall not be used unless approved by the Principal.
3. Exchangers with either integral cladding or weld overlay cladding shall comply with DEP 31.22.00.31-Gen. Appendix A, except as modified by this DEP.

The requirement for clad or weld overlay tubesheets are more stringent than the general clad/overlay requirements provided in DEP 31.22.00.31-Gen.

4. Where alloy clad or weld overlay pressure components are specified on the data/requisition sheet, substitution with solid alloy components shall be subject to approval by the Principal.

7.3 Shell Supports

7.3.1

Add the following to this clause:

1. 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

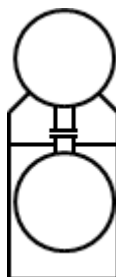
Add the following to this clause:

- f. Saddles shall project 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 the following to this clause:

1. If the lower shell has a nominal diameter of 1000 mm (40 in) or greater, then the saddle of the lower exchanger shall be configured as shown in Figure 5.
 - a. The outer gusset ribs shall extend at least 50 mm (2 in) beyond the outside diameter of lower shell.
2. Exchanger shells shall not be stacked in combinations of more than two, unless approved by the Principal.

Figure 5 Saddle for stacked heat exchangers**7.3.6**

Replace this clause with the following:

1. The local stresses in the shell of horizontal exchangers due to the saddle supports shall be analysed in accordance with ASME Section VIII, Div. 2, Part 4 clause 4.15.3 or PD 5500 Appendix G.

7.3.7

Replace this clause with the following:

1. All exchangers shall be provided with a least two earthing lugs in accordance with Standard Drawing S 68.004 and located on diagonally opposite sides.

Add the following new clauses:

7.3.8

1. Exchangers and their supports shall be designed for the load cases and load combinations specified in DEP 31.22.00.31-Gen. clauses 5.3 and 5.4.
2. When specified for marine service, the additional loads specified in DEP 31.22.00.31-Gen. clause 5.6 shall apply.

7.3.9

1. Support design shall comply with the applicable pressure design code including any non-mandatory or recommended annexes.

7.3.10

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

7.4 Stationary and Floating Heads**7.4.2**

Add the following to this clause:

1. Rods, bars, or other devices may be used to stiffen pass partition plates when approved by the Principal.

7.4.3

Add the following to this clause:

1. Floating heads shall be through-bolted.

7.4.11

Delete the text "When specified by the purchaser" from the beginning of this clause.

Add the following new clauses:

7.4.12

1. When an axial nozzle is used on stationary or floating heads, the minimum distance from the intersection of the nozzle centreline and the head, to the tubesheet shall be equal to $(0.6) \times (\text{inside bonnet (or channel) radius} - \text{inside nozzle radius})$.

This supersedes TEMA RCB 9-12.

2. For TEMA style N or C heads with conical reducing channels, a straight section of 200 mm (8 in) minimum length shall be provided at the tubesheet to facilitate peripheral tube cleaning and/or inspection.
3. Integral shell covers shall be used on all sizes of U-tube and multi-tubepass pull-through floating head exchangers.
4. The design stress value of the floating head flange and tubesheets extended as flanges shall be based on a maximum of 88 % of the allowable stress from the pressure design code;
5. All floating head flanges and floating tubesheets extended as flanges shall have a maximum flange rigidity factor (J) of 0.8 as calculated in accordance with ASME Section VIII, Div. 1, Appendix 2.
6. Where flanged style floating head tailpipe joints are used, the type shall be as indicated by the Contractor from Standard Drawing S 21.085.
7. Where no tailpipe-to-shell cover seal type has been specified, the Manufacturer/Supplier shall indicate the type selected in the proposal for approval by the Contractor.
 - a. Alternate designs not indicated in Standard Drawing S 21.085 may only be used when approved by the Principal.
8. The external tailpipe connections shall be provided with an ASME B16.5 or ASME B16.47 flange, complying with DEP 31.22.00.31-Gen. clause 5.14, for attachment to the adjoining pipe, except when the tailpipe is connected to another tailpipe of a stacked exchanger in series.
9. If the tailpipe is connected to another tailpipe of a stacked exchanger in series, the interconnecting pipe spool assembly shall be furnished by the Manufacturer/Supplier, with all resulting loads (including thermal) incorporated in the design.
10. Floating head tailpipes incorporating expansion joints shall be provided with the necessary lugs on the floating head cover and tailpipe, and retaining rods.
 - a. The retaining rods shall also act as guide bars.
 - b. The retaining rods shall be designed to allow for hydrotesting of the bundle outside of the shell.

7.5 Tube Bundle**7.5.1 Tubes****7.5.1.2**

Replace this clause and Table 1 with the following:

Table 1 provides the outside tube diameters and minimum required tube gauges for bare tubes of copper alloys, carbon steel, low alloy steel, aluminium and high alloys.

1. The tube wall thickness shall be as listed in Table 1.

Table 1 Minimum Thickness of Tubes

Tube material	Tube outside diameter		Tube gauge (SWG) (Note 1)	Tube wall thickness	
	mm	(in)		mm	(in)
Copper and 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 (max. 9 % chromium), aluminium 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 alloy (austenitic, ferritic, and austenitic/ferritic (duplex)) steel and other non-ferrous materials	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)
Titanium	15.87	(5/8)	18	1.22	(0.048)
	19.05	(3/4)	18	1.22	(0.048)
	25.40	(1)	18	1.22	(0.048)
	31.75	(1-1/4)	16	1.63	(0.064)
	38.10	(1-1/2)	16	1.63	(0.064)
	50.80	(2)	16	1.63	(0.064)
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.					

2. Tubes shall be supplied as minimum wall, except that high alloys and titanium tubes may be supplied as average wall.
3. The actual thickness provided shall be suitable for all of the following:
 - a. both internal and external design pressure,
 - b. any vacuum conditions,
 - c. design temperature,

- d. tube thinning in U-bends,
 - e. any specified corrosion allowance for the tubes.
4. Unless otherwise specified, a corrosion allowance of 0.8 mm (1/32 in) shall be applied for carbon and low alloy steel tubes and 0.4 mm (1/64 in) for all other materials.

7.5.1.3

Add the following to this clause:

1. For finned tubes in other materials, the plain end average wall thickness shall be two gauges heavier than shown in Table 1.

7.5.1.4

Replace this clause with the following:

1. 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 be greater than or equal to the following, as applicable:
 - a. 75 mm (3 in) for tubes of an outside diameter less than 25.4 mm (1 in).
 - b. two times the nominal outside diameter of the tube for tube diameters greater than or equal to 25.4 mm (1 in).
2. Where titanium tubes are specified, the mean radius of U-Bends shall be greater than or equal to one of the following, as applicable:
 - a. two times the nominal outside tube diameter for tube diameters less than 25.4 mm (1 in);
 - b. times the nominal tube diameter for tube diameters greater than or equal to 25.4 mm (1 in);
 - c. a larger bend radius where this is required for mechanical cleaning.
3. Where standard duplex stainless steel (e.g., S31803 or S32205) tubes are specified, the mean radius of U-Bends shall be one of the following as applicable:
 - a. greater than or equal to 3.3 times the nominal outside diameter of the tube;
 - b. in benign services (e.g., not sour or wet H₂S), a minimum of two times the nominal tube diameter may be used when approved by the Principal.
4. Where super duplex stainless steel (e.g. S32750) or high nickel alloys (>30 wt% Ni) tubes are specified, the mean radius shall be greater than or equal to two times the nominal outside diameter of the tube unless a larger bend radius is required for mechanical cleaning.
5. The mean radius shall be greater than or equal to 1.5 times the nominal outside diameter of the tube when none of the requirements of (7.5.1.4 Items 1 through 4) are applicable.

Add the following new clauses:

7.5.1.8

1. There shall be at least two tube rows per pass.

7.5.2 Tubesheets

7.5.2.1

Add the following to this clause:

1. Integral (one-piece) collar bolts shall be provided, i.e., the use of drilled and tapped holes is prohibited.

7.5.2.4

Add the following to this clause:

1. Integral (one-piece) collar bolts shall be provided, i.e., the use of drilled and tapped holes is prohibited.

7.5.2.5

Replace this clause with the following:

1. Tubesheets shall be provided with 3 mm (1/8 in) future machining allowance on each gasket contact seating surface (including pass partition surfaces).
 - a. The additional thickness shall not be used in the calculation of maximum allowable working pressure.

Add the following new clauses:

7.5.2.7

1. Regardless of the pressure design code that is applied, the tubesheet thickness shall not be less than that calculated by the pressure design code, ASME Section VIII, Div.1, Part UHX, or the minimum thickness required by TEMA clause R-7.11, whichever is greater.
2. When the tubesheet design is outside of the scope of ASME Section VIII, Div.1, Part UHX (e.g. thin flexible tubesheets), the method of design analysis shall be subject to approval by the Principal.
3. The tube and tube-to-tubesheet joint stresses due to the differential metal temperature between tubes in adjacent passes shall be examined for any fixed tubesheet or floating head heat exchanger when the temperature difference between passes exceeds 40 °C (72 °F).

7.5.2.8

1. The welded connections between a tubesheet and the adjacent cylinder shall be in accordance with ASME Section VIII, Div. 1 Figure UW-13.3, Type (a) (b) or (c) or equivalent configurations from the applied pressure vessel design code.
 - a. Tubesheet connection details indicated in ASME Section VIII, Div. 1 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).

7.5.3 Baffles and Support Plates

7.5.3.1

Add the following to this clause:

1. The thickness of baffles and support plates provided for tube bundles with titanium tubes shall not be less than 5 mm (3/16 in).
2. The thickness of baffles and support plates provided for tube bundles with low-finned tubes shall be the thinner of the following:
 - a. two times the thickness required by TEMA R-4.41
 - b. 19 mm (3/4 in).

Add the following new clauses:

7.5.3.4

1. Standard tube holes in all transverse baffle and full support plates shall have a diameter 0.4 mm (1/64 in) more than the outside diameter of the tubes.

7.5.3.5

1. 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 with the following characteristics to allow fluid circulation through the U-bend area and fully support the tubes:
 - a. cut outs located above the upper rows of tubes;
 - b. cut outs located below the lower rows of tubes;
 - c. height of the cut out not exceeding 5 % of the nominal shell diameter.
2. A full support baffle, without cut-outs, shall be provided at the tangent line of U-bends for TEMA types G, H, X and J shells.
 - a. The full supports shall be provided with a 12 mm (1/2 in) notch on the top and bottom for venting and draining purposes.
3. A full support baffle shall be provided at the centreline of the shell nozzles in accordance with the following locations.
 - a. At the inlet and exit nozzles for TEMA shell types G and H.
 - b. At the central nozzle for TEMA type J shells.
 - c. At each shell side nozzle in TEMA Type X shells.
4. For TEMA Type X shells, tube supports excluding the U-bend support (when applicable) shall be cut 3 mm (1/8 in) above the top tube rows and 3 mm (1/8 in) below the bottom tube rows, so as to fully support these tubes.

This includes the full support provided at nozzle centerlines.
5. A partial support, of a thickness that is 3 mm (1/8 in) greater than the tube support baffles, shall be provided as close as practicable from the floating tubesheet for the following:
 - a. Floating head exchangers for all shells with removable shell covers.
 - b. When required for anchoring seal strips in floating head exchangers with integral shell covers.

The baffle should be located as close as practicable to the tubesheet while allowing for fabrication tolerances and mechanical clearance requirements; a distance of 50 mm to 125 mm (2 in to 5 in) is normally expected.

7.5.3.6

1. For NTIW bundles with an unsupported span between the full support baffles exceeding the TEMA maximum span based on the tube diameter, tie rods located in the un-tubed area shall comply with the following.
 - a. Skid bars, sized in accordance with Table 9 and located in such a way as to not obstruct flow into or out of the heat exchanger, shall be used in lieu of tie rods for spans up to 3.2 times the TEMA maximum span.
 - b. For spans exceeding 3.2 times the TEMA maximum span, provide a continuous ring on the baffles and intermediate supports to reduce the unsupported span.

7.5.3.7

1. When a seal between the longitudinal baffle and the shell is required, the baffle shall be continuously welded to the shell.

Seals are normally required for all configurations, except TEMA G and H shells in reboiler service.

- a. Flexible spring seal sets with longitudinal baffles may only be used when specified or approved by the Principal.