

DEP SPECIFICATION

**HAIRPIN-TYPE HEAT EXCHANGERS
(AMENDMENTS/SUPPLEMENTS TO ISO 12212:2012)**

DEP 31.21.07.30-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 07:12:52

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 1	INTRODUCTION	5
1.1	SCOPE	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES.....	7
1.6	COMMENTS ON THIS DEP	7
1.7	DUAL UNITS.....	7
1.8	NON NORMATIVE TEXT (COMMENTARY).....	7
PART II	GENERAL	8
1	DESIGN SPECIFICATIONS.....	8
1.1	THERMAL DESIGN AND RATING.....	8
1.2	MATERIALS SPECIFICATIONS	9
2	ORDERING.....	9
2.1	SCOPE OF SUPPLY	9
PART III	AMENDMENTS/SUPPLEMENTS TO ISO 12212:2012	10
3	Terms and definitions	10
3.20	Wet hydrogen sulphide service.....	10
3.21	Very toxic service.....	10
4	General.....	10
5	Proposal information required	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.....	12
6.3	Reports and records	13
7	Design	14
7.1	Design temperature	14
7.2	Design pressure.....	14
7.3	Cyclic design.....	14
7.4	Shell	14
7.5	Front closure	15
7.6	Rear closure.....	15
7.7	Tube bundle	15
7.8	Nozzles and other connections.....	21
7.9	Shell supports	23
7.10	Gaskets.....	23
7.11	Flanged external girth joints.....	24
7.12	Cladding for corrosion allowance.....	25
8	Materials	25
8.1	General	25
8.2	Requirements for sour or wet hydrogen sulfide service	26
8.3	Gaskets.....	27
8.4	Tubes	27
8.5	External bolting	29
8.6	Cathodic protection	29
9	Fabrication.....	29
9.1	Shells	29
9.3	Welding.....	30
9.4	Heat treatment	31
9.5	Dimensional tolerances	32
9.6	Gasket contact surfaces other than nozzle-flange facings.....	32

9.7	Tube-to-tubesheet joints	33
9.8	Assembly	33
9.9	Insulation supports.....	34
10	Inspection and testing.....	34
10.1	Quality assurance	34
10.2	Quality control	35
10.3	Pressure testing	36
10.4	Nameplates and stampings	37
10.5	Repairs.....	38
11	Preparation for shipment	38
11.1	Protection	38
11.2	Identification	40
12	Supplemental requirements	40
12.1	General	40
12.2	Design	40
ANNEX A	(informative) Recommended practices	42
ANNEX B	(informative) Hairpin heat exchanger checklist.....	42
ANNEX C	(informative) Hairpin heat exchanger data sheets	42
PART IV	REFERENCES	43

APPENDICES

APPENDIX 1	METHOD OF DETECTION OF HARMFUL OXIDE FILMS ON COPPER-NICKEL ALLOY TUBES	46
-------------------	--	-----------

PART 1 INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the design and construction of hairpin-type heat exchangers.

Part III of this DEP is written in the form of amendments and supplements to ISO 12212:2012 and follows the clause numbering of ISO 12212 for easy reference.

All clauses of ISO 12212 not modified by this DEP 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.

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 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 authorisation 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: In ISO 12212:2012, 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.

NOTE: In ISO 12212:2012, the term Purchaser is used. In this DEP, the term Purchaser shall be understood to mean the Principal

The word **shall** indicate a requirement.

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

The word **should** indicate a recommendation.

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

1.3.2 Abbreviations

Term	Definition
AARH	Arithmetic Average Roughness Height
ACI	American Concrete Institute
GTAW	Gas Tungsten Arc Welding
HTRI	Heat Transfer Research Inc.
ID	inner diameter
ITP	Inspection and Test Plan
KCl	potassium chloride
OD	outer diameter
PTFE	Polytetrafluoroethylene
SWG	Standard Wire Gauge
TEMA	Tubular Exchanger Manufacturers Association

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section 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 2013. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced shall/should, assigned numbers to Tables and Equations.

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.

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 DESIGN SPECIFICATIONS****1.1 THERMAL DESIGN AND RATING**

1. Details of the design including tube count, tube diameter, tube thickness, tube length, number of tube passes, tube layout angle, tube pitch, number of shell side cross-passes, baffle spacing, baffle cut and orientation may be specified on the data/requisition sheet (DEP 31.21.00.93-Gen., or equivalent) by the Contractor.
2. When the design details have been specified by the Contractor, Manufacturer's/Supplier's proposal shall include the base design specified by the Contractor.
 - a. The Supplier may propose an alternate design for consideration.
3. The Supplier shall provide a mechanical and thermal performance guarantee, regardless of the party who completes the initial thermal design or rating.
4. In the case of a proprietary design, the Contractor shall contact the Principal to agree on the calculation method and responsibility.
5. Designs with helical baffles, grid baffles, twisted tubes, low-finned tubes or other enhanced tube types (including tube inserts) shall be subject to approval 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.
6. All multi-tube exchangers SHALL [PS] be analyzed for flow induced mechanical vibration.
7. All exchangers with single phase vapour at the shell side inlet shall be analyzed for acoustic vibration noise.
8. For exchangers with vapour or two-phase flow on the shell side, or for those with baffle cuts 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.
9. In the event of disagreements about tube vibration, the HTRI Xist program shall be used as a basis for assessing tube vibration.
10. The use of the HTRI Xvib program shall be subject to the approval of the Principal.
11. Contractor shall include the following factors into account while finalising the design of the exchangers:
 - a. restrictions on bundle size (diameter, length, weight);
 - b. special provisions for bundle maintenance based on the bundle pulling, handling or cleaning equipment used at the operating site;
 - c. applicable economic considerations for exchanger foundations, structures;
 - d. required maintenance access.
12. The standard form checklist in (Annex B) (DEP 31.21.01.83-Gen.) shall be completed for each project and included with the requisition documents.

1.2 MATERIALS SPECIFICATIONS

1. Contractor shall specify the generic materials of construction for all pressure components (including bolting and gaskets) and non-pressure components (including baffles, impingement devices, tie rods and sealing devices) on the data/requisition sheet.
2. The Manufacturer/Supplier shall indicate the specific materials grade and specifications for all components in their proposal for approval by the Principal.

2 ORDERING

2.1 SCOPE OF SUPPLY

1. The Manufacturer/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. external, interconnecting tube side piping of stacked heat exchangers.
2. The number of spare sets of gaskets and bolting for construction and start up spares shall be identified by the Contractor.
3. 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.
4. Excluded from the scope of supply are foundations, the erection of the supporting structure, instruments, insulation, and fireproofing of saddles or structural support steel.



PART III AMENDMENTS/SUPPLEMENTS TO ISO 12212:2012**3 Terms and definitions**

Add new terms:

3.20 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.

3.21 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:

1. Hairpin heat exchangers shall comply with the specified pressure design code.
 - a. The Contractor shall specify the applicable pressure design code on the data/requisition sheets.
 - b. ASME Section VIII, Division 1 shall be applied for all heat exchangers unless specified otherwise on the data/requisition sheets
 - c. If Supplier proposes any other design code different from item a) and b) above, the same shall be subject to approval by Principal.
 - d. For requirements pertaining to Heat exchangers based on the specified vessel category, refer to DEP 31.22.00.31-Gen.
 - e. For identification of heat exchanger vessel category refer to DEP 31.22.00.30-Gen.

4.2

Replace this clause with:

1. Where the use of TEMA is specified within this international standard, the heat-exchanger construction shall conform to TEMA (latest edition), Class R, unless otherwise specified on the data/requisition sheet.
 - f. The Recommended Good Practice section of TEMA shall be applied, where applicable.

4.4

Add to this clause:

- a. Exchangers shall be registered in accordance with the applicable regulations or as specified in data/requisition sheet.

Add new clause:

4.8

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

5 Proposal information required

5.1

Replace this clause with:

1. 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.
 - a. When a tube count-shell diameter combination has been specified on the Contractor's data sheet which cannot be met, the Supplier shall state the maximum tube count obtainable for the specified shell diameter.
 - b. The Supplier shall provide an alternate design incorporating all design changes necessary, for the Supplier to provide a thermal/hydraulic performance guarantee.
 - c. The adequacy of the Supplier's design will be determined on a case-by-case basis.

5.3

Add to this clause:

- a. If the Supplier complies with all the requirements specified in Purchaser's enquiry document, the same shall be stated 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:

- i. Corrosion allowance shall also be included when a value is specified separately for internal components (i.e., tubes).
- ii. 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 hydro test weights, wind and earthquake loads, and bundle pulling loads.

Add new clause:

6.1.4

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

6.2 Information required after outline drawings are reviewed

6.2.2

b) *Add to this clause:*

1. Tube description (i.e. outside diameter, thickness, material type, material grade, fin quantity, fin dimensions if applicable) and number.

Add new clauses:

- i. weld map for each heat exchanger showing the weld joints, including welding procedure number(s);
- j. special installation and maintenance instructions including lifting and handling;
- k. location of and notation of sub-Supplier's component identification number;
- l. vacuum ratings;
- m. stress relieving requirements for U-tubes (included in the U-tube bend schedule drawing);
- n. requirements for spring washers, if applicable;
- o. special handling, special hydro test requirements, shipping or storage requirements.

6.2.3

Replace this clause with:

1. Supplier shall submit the following details for Principal's review/approval prior to fabrication:
 - a. weld maps;
 - b. proposed welding procedures and qualifications (including tube-to-tube sheet welding procedures and qualifications);
 - c. all supporting test results such as impact tests, hardness tests, corrosion tests, as applicable.

6.2.4

Replace this clause with:

1. The Supplier shall submit for the Principal's review the following documentation.
 - a) *Modify this clause as follows:*
 1. Mechanical design calculations for shell thickness, tube thickness, nozzle reinforcement and other non proprietary pressure-retaining components.
 - i. If calculations are made using computer software, all input and output data shall be detailed so as to facilitate an understanding of the calculation procedures.
 - ii. The equations in the applicable sections of the pressure design code and TEMA shall be referenced.
 - iii. 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.
 - iv. The exchanger shall be assumed to be completely filled with process fluid, or water, whichever has the higher density.

- c) *Replace this clause with:*
1. Working pressure calculations as follows:
 - i. maximum allowable pressure (MAP) in uncorroded (new) and cold condition;
 - ii. maximum allowable working pressure (MAWP) allowable in the hot and corroded condition;
 - iii. the limiting component shall be identified.
- d) *Replace this clause with:*
1. Design calculations based on wind, seismic and transportation loads shall be provided, when defined by the Contractor.
 - i. The loading conditions shall not be less than those specified in DEP 31.22.00.31-Gen.
- e) *Add to this clause:*
1. The Supplier shall provide a tabulation of required bolt loadings (bolt torque, bolt stress, and axial force values) for the following on the drawings:
 - i. exchanger girth flange;
 - ii. channel cover flange;
 - iii. rear closure flange bolting.
- g) *Delete this clause*

Add new clause:

- i. The Supplier shall submit the Inspection and Test Plan (ITP) for review and approval.
- i. Surveillance requirements identified by the Contractor shall be incorporated into the Supplier's ITP.

6.2.5

Add new clause:

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

6.3 Reports and records

l) *Replace this clause with:*

1. Tube expansion/tube wall reduction values, recorded on a tube layout drawing.
 - i. The drawings incorporating expansion/tube wall reduction values shall be included in the Manufacturer's data book.

Add new clause:

- p. Wall thickness of two (2) randomly selected tubes measured at a distance of approximately 25 mm (1 in) behind the shell side face of the tube sheet.
 - i. The thickness of each tube sheet shall be measured at one position.
 - ii. The thicknesses shall be recorded on a tube layout drawing and included in the Manufacturer's data book.

7 Design

7.1 Design temperature

Replace 7.1.1 & 7.1.2 with this clause:

1. The design temperature for both shell and tube side shall be provided on the data/requisition sheet by the Contractor.

7.2 Design pressure

7.2.1

Replace this clause with:

1. Design pressures (including any applicable vacuum ratings) for the shell and tube sides shall be specified separately by the Contractor.
 - i. The most unfavourable combination of design pressures on the shell and tube side shall be used in the design and calculations for components.

Add new clause:

7.2.3

1. 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.
 - i. The use of differential design pressure shall not be applied, unless approved by the Principal.

7.3 Cyclic design

7.3.1

Replace this clause with:

1. The Contractor shall specify if cyclic service design is required.

7.3.2

Replace this clause with:

1. If cyclic service is specified, the Contractor shall specify the variation in the pressure and/or temperature loads (amplitude of fluctuation, duration and frequency of the fluctuation) along with the number of cycles to be considered and the required service life for fatigue analysis.

7.3.3

Replace this clause with:

1. If cyclic service is specified, the Contractor shall define the type of analysis required.
 - i. The Supplier shall demonstrate, by a calculation method approved by the Principal, that the heat exchanger can sustain the specified loading for the duration of its service life.

7.4 Shell

7.4.1

Add to this clause:

1. Multi-tube exchangers shall have a maximum nominal shell diameter of 610 mm (24 in) unless otherwise approved by the Principal.

7.5 Front closure

7.5.1

Add to the end of this clause:

- i. The closure design shall be a standard design that has been described in the Supplier's published literature or bulletins.

7.5.2

Replace this clause with:

1. Separate shell side and tube side bolting shall be used in the following conditions:
 - a. for services where the differential temperature (design or operating whichever is greater) across the tube sheets is greater than 110 °C (200 °F);
 - b. design pressure/temperature for either side exceeds ASME B16.5, class 300 flange ratings;
 - c. cyclic service;
 - d. hydrogen service;
 - e. when specified by the Principal.

7.6 Rear closure

7.6.3

Add to the end of this clause:

- a. The connection of the shell return housing end flange to the shell cylinder(s) shall be made by a butt-welded connection.
- b. A slip-on flange connection shall not be used.

7.7 Tube bundle

7.7.1 Tubes

7.7.1.1

Replace this clause with:

1. The inner pipe or tube bundle of the heat exchanger shall be removable through the use of bolted closure joints, unless otherwise specified by the Contractor.

7.7.1.3

Replace this clause with:

1. For tube bundles where the tube element is manufactured from tubing, the outside tube diameters and minimum required tube gauges/tube wall thickness for bare tubes of copper alloys, carbon steel, low alloy steel, aluminium and high alloys shall be as per Table-1.
 - c. The actual thickness provided shall be suitable for the following:
 - i. internal and external design pressure;
 - ii. any vacuum conditions;
 - iii. design temperature;
 - iv. tube thinning in U-bends;
 - v. specified corrosion allowance for the tubes.