TECHNICAL SPECIFICATION

SHELL AND TUBE HEAT EXCHANGERS (AMENDMENTS/SUPPLEMENTS TO TEMA STANDARDS)

DEP 31.21.01.30-Gen.

July 1996
(DEP Circular 04/97 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

PREFACE

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They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users 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 companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

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 m^2. Part IV of this DEP has been written in the form of amendments and supplements to "STANDARDS OF THE TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION", Seventh Edition, 1988, and its 1990 and 1991 ERRATA, known as TEMA Standards.

This DEP is a revision of the DEP of the same number dated February 1991.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements are 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 as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

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

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

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. 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 word **should** indicates a recommendation.

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 V).

PART II GENERAL INFORMATION AND DEFINITIONS

2.1 DESIGN RULES

The design, engineering and fabrication of shell and tube heat exchangers with a bare tube surface area of greater than 0.5 m^2 shall be based on TEMA Standards, Seventh Edition, 1988, and its 1990 and 1991 ERRATA and this DEP.

For clarity and ease of reference, the section, paragraph and clause numbering of TEMA Standards has been followed throughout Part IV of this DEP.

The paragraphs/clauses in the TEMA Standards not referred to in this DEP remain valid, except that Section 8 of TEMA Standards ("Physical Properties of Fluids") is not applicable to this DEP.

Except for the requirements regarding national and/or local regulations in Part I, other deviations from this DEP or the TEMA Standards are not permitted without the prior written approval of the Principal. Such approval shall be valid only for a specific case, and shall not be construed as having general validity for wider application.

In case of conflict between documents relating to an order, the following hierarchy shall apply:
1. the purchase order
2. this DEP

In the event of such conflict, the Principal shall be consulted in writing.

When a heat exchanger is specified during the Project Specification or the detailed engineering phase, the applicable standard forms, requisition and data/requisition sheets listed in Appendix A of this DEP shall be used. Data/requisition sheet DEP 31.21.00.93-Gen., sheet 1, shall be completed in accordance with the guidelines given on its reverse side.

It shall be stated on the data/requisition sheets DEP 31.21.00.93-Gen. to which class of the Mechanical Standards of TEMA the exchanger is to be designed and fabricated:
- However, the design, engineering, fabrication and material selection of heat exchangers specified as Class 'B' in the data/requisition sheet shall be carried out as if they were specified as being Class 'R', as amended and supplemented by this DEP.
- The use of TEMA Class 'C' for heat exchangers is restricted to pressurized water-cooled seal and lube-oil coolers as mentioned in paragraph 'Coolers' of API Standard 614. API Standard 614 (and hence TEMA Class 'C') is also applicable to API Standards 610, 611, 612, 613, 616, 617, 618, 619, 672, 673, 674, 675, 676, 677 and 680.

The party (e.g. Principal, Contractor, Manufacturer) who performs the thermal design or rating of the shell and tube heat exchanger during the design phase, e.g. Project Specification, Basic Design Engineering Package (BDEP) etc., shall be responsible for the thermal design.

For thermosyphon reboilers, the party responsible for detailed engineering shall check the fluid dynamics (piping configuration, equivalent length) of the thermosyphon reboilers and inform the Principal or Contractor if the results of the calculation of the actual situation deviate from the requirements laid down in the data/requisition sheets.

In the case of a proprietary design, the Contractor shall contact the Principal to agree on the calculation method and responsibility.

2.2 PRESSURE VESSEL CODE

Shell and tube heat exchangers shall be considered to be pressure vessels.

Unless otherwise specified, the Pressure Vessel Code shall be ASME VIII, Division 1 and 2 as amended/supplemented by DEP 31.22.20.31-Gen. Only requirements for shell and tube heat exchangers additional to those in the Pressure Vessel Code are stated in this DEP.

The Principal shall state the Pressure Vessel Code, e.g. in the Basis of Design, Basic Design Package, etc. and the party responsible for the thermal design or rating shall specify the Pressure Vessel Code on the data/requisition sheet and, where applicable, in the Project Specification or BDEP.

2.3 MATERIALS OF CONSTRUCTION

The most commonly used materials for shell and tube heat exchangers are described in DEP 31.21.01.31-Gen.

2.4 CORROSION PROTECTION

If specified by the Principal, corrosion protection by means of sacrificial anodes/plates shall be provided. They shall be in accordance with DEP 30.10.73.10-Gen. and with DEP 31.21.01.31-Gen.

Sacrificial anode/plate shall not obstruct tube side flow.

Studs required for sacrificial anodes shall have the same type of screw thread as used for other bolting of the heat exchanger.

An epikote coating may be considered as corrosion protection of tubesheets made of an alloy steel or non-ferrous material.

2.5 UNITS OF MEASUREMENT

The SI unit system has been applied in this DEP but, where considered necessary, the metric sizes are followed by their imperial equivalents in brackets.

Care shall always be taken to indicate whether absolute pressure or gauge pressure is intended. The unit of pressure should be qualified as bar (abs) or bar (ga), whichever is applicable.

Where TEMA specifies dimensions in inches but SI units are used in the actual design, the nearest integer value in millimeters may be used, except for line pipe dimensions up to nominal shell diameter of DN 500 mm and for tube wall thicknesses.

2.6 END FLANGES

For the purpose of this DEP, end flanges shall include stationary head flanges, shell flanges, shell cover flanges and floating head cover flanges.

2.7 EQUIPMENT NUMBERING

Heat transfer equipment shall be identified by a specific equipment number in accordance with DEP 31.10.03.10-Gen.
Equipment consisting of two or more heat exchangers connected in series or parallel and performing a common duty is termed a unit. In such cases, the unit as a whole is identified by the specific equipment number, and each heat exchanger within the unit is separately identified by the addition of a capital letter in alphabetical progression, e.g. E-101-A, E-101-B, E-101-C, etc.

PART III GENERAL REQUIREMENTS

3.1 SELECTION OF TYPE

The following order of preference shall be used in selecting a type of heat exchanger:

- Fixed tubesheet heat exchangers shall be used only in services where all of the following conditions are satisfied:
  - Stresses caused by differential expansion between the tubes and the shell shall not exceed the design stress limits. A floating head type or U-tube type heat exchanger should be selected if flexibility is required to avoid overstressing. The use of a flexible shell element is allowed only if required by specific process requirements and shall be agreed by the Principal.
  - Shell side fluid is non-fouling, or shell side fouling can be removed by chemical cleaning.
  - Start-up, turn down and other operating scenarios shall be considered.
  - Winter conditions, steaming out conditions, etc. shall be considered.
  - Inspection requirements shall be considered.

- U-tube bundle heat exchangers shall be used only in services where at least one of the following conditions are satisfied:
  - Tube side mechanical cleaning is not required or, if it is required, then mechanical cleaning shall be possible. In this respect tube side mechanical cleaning is considered possible if the centre-to-centre distance between the parallel legs of the U-tube is at least 150 mm. However, this latter option may be used only if required by specific process requirements
  - Tube side fouling can be removed by chemical cleaning.

- Floating head heat exchangers should be used in all other services.

3.1.1 SHELL SELECTION

The single-pass shell, Type E, shall be selected for general duties, except as indicated below:

- Where the temperature profile of the process fluids (temperature cross) requires two or more heat exchangers with more than one tube side pass in series, the Type F may be considered in order to reduce the number of shells in series.
- Where the shell side pressure drop is a constraint, the divided flow shell Type J or cross-flow shell Type X or double-split flow shell Type H should be considered.
- For horizontal shell side thermosyphon reboilers, the split flow shell, Type G or Type H, should be selected.
- The kettle type shell, Type K, should be selected for boiling where almost 100% vaporization (0-5% entrainment) is required or where phase separation is required.

3.1.2 FRONT END AND REAR END SELECTION

In general, bonnet Type B should be used for the front end stationary head. For water-cooled exchangers where frequent tube side cleaning is anticipated and the tube side design pressure is less than 10 bar (ga), the front end stationary head shall be Type A.

Rear end head Type M should be used for fixed tubesheet designs; however, for heat exchangers with a Type A front end stationary head and an odd number of tube passes, Type L shall be selected.

Rear end head Type S should be used for floating head type heat exchangers with a nominal shell diameter of more than DN 250. For heat exchangers with a shell diameter up to DN 250 an alternative construction is allowed if agreed by the Principal. Rear end head Type T shall be used for a kettle type heat exchanger with floating head.

3.2 WATER-COOLED HEAT EXCHANGERS

The following restrictions shall apply to water-cooled heat exchangers:

- cooling water shall be on the tube side and shall run upwards through the tubes in order

to avoid build-up of gas. The tube side velocity and maximum water side skin temperature should be as specified in DEP 20.21.00.31-Gen.
- the tube side shall be maintained at an atmospheric over-pressure so that air cannot separate from or be sucked into the water.
- in open cooling water systems, the cooling water outlet temperature shall not be higher than 42 °C. The actual outlet temperature may be limited by national and/or local regulations regarding maximum temperature increase.
- In fouling service (under all operating conditions) the tube side water velocity shall not be allowed to fall below the minimum values specified in DEP 20.21.00.31-Gen. in order to reduce the fouling tendency.
- Internal bellows shall not be used.

The Principal shall decide whether the above restrictions are applicable to a dedicated closed cooling water system.

3.3 HORIZONTAL AND VERTICAL EXCHANGERS

Heat exchangers should be of the horizontal type; however, the vertical arrangement may be considered for certain process requirements, or if cleaning and other maintenance will be infrequent or if there is limited space available.

For thermosyphon reboilers, vertical orientation is preferred to horizontal orientation, even if the heating medium is fouling.

If horizontal arrangements are preferred, the stacking of exchangers should be considered in order to economise on the use of space in the structure.

If the maximum nominal shell diameter and maximum tube length do not exceed the values specified in the TEMA (Section 5, maximum nominal shell diameter 1524 mm) and this DEP (maximum tube length 7315 mm), the ease of handling of the tube bundle and/or heat exchanger is ensured. For bigger dimensions the Principal shall be consulted.

3.4 DOUBLE-PIPE AND MULTI-TUBE HEAT EXCHANGERS

Amended per Circular 04/97

Requirements specified in the TEMA standards and this DEP shall be followed as far as practical and economical.

Double-pipe and multi-tube heat exchangers shall have a maximum shell diameter of DN 150, unless otherwise approved by the Principal.

The following restrictions shall apply to double-pipe and multi-tube heat exchangers:

- hydrogen service is not permitted on the shell side. Fluids with hydrogen at a partial pressure below 6.9 bar (abs) (100 psi (abs)) may be considered as non-hydrogen service;
- if condensing steam is used as a heating medium on the shell side, the superheated inlet temperature shall be not more than 30 °C above the dew point temperature of the steam;
- finned tubes shall not be used for multi-tube heat exchangers if fouling is expected or if mechanical cleaning is specified on the shell side;
- fins shall be of a corrosion resistant material, otherwise finning shall not be used;
- the maximum allowable moments and forces for nozzles as specified in the API 661 shall be observed for the tube side nozzles.

For a water-cooled double-pipe heat exchanger, cooling water on the shell side is acceptable.

Standard constructions used by approved Manufacturers/Suppliers are acceptable.

3.5 STEAM SURFACE CONDENSERS

Steam surface condensers shall be constructed in accordance with the 'Standard for Steam

Surface Condensers' published by the Heat Exchange Institute. For matters not covered by the above-mentioned standard, the TEMA standards and this DEP shall be used.

3.6 ELECTRIC HEATERS

The shell side of an electric heater shall be in accordance with this DEP.

PART IV AMENDMENTS/SUPPLEMENTS TO TEMA STANDARDS

SECTION 1 HEAT EXCHANGER NOMENCLATURE

N-1.2 TYPE

Add to this clause:

The two-pass shell with longitudinal baffle (Type F) may be used only if an approved mechanical construction is employed, see clause (R-4.42) of this DEP.

The outside packed floating head (Type P) and the externally sealed floating tubesheet (Type W) shall not be used.

N-1.3 TYPICAL EXAMPLES

Add to this clause:

To conform with the use of SI units in this DEP, the nomenclature with size indications used in the typical examples N-1.31 through N-1.35 is not applicable.

SECTION 2 HEAT EXCHANGER FABRICATION TOLERANCES

F-3 TUBESHEETS, PARTITIONS, COVERS AND FLANGES

Add to this clause:

The alternate tongue and groove joint arrangement shown in Figure F-3 shall not be used.

The outside diameter of the stationary tubesheet should be equal to the outside diameter of the shell flange, see clause (RCB-7) of this DEP.

Replace the last sentence of Note 1 by:

However the plus tolerance on dimension R4 shall be 5 mm.

SECTION 3 GENERAL FABRICATION AND PERFORMANCE INFORMATION

G-2.1 MANUFACTURER'S INSPECTION

Add to this clause:

The Manufacturer shall perform the following tests:
- tests specified in the Pressure Vessel Code (as amended/supplemented by the relevant DEP), national and/or local regulations, the TEMA Standards and the requisition;
- routine tests specified by the Manufacturer to verify the proven design.

NOTES: Unless otherwise agreed by the Principal:

1) The Manufacturer's routine tests shall not be used for the purposes of design development. They shall be used only to verify the proven design.

2) The Manufacturer shall not extend the severity of any specific test for the purposes of gathering design development data.

G-3.3 ASSET NUMBER PLATE (new clause)

If specified by the Principal, an asset number plate of corrosion-resistant metallic material shall be provided, attached to the exchanger alongside the Manufacturer's name plate.

If a spare tube bundle forms part of the supply, an asset number plate shall also be provided and fixed to the tubesheet.

If test flanges and/or test rings form part of the supply, an asset number plate shall also be provided and fixed to the test flanges and/or test rings.

The asset number plate shall show the text 'ASSET No.' in lettering 6 mm high, followed by a block of 15 mm by 65 mm for the asset number.

G-4.1 DRAWINGS FOR APPROVAL AND CHANGE

Add to this clause:

Approval drawings shall be supplied in accordance with the requirements of DEP 40.10.01.93-Gen. and standard form DEP 05.00.54.81-Gen.

G-4.2 DRAWINGS FOR RECORD

Replace this clause by:

Final drawings shall be supplied in accordance with the requirements of DEP 40.10.01.93-Gen. and standard form DEP 05.00.54.82-Gen.

G-5.1 GENERAL

Add to this clause:

For the responsibility for thermal design or rating see PART II, Section 2.1 of this DEP.

G-5.21 THERMAL PERFORMANCE TEST

Add to this clause:

If the thermal performance rating was not performed by the Manufacturer, test conditions and procedures shall be agreed between the Principal and the party who performed the thermal design.

G-6.2 DRAINING

Delete the last sentence of this clause.

G-6.4 THREADED CONNECTION PROTECTION

Replace this clause by:

Threaded connections shall not be used.

G-7.11 HORIZONTAL UNITS

Replace paragraph 5 by:

Support saddles shall be in accordance with Standard Drawings S 22.001 and S 22.002, as applicable.

For stacked exchangers, the combined construction shall be able to accommodate the weight and withstand the pulling force as per TEMA Standards otherwise the saddles shall be continuous over the shell circumference, except for the top shell.

The sliding plate underneath the sliding support saddle shall be in accordance with Standard Drawing S 22.003.

The holes for anchor bolts shall be provided in the fixed saddle support.

For stacked heat exchangers where the nozzles on the shell side and channel side are directly connected in series, a set of shim plates of corrosion-resistant material with a total thickness of 12 mm shall be provided for inserting between the upper and lower saddle supports.

Bolting of flanges of mating connections between stacked exchangers shall be removable without moving the exchangers.

Bolts, nuts and gaskets for the interconnecting nozzles between stacked shells shall be in the scope of supply of the Manufacturer.

To ensure correct alignment when installed, a trial assembly shall be carried out at Manufacturer's works, using the specified gaskets between the nozzle flanges.

Sliding saddles shall be designed to allow thermal expansion and contraction during service.

Saddles shall protrude beyond the bottom nozzles, including the drain nozzle with blind flange, by at least 50 mm to prevent damage to flange facings during transport, storage and maintenance.

G-7.12 VERTICAL UNITS

Add to this clause:

Support brackets shall be in accordance with Standard Drawing S 21.017.

G-7.2 LIFTING DEVICES

Add to first paragraph:

The lifting devices shall be located above the centre of gravity of the parts to which they are welded or cast.

Where welded plate type lugs are used, these shall be welded on with full penetration welds and shall be in accordance with Standard Drawing S 10.030.

For cast components the lugs shall be integrally cast with the casing.

The hole diameter shall be 28 mm diameter minimum.

The load bearing capacity of the lugs in supporting the required load shall be demonstrated by calculation. In any case the lugs shall be designed for a static force of at least twice the mass of the heat exchanger part(s).

Eye bolts shall be of ASTM A 307 grade B material. Unless special dimensions are used, eyebolts should not be in the scope of supply of the Manufacturer.

Stationary tubesheets shall have two or more holes UNC threaded to take eye bolts for removing the tube bundles from the shells. Floating head covers shall have one hole UNC threaded to take an eye bolt.

NOTE: 1) The required size and length of thread for the eye bolt shall be calculated to resist the force of tube bundle removal. The threads shall be well formed and be a tight fit for maximum grip.

Removable threaded plugs shall be provided to protect the eye bolt holes during operation; they shall be of a material equivalent to that of the part concerned.

Jack bolts shall be provided in heat exchanger end flanges.

SECTION 4 INSTALLATION, OPERATION AND MAINTENANCE

E-2.12 FOUNDATIONS

Add to this clause:

In concrete footings for fixed point saddles, the foundation bolts shall meet the requirements of Standard Drawings S 22.001 and S 22.002.

In concrete footings for sliding point saddles, holes shall be provided to accommodate the anchors of the sliding plate in accordance with Standard Drawing S 22.003.

E-2.13 FOUNDATION BOLTS

Replace this clause by:

The requirements of Standard Drawings S 22.001, S 22.002 and S 22.003 provide for free expansion of the heat exchanger in the longitudinal direction.

E-2.32 TEST CONNECTIONS

Replace this clause by:

There shall be no thermometer or pressure gauge connections in heat exchanger nozzles, except for direct interconnecting nozzles of stacked exchangers, see (RC-10.32) and (RC-10.33) of this DEP.

E-3.25 RECOMMENDED BOLT TIGHTENING PROCEDURE

Add to this clause:

Hydraulic bolt-tensioning shall be in accordance with DEP 70.08.10.11-Gen.

If the application of bolt-tensioning equipment is anticipated in the design stage, due attention shall be given to the clearance required to accommodate the tensioning tools.

E-4.14 TEST RING AND TEST FLANGE (new clause)

Shell and tube heat exchangers shall be provided with test flanges or test rings as follows:

- Each exchanger with a bonnet-type head, a removable bundle, and a tubesheet of diameter smaller than the outside diameter of the connecting shell flange shall be provided with a test flange.
- Each exchanger with split ring floating head (S type) shall be provided with a test ring with packing gland.

Unless otherwise specified in the data/requisition sheet, each unit of identical heat exchangers performing a common duty shall be equipped as follows:

(1) One test flange or ring, for two bundles per unit.
(2) Two test flanges or rings, for three or more bundles per unit.
(3) Two test flanges or rings, for stacked exchangers with direct interconnections.

E-4.2 TUBE BUNDLE REMOVAL AND HANDLING

Replace this clause by:

During removal of a tube bundle from a shell, a pulling cable shall be attached to eye bolts screwed into the tubesheet. The bundle shall be supported on the tube baffles, supports or tubesheets to prevent damage to the tubes. Contact surfaces shall be protected, see (G-7.2) of this DEP. If tube bundle pulling equipment which requires special provisions is to be used this shall be stated in the Project Specification and on the data/ requisition sheets.

E-4.31 CLEANING METHODS

Add after second sentence of second paragraph:

Guidelines for chemical and mechanical cleaning are specified in DEP 70.10.80.11-Gen.

E-4.5 GASKET REPLACEMENT

Add to this clause:

If a heat exchanger is dismantled for any reason, it shall be reassembled with new gaskets.

Flanges with a nubbin shall not be used.

E-4.6 SPARE AND REPLACEMENT PARTS

Replace the last sentence of this clause by:

Spares and replacement parts shall be in accordance with DEP 70.10.90.11-Gen.

E-4.7 PRESERVATION OF EQUIPMENT (new clause)

DEP 70.10.70.11-Gen. shall apply and covers temporary, short-term and long-term preservation.

SECTION 5 MECHANICAL STANDARDS TEMA CLASS R C B

RCB-1.21 DESIGN PRESSURE

Add to this clause:

The most unfavourable combination of design pressures on the shell and tube side shall be used in the calculations for tubesheets, floating heads and tubes.

For the determination of the design pressure on the low pressure side, the initial design pressure on the low pressure side or 2/3 of the design pressure on the high pressure side, whichever is greater, shall be taken (refer to DEP 01.00.01.30-Gen. for limitations). However, if it is economic to maintain the initial design pressure on the low pressure side by installing a relief device, this may be considered. The size of the relief device then shall be determined based on a full tube rupture. The size of the leak shall be taken as twice the internal cross-sectional area of one tube. To determine the influence of piping on the low pressure side of the heat exchanger, either in eliminating the need for a relief device or in reducing relief quantities, reference is made to API RP 521. A flowchart summarising the determination of the design pressure low pressure side is shown in Appendix B of this DEP.

All parts of a heat exchanger that are subjected to a differential pressure only, i.e. if the circuit between shell and tube side is open, may be designed based on the maximum differential design pressure between shell and tube side. A WARNING sign, stating the maximum differential design pressure and the maximum differential test pressure, shall be located next to the nameplate.

The possibility of exposure to system pressure waves, e.g. water hammer, shall be taken into account.

RCB-1.42 DESIGN TEMPERATURE OF HEAT EXCHANGER PARTS

Add to this clause:

For heat exchangers in series, individual shells of a unit may have different design temperatures for economic material selection. Where this applies, measures shall be taken to prevent incorrect line-up of shells within the unit.

The effect of a non-linear temperature profile across a thick walled tubesheet shall be taken into account because this may have a significant consequence on the "mean metal temperature" as well as on the stresses within the tubesheet.

The Manufacturer shall be informed by the Principal or Contractor if there is severe thermal cyclic loading. The Manufacturer shall prove by agreed calculation method that the heat exchanger will be able to sustain this loading during service life.

RC-1.54 LINING, CLADDING AND WELD OVERLAYS (new clause)

Where corrosion-resistant lining or cladding is specified it shall apply to all exposed (wetted) surfaces including the surface of pass partition plates and the side and bottom of gasket grooves.

RCB-1.62 EXTERNAL PACKED JOINTS

This clause is not applicable to this DEP.

RCB-2.1 TUBE LENGTH

Add to this clause:

For straight tubes, standard tube lengths as per TEMA Standards should be used. A tube length of 7315 mm may also be used.

The maximum tube length for vertical thermosyphon reboilers is 6096 mm.

The ratio of tube length to tube bundle outer diameter for removable bundles should not exceed 12 : 1.

RCB-2.21 BARE TUBES

Add to this clause :

The following table RCB-2.21 shows the outside tube diameters and minimum required nominal tube wall thickness for bare tubes of copper, carbon steel, aluminium and alloys.

TABLE RCB-2.21 BARE TUBE DIAMETERS AND GAUGES

Tube material	Nominal tube outside diameter		Tube wall gauge (SWG)	Nominal tube wall thickness	
	mm	(inch)		mm	(inch)
Copper and copper alloys	15.87	(5/8)	16	1.626	(0.064)
	19.05	(3/4)	16	1.626	(0.064)
	25.40	(1)	14	2.032	(0.080)
	31.75	(1 1/4)	12	2.642	(0.104)
	38.10	(1 1/2)	12	2.642	(0.104)
Carbon steel, aluminium and aluminium alloys	15.87	(5/8)	14	2.032	(0.080)
	19.05	(3/4)	14	2.032	(0.080)
	25.40	(1)	12	2.642	(0.104)
	31.75	(1 1/4)	10	3.251	(0.128)
	38.10	(1 1/2)	10	3.251	(0.128)
Other alloys	15.87	(5/8)	16	1.626	(0.064)
	19.05	(3/4)	16	1.626	(0.064)
	25.40	(1)	14	2.032	(0.080)
	31.75	(1 1/4)	12	2.642	(0.104)
	38.10	(1 1/2)	12	2.642	(0.104)

NOTES: 1. For special materials e.g. Ti tubes, other tube wall thickness should be considered.

2. In the thermal design phase, the Principal or the Contractor may choose Birmingham Wire Gauge (BWG) with the same gauge number instead of Standard Wire Gauge (SWG). The Standard used shall be specified on the data/ requisition sheet.

RC-2.211 SELECTION OF BARE TUBE DIAMETER (new clause)

Tubes with an outside diameter of 15.87 mm (5/8 inch) may be considered for:

1. Feed/Effluent heat exchangers in relatively clean applications (the so-called Texas Towers in Platformer units).

Tubes with an outside diameter of 19.05 mm (3/4 inch) should be used for:

1. Heat exchangers, provided that the medium to be handled on the tube side has a fouling resistance of less than 0.00034 m^2.K/W.
2. Water-cooled heat exchangers with the cooling water through the tubes, with no restrictions with respect to fouling resistance.

Tubes with an outside diameter of 25.40 mm (1 inch) should be used for:

1. Heat exchangers, provided that the medium to be handled on the tube side has a fouling resistance of 0.00034 m^2.K/W or higher.
2. Heat exchangers where it would be economical to use 25.40 mm tubes because of process design restraints, e.g. pressure drop limitations.

Tubes with an outside diameter of 31.75 mm (1 1/4 inch) or 38.10 mm (1 1/2) should be used for:

1. Special types of shell and tube heat exchangers in SRU and SCOT units. The tube wall thickness may be increased for these special applications.
2. Heat exchangers where it would be economical to use 31.75 mm or 38.10 mm tubes because of process design restraints, e.g. pressure drop limitations.

RCB-2.22 CIRCUMFERENTIALLY-FINNED TUBES

Add to this clause:

In general, finned tubing shall be used only in clean service (fouling resistance less than or equal to 0.00017 m^2.K/W) and non-abrasive services. Tubes shall have no more than 1181 fins per metre (30 fins per inch).

To avoid fretting of the finned tubes without lands (unfinned portion) in baffle/support plates, the baffle/support plates shall have a thickness in accordance with Table R-4.41 and Table CB-4.41; however, the minimum thickness shall not be less than 13 mm.

High-finned tubing shall not be used.

RC-2.23 LONGITUDINALLY-FINNED TUBES (new clause)

Longitudinally high finned tubes may be used only for double-pipe and multi-tube heat exchangers.

RCB-2.3 U-TUBES

Add to this clause:

Only seamless tubes may be used for U-tube bundles. However welded tubes may be accepted for specific cases but the Principal, who will supply additional testing requirements, shall be consulted. U-tubes shall not be constructed by welding U-bends to straight tubes.

RCB-2.31 U-BEND REQUIREMENTS

Add to this clause:

Bends with radius R < 1.5 times nominal tube OD shall not be used.

RCB-2.321 CENTER-TO-CENTER DIMENSION

Add to this clause:

The tolerance of the centre-to-centre distance between the parallel legs of the U-tubes shall be as follows:

CENTRE-TO-CENTRE DISTANCE	TOLERANCE
≤ five times the nominal tube OD	± 1.0 mm
> five times the nominal tube OD	± 1.5 mm

RCB-2.33 HEAT TREATMENT

Add to this clause:

For U-tubes the following heat treatment shall be applied:
- Post weld heat treatment of the bend area for carbon steel and low alloy steel U-tube bends having a mean radius smaller than 5 times the nominal tube OD.
- For general refinery service, solution anneal heat treatment of the bend area and at least 150 mm of the adjacent straight length for austenitic stainless steel U-tube bends having a mean radius smaller than 5 times the nominal tube OD.
- For severe corrosion service, solution anneal heat treatment of the whole tube for austenitic stainless steel U-tubes, regardless of the mean radius of the bend.
- For nickel alloys, the heat treatment procedure for U-tubes shall be agreed with the Principal.

If cold working induces susceptibility to stress corrosion in some materials or environments then heat treatment shall be required. This shall be specified and clarified (e.g. required for process reasons) by the Principal or Contractor on the relevant data/requisition sheet.

Unless otherwise agreed with the Principal, heat treatment shall be applied for bonnets and floating head cover if there are 4 or more tube side passes and the partition plates are in two different planes.

RCB-2.42 TRIANGULAR PATTERN

Add to this clause :

Triangular or rotated triangular pattern should not be used for retractable tube bundles.

R-2.5 TUBE PITCH

Add to this clause :

The minimum nominal ligament shall be 6.35 mm for tubes with a nominal tube OD of 25.4 mm or less.

RC-2.6 TUBE PITCH OVER PASS PARTITION LANE (new clause)

The minimum tube pitch over the pass partition lane is determined as follows:

For straight tubes with a tube pattern of 30 or 60 degrees, the centre-to-centre distance is determined by the nominal tube OD and the width of the pass partition plate gasket groove, see (RCB-6.4) of TEMA standards.

The following requirements shall apply:
- the difference between the thickness of the partition plate (at the tapered end) and the width of the gasket groove shall result in a clearance of 3.2 mm with a tolerance of ± 0.5 mm, and
- the minimum distance between the edge of the gasket groove and the tube hole shall be 1.5 mm for expanded tube-to-tubesheet joints, and 3.2 mm for strength-welded tube-to-tubesheet joints.

RC-2.7 TUBE LAY-OUT (new clause)

The tube lay-out shall ensure that the allowable stresses in the tubes due to temperature differences between tubes in adjacent passes are not exceeded.

For shell side heat transfer and the mechanical construction of the pass partition plates there shall be at least two tube rows per pass.

RC-2.8 STOVING LACQUER (new clause)

If the use of stoving lacquer is required, the tube-to-tubesheet connection shall be agreed upon by the Principal and the Manufacturer. Surface protection should then be in accordance with DIN 28051.

RCB-3.11 SHELL DIAMETERS

Add to this clause :

If Table R-3.13 applies, line pipe dimensions shall be used for carbon steel shells up to a nominal shell diameter of DN 500 mm (20 inch). For shells rolled from plate and with a nominal shell diameter above DN 500 mm (20 inch) the nominal diameter is the shell inside diameter.

RCB-3.2 SHELL COVER THICKNESS

Add to this clause :

Shell cover heads shall be of true semi-ellipsoidal shape, ratio 2:1, or Korbbogen. Klöpperboden (torospherical) heads should not be used.

RCB-4.1 TYPE OF TRANSVERSE BAFFLES

Add to this clause:

For single-phase fluid flow, horizontally cut baffles should be used. For two-phase fluid flow, or shells with a longitudinal baffle, transverse baffles with a vertical cut should be used.

Other baffle types, such as disk and doughnut, rod baffle and spiral (helix), require the approval of the Principal.

For draining heat exchanger shells, all baffles and support plates extending to the bottom of the shell shall have a V-notch, 20 mm wide and 17 mm high, at the lowest point.

The end support plate shall have rectangular or square windows located so that the unsupported span length of the tubes is not increased.

*RCB-4.3 TRANSVERSE BAFFLE AND SUPPORT CLEARANCE

Add to first paragraph:

The clearances given in Table RCB-4.3 shall only be exceeded if specified on the data/requisition sheets.

*RCB-4.41 TRANSVERSE BAFFLES AND SUPPORT PLATES

Add to this clause:

However, the minimum thickness shall not be less than twice the specified shell side corrosion allowance.

R-4.42 LONGITUDINAL BAFFLES

Add to this clause:

A two pass shell with a longitudinal baffle shall only be used if:
- the longitudinal baffle is welded to the shell;

or:
- for a removable bundle, the gap between the baffle and the shell is closed with a double-sided, multi-layered clip-on spring set.

On the shell side the difference between the inlet and outlet temperature shall not exceed 200 °C. If a spring set is used, the maximum allowable pressure drop over the longitudinal baffle shall be 0.5 bar. In either case there shall be no leakage between the longitudinal baffle and the stationary tube sheet.

RCB-4.52 MAXIMUM SPACING

Replace the first sentence of this clause by:

Tube support plates shall be spaced such that the unsupported tube span does not exceed 0.8 times the value indicated in Table RCB-4.52 for the tube material used.

RCB-4.61 SHELL SIDE IMPINGEMENT PROTECTION REQUIREMENTS

Add to this clause:

Heat exchangers with steam as heating medium on the shell side shall always have impingement protection.

For non-corrosive, non-abrasive, single-phase fluids, instead of using impingement protection the nozzle diameter should be increased to reduce the fluid velocities at the shell entrance.

Impingement protection shall take the form of either:

- at least two rows of impingement rods at a lay-out angle of 30 or 45 degrees with the following rod diameters:

Tube lay-out angle (degrees)	Grid lay-out angle (degrees)	Rod pitch (mm)	
		25.4	31.75
		Rod diameter (mm)	
30, 60, 90	30	16	20
45	45	22	25

or:

- a non-perforated plate, which may be rectangular, square or circular, extending at least 25 mm beyond the projection of the nozzle bore and having a thickness of not less than 6 mm.

RCB-4.63 TUBE SIDE

Replace this clause by:

Consideration shall be given to the need for special devices to prevent erosion of the tube ends:

- for gases and vapours if the ρV^2 in the tubes exceeds 7000 kg/(m.s^2);
- for liquids the ρV^2 calculated with the maximum water velocities as specified in DEP 20.21.00.31-Gen. for different materials will be the maximum value;
- for two-phase flow, the ρV^2 in the tubes shall be checked carefully against the danger of erosion of the tube ends. In such a case, the velocity and density shall be based on a homogeneous gas/liquid mixture.

V is the linear velocity in m/s and r is the density in kg/m^3 of the fluid.

*RCB-4.7TIE RODS AND SPACERS

Add to this clause:

Tie rods and spacers shall be evenly distributed around the circumference of the baffles.

Additional tie rods may be required near the centre of the bundle.

Spacers shall not be used if there is a hazardous service on the shell side.

R-4.71 NUMBER AND SIZE OF TIE RODS

Replace this clause and Table R-4.71 in the TEMA Standards by:

The following Table R-4.71 shows the minimum number of tie rods, the minimum diameter of the solid rod and the spacer pipe OD for various sizes of heat exchanger and tube ODs.

TABLE R-4.71 TIE ROD STANDARDS

Nominal shell diameter		Tube OD of 19.05 mm (3/4 in) and less		Tube OD of 25.4 mm (1 in) and larger		Minimum number of tie rods
mm	(inch)	Solid Rod minimum diameter mm	Spacer Pipe OD (sched 80) mm	Solid Rod minimum diameter mm	Spacer Pipe OD (sched 80) mm	
132- 393	(6-15)	12	17.15	12	17.15	4
394- 698	(16-27)	15	17.15	15	17.15	6
699- 850	(28-33)	15	17.15	19	21.34	6
851-1231	(34-48)	15	17.15	19	21.34	8
1232-1537	(49-60)	19	21.34	22	26.67	10

NOTES:
1. The baffles shall be supported by solid rods welded to the baffles or by spacer pipes, keeping the baffles at distance, with supporting rods inside.
2. The screw thread connection of the tie rod in the tubesheet shall have a diameter which is equal to, or slightly smaller than, the diameter of the tie rod.

RCB-4.8 SEALING DEVICES

Add to this clause:

Sealing and sliding devices should be located in such a way as to minimize the force exerted by the hoisting band on the outer tubes of the bundle.

Sealing strips shall be provided for all shell and tube exchangers, except in the case of fixed tubesheet and U-tube bundles with a diametric bundle-to-shell clearance of less than 19 mm (3/4 inch).

Sealing strips may be counted as tie rods if properly seated in the baffles, secured with a complete fillet weld and attached to the stationary tubesheet with a full penetration weld.

For floating head bundles, one pair of sealing devices shall be provided for every 5 to 6 rows of tubes in the cross flow area.

The sealing strips shall not protrude beyond the periphery of the baffles.

The sealing devices shall not obstruct the tube lanes or pass partition lanes for tube patterns of 45 or 90 degrees.

RC-4.9 SLIDING STRIPS (new clause)

Sliding strips shall be provided to facilitate pulling the tube bundle. Sliding strips may be counted as tie rods if properly seated in the baffles, secured with a complete fillet weld and attached to the stationary tubesheet with a full penetration weld. To avoid damage to the baffles during bundle pulling and replacement, the sliding strips shall protrude 1 to 2 mm beyond the periphery of the baffles.

For vertical exchangers, four sliding strips shall be provided, evenly divided around the circumference of the bundle.

The sliding strips shall not obstruct the tube lanes or pass partition lanes for tube patterns of 45 and 90 degrees (or hinder the liquid inflow to the centre tube rows in a kettle-type reboiler).

The following Table RC-4.9 shows the minimum required size of the sliding strips.

TABLE RC-4.9 MINIMUM SLIDING STRIP SIZE

Nominal Shell Diameter		Sliding strip dimensions (minimum)		
		Height	Thickness	
mm	(inch)	mm	mm	(inch)
132- 393	(6-15)	30	6.0	(1/4)
394- 698	(16-27)	40	10.0	(3/8)
699- 850	(28-33)	50	12.0	(1/2)
851-1231	(34-48)	60	12.0	(1/2)
1232-1537	(49-60)	75	15.0	(5/8)

RCB-5 FLOATING END CONSTRUCTION

Add to this clause:

The nominal wall thickness of floating head covers shall be at least equal to the minimum wall thickness of the appropriate nominal shell diameter given in Table R-3.13 or Table CB-3.13 of TEMA standards.

RCB-5.15 FLOATING HEAD NOZZLES

Replace this clause by:

Packed floating head nozzles and packing boxes shall not be used.

RCB-5.17 FLOATING HEAD EXPANSION JOINT (new clause)

For single tube pass heat exchangers, the floating head shall be connected to the shell

cover by means of an expansion joint of an approved type, similar to the construction shown in Standard Drawings T-832690 to T-832693.

For single tube pass heat exchangers, the expansion joint shall be located at the smallest nozzle and/or cold end of the heat exchanger.

RCB-5.2 OUTSIDE PACKED FLOATING HEADS (Type P)

Paragraphs RCB-5.21 through RCB-5.25 of the TEMA Standards are not applicable since Type P shall not be used.

RCB-5.3 EXTERNALLY SEALED FLOATING TUBESHEET (Type W)

Paragraphs RB-5.31 through RCB-5.34 of the TEMA Standards are not applicable since Type W shall not be used.

RCB-6 GASKETS

Add to this clause:

RCB-6.1 through CB-6.5 of this DEP refer solely to gaskets for end flanges (girth flanges).

Gaskets for nozzles shall comply with the requirements of (RCB-10.1) of this DEP.

*RCB-6.1 TYPE OF GASKETS

Add to this clause:

The type of gasket used shall be selected from those listed in Table RCB-6.1 below.

TABLE RCB-6.1 TYPE OF GASKETS

Type	Description	Minimum Width mm	Minimum Thickness mm
1	CAF, oil or acid resistant	9.53	1.6 [4)]
2	Solid flat metal 5 Cr-0.5 Mo, maximum hardness Brinell 160	6.35	2.4
3	Solid flat metal soft iron, maximum hardness Brinell 90	6.35	2.4
4	Solid flat metal AISI 316, maximum hardness Brinell 160	6.35	2.4
5	Spiral-wound AISI 316 with graphite filler (flexicarbon)	10.0	4.5 [1) 3)]
6	Grooved gasket, AISI 316 (L) or Ti with graphite tape, min. 0.5 mm thick	12.7	3.0 [2) 3)]
7	Grooved gasket, AISI 304 H with graphite tape, min. 0.5 mm thick	12.7	3.0 [2) 3)]
8	Metal reinforced expanded graphite	9.53	1.6 [3)]

NOTES:
1. To avoid overstressing of the spiral-wound gasket, an inner and/or centring ring will be required.
2. Thickness is exclusive of the tape. For shell diameters above 1000 mm the minimum thickness shall be 4 mm.
3. For sea water applications, materials other than graphite filler or graphite tape should be considered.
4. Gaskets contain asbestos. These types of gaskets may be restricted or prohibited by local regulations.

R-6.2 GASKET MATERIALS

Replace this clause by:

GASKET SELECTION

The service conditions to which exchangers are generally exposed are described in Table R-6.21 below.

TABLE R-6.21 SERVICE CONDITIONS

Service Condition	Description
I	Non-corrosive and mildly corrosive
II	Hydrocarbon streams containing sulphur compounds and naphthenic acids with an acid value exceeding 0.3 mg KOH/g, and for maximum operating temperatures above 230 °C
III	Hydrocarbon streams containing sulphur compounds and naphthenic acids with an acid value not exceeding 0.3 mg KOH/g, and for maximum operating temperatures above 330 °C
IV	Hydrocarbon streams containing hydrogen
V	Non-corrosive cooling water below 50 °C
VI	Mildly corrosive cooling water below 50 °C
VII	Corrosive cooling water below 50 °C
VIII	Any other corrosive environment
IX	Frequent changes in temperature and pressure, (e.g. hot washing, dewaxing, chilling) and frequent cleaning (i.e. more than twice a year under all conditions I to VIII).

The selection of gaskets depends on the design temperature and pressure, and the corrosivity of the service to which the flange and gasket are exposed.

Gasket selection shall be in accordance with Table R-6.22 of this DEP.

For design temperatures and pressures, and service conditions other than those given in the tables, gasket selection shall be as agreed between the Principal and the Manufacturer.

If two gasketed joints are compressed by the same bolting, gasket selection and area of gasket facing shall be such as to ensure effective sealing of both joints without crushing of the gasket under the required bolt load. This shall be demonstrated with calculations, for approval by the Principal.

TABLE R-6.22 SELECTION OF TYPE OF GASKET

Service Condition	Design Temperature °C	Design Pressure bar (ga)	Preferred Type	Alternative Type
I	0 - 240	20.5 max.	8	1
	0 - 240	20.5 - 31.0	6	5
	240 - 450	31.0 max.	6	5
	0 - 450	31.0 - 103.0	6	3, 5
	450 - 550	103.0 max.	6	3, 5, 7
	-200 - 0	31.0 max.	6	5
	-200 - 0	31.0 - 103.0	6	4, 5
II	230 - 240	20.5 max.	8	1
	230 - 240	20.5 - 31.0	6	5
	240 - 350	31.0 max.	6	5
	230 - 350	31.0 - 103.0	6	4, 5
	350 - 550	103.0 max.	6	4, 5, 7
III	330 - 450	31.0 max.	6	5
	330 - 400	31.0 - 103.0	6	4, 5
	400 - 450	31.0 - 103.0	6	4, 5, 7
	450 - 550	103.0 max.	6	4, 5, 7
IV	0 - 400	103.0 max.	6	2, 5
	400 - 550	103.0 max.	7	2, 5
V VI VII	0 - 50	-	8 3.2 mm (1/8") thick	1
VIII	-	-	Note 1	-
IX	0 - 400	103.0 max.	6	-
	400 - 550	103.0 max.	7	-

1. See the data/requisition sheet or as agreed between the Principal and the Manufacturer.
2. For a description of the gasket type, see Table RCB-6.1 and for service conditions, see Table R-6.21, both of this DEP.

RC-6.31 GASKET MINIMUM WIDTH

Replace this clause by:

The minimum width of peripheral ring gaskets shall be in accordance with Table RCB-6.1 of this DEP for the type of gasket selected.

R-6.32 GASKET CONTACT SURFACE

Replace this clause by:

The arithmetic average roughness, R_a, which defines the flange face surface finish required for each type of gasket, is given in Table R-6.32 below.

See Table RCB-6.1 of this DEP for a description of the gasket type.

TABLE R-6.32 GASKET CONTACT SURFACE FINISH

Gasket type	R_a value	
	µm	(micro-inch)
1, 5, 6, 7, 8	3.2 - 6.3	(125 - 250)
2, 3, 4	0.8 - 1.6	(32 - 63)

RCB-7 TUBESHEETS

Add to this clause:

For tubesheets with an effective tubesheet thickness of 30 mm or greater, the OD of the stationary tubesheet of retractable bundles should be equal to the OD of the shell flange. The extended part shall be strong enough to carry the bolt load during hydrotesting in order

to replace the test flange.

Divided floating heads shall not be used (see Table RCB-7.132).

If the tubesheet forms a flange or is directly welded to the shell it shall be a forging and not a plate material.

RCB-7.13 REQUIRED EFFECTIVE TUBESHEET THICKNESS

Insert before the first paragraph:

If the selected Pressure Vessel Code includes design rules for calculating the required effective tubesheet thickness, then the Pressure Vessel Code shall overrule the calculation method of the TEMA Standards, and in that case paragraphs RCB-7-123 and RCB-7.133 are not applicable.

RCB-7.141 OUTSIDE PACKED FLOATING HEAD (Type P)

Paragraph RCB-7.141 and sub-paragraphs RCB-7.1411 and RCB-7.1412 of TEMA Standards are not applicable, see (N-1.2) of this DEP.

RCB-7.142 PACKED FLOATING TUBESHEET WITH LANTERN RING (Type W)

Paragraph RCB-7.142 of TEMA Standards is not applicable, see (N-1.2) of this DEP.

RB-7.44 TUBE HOLE GROOVING

Add to this clause:

The distance from the centre line of the first groove to the cover side of the tubesheet should be 9.5 mm. The distance between groove centre lines should be 9.0 mm.

For tubesheets constructed of integrally clad plate or with applied corrosion-resistant facings, one groove shall be in the centre of the cladding/facing material layer.

*RCB-7.52 WELDED TUBE-TO-TUBESHEET JOINTS

Add to this clause:

Tubes shall be welded to the tubesheet only if specified on the data/requisition sheet.

RCB-7.521 SEAL WELDED JOINTS

Replace this clause by:

Seal-welded joints shall not be used.

RCB-7.522 STRENGTH WELDED JOINTS

Add to this clause:

If specified by the Principal, tubes shall be welded to the tubesheet.

RCB-7.53 EXPLOSIVE BONDED TUBE-TO-TUBESHEET JOINTS

Replace the first sentence of this clause by:

Where appropriate, and if approved by the Principal, explosive bonding and/or explosive expanding may be used to attach the tubes to the tubesheets.

RB-7.8 CLAD AND FACED TUBESHEETS

Replace this clause by:

Tubesheets with non-ferrous or alloy cladding for corrosion protection shall meet the following requirements:

1. The cladding shall be integrally and continuously bonded to the base material.
2. All surfaces exposed to the corrosive medium, excluding gasket seating surfaces, shall have at least a 10 mm thickness of cladding if tubes are expanded only (to allow a

groove within the cladding thickness) and at least a 5 mm thickness for a strength-welded connection.

3. Brazing shall not be used to bond the cladding to the tubesheet.
4. Integrally clad tubesheets and tubesheets with cladding applied by overlay welding shall be ultrasonically tested to check the integrity of the bonding in accordance with ASTM A 578, with an acceptance level of S7.

RCB-8 FLEXIBLE SHELL ELEMENTS

Add before first clause:

The use of flexible shell side elements is subject to the approval of the Principal.

Add to this clause:

If specified, the light gauge bellow type expansion joint shall be designed in accordance with the EJMA Standards and BS 6129 on the basis of a minimum of 10 000 cycles before rupture may occur.

Light gauge bellow type joints shall be properly protected against damage during installation and transportation.

Data/requisition sheet DEP 31.27.30.93-Gen. shall be used to specify the joint.

Inspection and testing shall be in accordance with BS 6129 Part 1.

RCB-9 CHANNELS, COVERS AND BONNETS

Add to this clause:

Bonnets shall be of true semi-ellipsoidal shape, ratio 2:1, or Korbbogen. Klöpperboden (torospherical) should not be used.

*RCB-9.13 PASS PARTITION PLATES

Add to this clause:

Drain holes shall be provided in pass partition plates only in very toxic or environmentally harmful services.

RCB-9.132 PASS PARTITION PLATE FORMULA

Add to this clause:

For the pressure drop across the plate, the full pressure drop across the heat exchanger shall be taken.

RCB-9.133 PASS PARTITION WELD SIZE

Add to this clause:

The first 50 mm of the weld from the joint face of the partition plate shall be full penetration.

R-9.135 ALIGNMENT (new clause)

To allow full tightening of the flange bolting the free edge of pass partition plates shall be recessed with 0.2 mm measured from the joint face of the head flange.

RCB-10.1 NOZZLE CONSTRUCTION

Add to this clause:

The selection of gaskets shall be in accordance with the appropriate MF Piping Class or EP Piping Classes (see DEP 31.38.01.12-Gen. or DEP 31.38.01.15-Gen., respectively) applied for the connecting lines.

RCB-10.31 VENT AND DRAIN CONNECTIONS

Add to this clause:

All connections shall be flanged and provided with a blind flange unless otherwise noted on the data/requisition sheets.

The following Table RCB-10.31 shows the minimum size for vent and drain connections on heat exchangers.

TABLE RCB-10.31 MINIMUM VENT AND DRAIN CONNECTION SIZES

Nominal Shell Diameter mm	Minimum vent and drain sizes, DN mm
150-300	40 x 25 (reducer)
350-500	40
Above 500	50

NOTE: If a vent or drain connection will be used as cleaning connection the minimum connection size shall be DN 50.

RC-10.32 PRESSURE GAUGE CONNECTIONS

Replace R-10.32 and C-10.32 by:

If required, pressure gauge connections shall be specified on the data/requisition sheets (DEP 31.22.00.94-Gen.).

There shall be no pressure gauge connections in heat exchanger nozzles, except for direct interconnection nozzles of stacked exchangers.

RB-10.33THERMOMETER CONNECTIONS

Replace RB-10.33 and C-10.33 by:

TEMPERATURE INSTRUMENT CONNECTIONS

If required, temperature instrument connections shall be specified on the data/requisition sheets (DEP 31.22.00.94-Gen.). There shall be no temperature instrument connections in heat exchanger nozzles, except for direct interconnecting nozzles of stacked exchangers.

RC-10.34 CLEANING CONNECTIONS (new clause)

If exchangers will require in-service cleaning with hot water, steam, solvents or other chemical methods, suitable flanged nozzle connections of DN 50 minimum size shall be provided on the shell. There shall be no cleaning connections on exchanger nozzles, but they may be located on the connecting piping.

RC-10.35 SAFETY/RELIEF VALVE CONNECTIONS (new clause)

Flanges for safety/relief valve nozzles shall have a minimum rating of ANS Class 300.

RCB-11 END FLANGES AND BOLTING

Add to this clause:

Nuts shall have a height equal to the bolt diameter.

RCB-11.24 BOLT ORIENTATION

Delete the last sentence from this clause.

SECTION 6 FLOW INDUCED VIBRATION

V-1 SCOPE AND GENERAL

Add to this clause:

The computer programs used for the thermal design of the heat exchangers contain routines to check the likelihood of mechanical and/or acoustic vibrations. The thermal designer should analyse the vibration warnings generated by the program and incorporate the appropriate measures.

V-2.5 ACOUSTIC VIBRATION

Add to this clause:

If a detuning baffle (parallel to the flow) is fitted to change the acoustic frequency, it shall extend at one side of the bundle as far as possible towards the shell wall.

SECTION 7 THERMAL RELATIONS

T-1.1 SCOPE

Add to this clause:

The thermal design and rating of shell and tube heat exchangers shall be based on design methods which have been proven in practice. In this respect, the design procedures and computer programs published by the Heat Transfer Research Institute (HTRI), e.g. ST, CST, and those published by the Heat Transfer & Fluid Flow Service (HTFS), e.g. TASC, are considered proven design methods.

In the event of disagreements about performance, the following HTRI computer programs shall be used as the basis for assessing the thermal performance rating:

1. Shell and Tube Heat Exchanger Program : ST
2. Shell and Tube Condenser Program : CST
3. Kettle Reboil/Horizontal Thermosyphon Program : RKH
4. Axial Flow Reboiler Program : RTF
5. Mean Tubewall Metal Temperature Program : TWL

The applicable versions and/or modifications (if any) shall be agreed between the Principal and the party who performs the thermal design and shall be stated in the applicable Project Specification or BDEP.

The print-out of the computer runs shall correspond to the input data. There shall be no changes or deviations introduced between running the program and printing the results.

Special requirements for the thermal design shall be recorded appropriately and/or shown on scaled drawings or sketches.

T-1.6 DETAILED INSTRUCTIONS TO COMPUTER PROGRAMS (new clause)

The physical properties of the fluid shall be specified by the process design group, in the data/requisition sheet (DEP 31.21.00.93-Gen.). If the data thus provided is considered by the designer or Manufacturer to be insufficient for design purposes, it is his responsibility to request further information from the Principal.

T-1.61 TUBE VIBRATIONS (new sub-clause)

Shell and tube heat exchangers shall be checked for potential tube vibration.

In the event of disagreements about vibration, the HTRI computer program VIB shall be used as a basis for assessing tube vibration.

T-1.62 PRESSURE DROP (new sub-clause)

To allow for increasing pressure drop due to fouling, the pressure drop for the fouled condition shall be obtained by multiplying the pressure drop calculated for the clean condition by the appropriate factor from Table T-1.62 of this DEP. The pressure drop for the fouled condition shall be specified on the data/requisition sheet.

TABLE T-1.62 PRESSURE DROP MULTIPLICATION FACTORS

Fouling resistance $m^2.K/W$	Multiplication factor
0.00009 - 0.00033	1.10
0.00034 - 0.00085	1.20
0.00086 and higher	1.50

In order to design a heat exchanger with a minimum area requirement, the allowable pressure drop on the heat transfer controlling side should be fully utilized.

T-1.63 TUBE LAYOUT/SHELL DIAMETER (new sub-clause)

The Party performing the thermal design shall ensure that the number of tubes resulting

from the computer calculation will fit into the shell.

Data/requisition DEP 30.10.00.94-Gen. shall include the tubesheet layout drawing, on which at least the following shall be indicated:

- tube pattern
- number of tubes per pass
- the provision of impingement protection
- the provision of sliding strips
- the provision of sealing devices
- baffle cut and orientation
- support plates
- tie rods
- drain notch
- nozzles, and
- the main dimensions in millimetres (including actual outer tube limit).

The tubesheet layout drawing shall show at least one half of the tubesheet (if symmetrical to the other half). Otherwise the complete tubesheet layout drawing shall be provided.

The HTFS computer program OPTU ("Windows" version with "Draw" option) should be used.

T-1.64 BAFFLE SPACING OF END COMPARTMENTS (new sub-clause)

Except for divided or split flow, baffles and end supports shall be spaced so that they do not obstruct the shell-side nozzles.

T-1.65 KETTLE-TYPE REBOILERS AND EVAPORATORS (new sub-clause)

The shell diameter depends on the required vapour escape area above the tube bundle. Vapour velocities shall nowhere exceed the maximum vapour velocity defined by the entrainment requirements.

These entrainment requirements shall be specified in the data/requisition sheet (DEP 31.21.00.93-Gen.). The maximum vapour velocity shall then be calculated in accordance with the method described in HTRI Report B-K-1/2.

The design shall take into account that frothing is likely to occur above the liquid level. An allowance of 125 mm shall be made for this frothing. The height of the escape area above the frothing allowance shall be at least 250 mm.

The entry of vapour/liquid mixture shall be above the boiling pool. Provisions shall be made to separate the vapour phase from the liquid phase by using a spider pipe or splash plates. These devices shall be in pair(s) and symmetrically located on both sides of the vertical centreline.

The requirements for spider pipes are as follows:
- they shall be located at the position of lowest vapour generation (lowest delta T);
- the mixed vapour/liquid stream should be directed downwards against the shell wall to promote separation of the liquid and vapour;
- there shall be no holes in the direct path from the inlet nozzle;
- the velocity head in the inlet nozzle shall be maximum 4000 kg/m.s^2;
- the velocity head in the spider header shall be maximum 1000 kg/m.s^2;
- the velocity head in the holes shall be maximum 4000 kg/m.s^2.

If considered necessary, provision shall be made for cleaning the spider.

The requirements for splash plates are as follows:
- the velocity head in the inlet nozzle shall be maximum 4000 kg/m.s^2;
- the velocity head in the splash plate header shall be maximum 1000 kg/m.s^2.

The velocity head in the vapour outlet nozzle shall be maximum 3750 kg/m.s^2.

A vortex breaker, see Standard Drawing S 10.010, shall be provided for the liquid outlet nozzle.

If the liquid level is to be maintained at a fixed height, a weir shall be installed between the

boiling compartment and the rundown compartment to keep the bundle submerged. The top of the weir shall be at least 25 mm above the top of the bundle. Unless required by process considerations, there shall be no drain holes in this weir.

If the liquid level is to be controlled by instrumentation, a calming baffle shall be installed to prevent boiling turbulence from affecting the level instruments.

The liquid space shall be determined by the liquid hold-up requirements.

If no weir or calming plate is installed, it shall be made possible to measure the liquid level in a consistent and adequate way not interfering with the operation of the kettles. Liquid levels required for control, hold-up and entrainment calculation shall be specified.

A distance of at least 50 mm shall be maintained between the bottom of the bundle and the bottom inside diameter of the shell in order not to obstruct liquid re-circulation into the bundle.

T-1.66 TURBULATORS (new sub-clause)

The application of turbulators and/or static mixers requires approval by the Principal.

T-1.67 MASS ESTIMATE (new sub-clause)

The mass derived from the computer output sheets shall be considered only as a first estimate.

SECTION 10 RECOMMENDED GOOD PRACTICE

RECOMMENDED GOOD PRACTICE RGP SECTION

Add to this clause:

For the purpose of this DEP, this section 'Recommended Good Practice' sets out the requirements which shall be considered as additional to the requirements of the corresponding paragraphs in the main sections of the TEMA Standards, whether or not amended by this DEP.

RGP-RCB-2 PLUGGING TUBES IN TUBE BUNDLES

Add to this clause :

If tubes have to be plugged, defective tubes shall be cut and the method agreed with the Principal.

Faulty tubes in hydrogen and/or very toxic service shall not be plugged. Each tube shall be removed and be replaced by two solid rods. The rods shall be welded to the tubesheet and shall fill the holes in the baffle plates.

RGP-RCB-3.13 MINIMUM SHELL THICKNESS

Replace this clause by:

Shell thickness shall be determined by the Pressure Vessel Code design formulae, plus corrosion allowance, but in no case shall the nominal thickness be less than shown in the Table RGP-RCB-3.13. The nominal total thickness for clad plate or lined shells should be the same as for carbon steel plate shells.

RGP-RCB-4.3 TRANSVERSE BAFFLE AND SUPPORT CLEARANCE

Add to this clause:

The clearance given in Table RGP-RCB-4.3 shall only be exceeded if specified on the data/requisition sheets.

RGP-RCB-4.41 TRANSVERSE BAFFLES AND SUPPORT PLATES

Add to this clause:

The minimum thickness shall be not less than twice the specified shell side corrosion allowance.

RGP-RCB-4.71 NUMBER AND SIZE OF TIE RODS

Replace this clause and Table RGP-RCB-4.71 by:

The following Table RGP-RCB-4.71 shows the minimum number of tie rods, the minimum diameter of the solid rod and the spacer pipe OD for various sizes of heat exchanger and tube ODs.

TABLE RGP-RCB-4.71 TIE ROD STANDARDS

Nominal shell diameter		Tube OD of 19.05 mm (3/4 in) and less		Tube OD of 25.4 mm (1 in) and larger		Minimum number of tie rods
		Solid Rod minimum diameter	Spacer Pipe OD (sched 80)	Solid Rod minimum diameter	Spacer Pipe OD (sched 80)	
mm	(inch)	mm	mm	mm	mm	
1538-2540	(61-100)	19	21.34	22	26.67	12

NOTES: 1. The baffles shall be supported by solid rods welded to the baffles or by spacer pipes, keeping the baffles at distance, with supporting rods inside.

2. The screw thread connection of the tie rod in the tubesheet shall have a diameter which is equal to, or slightly smaller than, the diameter of the tie rod.

RGP-RC-4.9MINIMUM SLIDING STRIP SIZE (new clause)

The following Table RGP-RC-4.9 shows the minimum required size of the sliding strips.

TABLE RGP-RC-4.9 MINIMUM SLIDING STRIP SIZE

Nominal Shell Diameter		Sliding strip dimensions (minimum)		
		Height	Thickness	
mm	(inch)	mm	mm	(inch)
1538-2540	(61-100)	75	19.05	(3/4)

RGP-T-2.4 DESIGN FOULING RESISTANCES

Replace this clause by:

Typical fouling resistances, with reference to the surface on which they occur, shall be taken from DEP 20.21.00.31-Gen.

If specific data for setting proper resistances are not covered by the above DEP or are not stated on the data/requisition sheet, the Principal shall be consulted.

PART V REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

DEPs

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Standard forms binder	DEP 00.00.10.05-Gen.
Definition and determination of temperature and pressure levels	DEP 01.00.01.30-Gen.
Fouling resistances for heat transfer equipment	DEP 20.21.00.31-Gen.
Requisitioning binder	DEP 30.10.01.10-Gen.
Cathodic protection	DEP 30.10.73.10-Gen.
Symbols and identification system - Mechanical	DEP 31.10.03.10-Gen.
Selected construction materials for shell and tube heat exchangers	DEP 31.21.01.31-Gen.
Pressure vessels (Amendments/supplements to ASME Section VIII, Division 1 and Division 2)	DEP 31.22.20.31-Gen.
MF Piping classes	DEP 31.38.01.12-Gen.
EP Piping classes	DEP 31.38.01.15-Gen.
Equipment and tools for maintenance and inspection	DEP 70.08.10.11-Gen.
The preservation of old and new equipment and piping standing idle	DEP 70.10.70.11-Gen.
Cleaning of equipment	DEP 70.10.80.11-Gen.
Spare parts for initial and normal operation	DEP 70.10.90.11-Gen.

DATA/REQUISITION SHEETS

General data/requisition sheet	DEP 30.10.00.94-Gen.
Shell and tube heat exchangers	DEP 31.21.00.93-Gen.
Outline drawing for horizontal heat exchanger	DEP 31.21.06.93-Gen.
Outline drawing for hairpin heat exchanger	DEP 31.21.07.93-Gen.
Outline drawing for vertical reboiler with floating head	DEP 31.21.12.93-Gen.
Outline drawing for horizontal cooler with welded channel	DEP 31.21.20.93-Gen.
Outline drawing for horizontal cooler with cast channel	DEP 31.21.20.94-Gen.
Pressure vessels (Columns, reactors accumulators, etc.)	DEP 31.22.00.94-Gen.
Expansion joints	DEP 31.27.30.93-Gen.
EDP supplement	DEP 40.00.10.93-Gen.
Requisition for engineering documents	DEP 40.10.01.93-Gen.

NOTE: Data/requisition sheets are contained in the Requisitioning binder, DEP 30.10.01.10-Gen.

STANDARD FORMS

Heat exchanger summary	DEP 01.00.03.84-Gen
Specification of design and engineering documents	DEP 05.00.50.82-Gen.

Approval drawing specification	DEP 05.00.54.81-Gen.
Final drawing specification	DEP 05.00.54.82-Gen.

NOTE: Standard forms are contained in the Standard forms binder, DEP 00.00.10.05-Gen.

STANDARD DRAWINGS

Vortex breakers	S 10.010
Lifting lug for top covers (material: carbon steel, low alloy steel or stainless steel)	S 10.030
Brackets for standard vertical reboilers. Nom. dia. 350 up/incl. 1100 mm	S 21.017
Saddles for horizontal apparatus. Shell dia. 150 mm OD up to and incl. 1000 mm OD	S 22.001
Saddles for horizontal apparatus. Shell dia. 1050 mm OD up to and incl. 3600 mm OD	S 22.002
Sliding plate for saddles of horizontal apparatus. Shell dia. 350 mm OD up to and incl. 3600 mm OD	S 22.003
Bottom part for reboilers with floating head	
14", 16" and 18" nominal diameter with 100 mm diameter joint	T 832690
20", 24" and 26" nominal diameter with 100 mm diameter joint	T 832691
24", 26", 30", 32" and 36" nominal diameter with 200 mm diameter joint	T 832692
30", 32", 36", 40" and 44" nominal diameter with 300 mm diameter joint	T 832693

AMERICAN STANDARDS

Guide for pressure relief and depressurizing systems	API RP 521
Centrifugal pumps for petroleum, heavy duty chemical, and gas industry services	API 610
General-purpose steam turbines for refinery service	API 611
Special purpose steam turbines for petroleum, chemical and gas industry services	API 612
Special purpose gear units for petroleum, chemical and gas industry services	API 613
Lubrication, shaft-sealing and control-oil system for special-purpose applications	API 614
Gas turbines for refinery services	API 616
Centrifugal compressors for petroleum, chemical and gas service industries	API 617
Reciprocating compressors for petroleum, chemical and gas industry services	API 618
Rotary-type positive displacement compressors for general refinery services	API 619
Air-cooled heat exchangers for general refinery service	API 661
Packaged integrally geared centrifugal air compressors for general refinery service	API 672
Special purpose centrifugal fans for general refinery	API 673

services

Positive displacement pumps - reciprocating	API 674
Positive displacement pumps - controlled volume	API 675
Positive displacement pumps - rotary	API 676
General-purpose gear units for refinery service	API 677
Packaged reciprocating plant and instrument air compressors for general refinery services	API 680

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington, DC 20005, USA.

Metallic Gaskets for Pipe Flanges; ring-joint, spiral-wound and jacketed	ASME B16.20
ASME Boiler and Pressure Vessel Code-Pressure Vessels	ASME Section VIII, Divisions 1 and 2

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017, USA.

Specification for straight-beam ultrasonic examination of plain and clad steel plates for special applications	ASTM A 578
Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength	ASTM A 307

Issued by:
American Society for Testing and Materials
1916 Race Street, Philadelphia, 19103, USA.

Standards of the Expansion Joint Manufacturers Association	EJMA Standards

Issued by:
Expansion Joint Manufacturers Association, Inc.
707 West Chester Avenue
White Plains, New York 10604, USA.

Standard for Steam Surface Condensers	HEI Standard

Issued by:
Heat Exchange Institute
1230 Ceith Building
Cleveland, Ohio 44115, USA.

Standards of the Tubular Exchanger Manufacturers Association	TEMA Standards, Seventh Edition, 1988, including 1990 and 1991 errata

Issued by:
Tubular Exchanger Manufacturers Association, Inc.
331 Madison Avenue, New York,
NY 10017, USA.

Heat transfer calculations for tubular equipment - computer programmes :

1. Shell and Tube Heat Exchanger Program	: ST
2. Shell and Tube Condenser Program	: CST
3. Kettle Reboil/Horizontal thermosyphon Program	: RKH
4. Axial Flow Reboiler Program	: RTF

5. Mean Tubewall Metal Temperature Program : TWL
6. Flow-Induced Vibration Analysis Program : VIB

Issued by:
Heat Transfer Research Inc.
1500 Research Parkway, Suite 100
College Station, Texas, 77842, USA.

BRITISH STANDARDS

Code of practice for the selection and application of bellows expansion joints for use in pressure systems — BS 6129 Part 1

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
United Kingdom.

Heat transfer calculations for tubular equipment - computer programs:
Shell and tube Heat Exchanger Program — TASC
Tube lay-out Program — OPTU

Issued by:
Heat Transfer and Fluid Flow Service
Building 392.7, AEA, Harwell
Didcot, Oxfordshire, OX 11 0RA, UK.

GERMAN STANDARD

Design of metallic components to receive organic coating and linings for use in process engineering — DIN 28051

Issued by:
Deutsches Institut für Normung e.V (DIN)
Deutsches Information Centre for Technical Rules (DITR) and
Beuth Verlag GmbH, Burggrafenstrasse 4-10,
D-1000 Berlin 30, West Germany.

APPENDIX A STANDARD FORMS, REQUISITION AND DATA/REQUISITION SHEETS

The following standard forms from DEP 00.00.10.05-Gen, and requisition and data/requisition sheets from DEP 30.10.01.10-Gen, shall be used for the specification of heat exchangers in conjunction with this DEP, The sheets shall be submitted with the DEPs listed below as appropriate.

Specification of design and engineering documents	DEP 05.00.50.82-Gen.
Approval drawing specification	DEP 05.00.54.81-Gen.
Final drawing specification	DEP 05.00.54.82-Gen.

To be submitted during Detailed Engineering phase (purchasing phase) :

DEP 01.00.03.84-Gen., sheet 1	Heat exchanger summary
DEP 40.00.10.93-Gen., sheets 1 / 2	EDP supplement
DEP 40.10.01.93-Gen.	Requisitioning for engineering documents

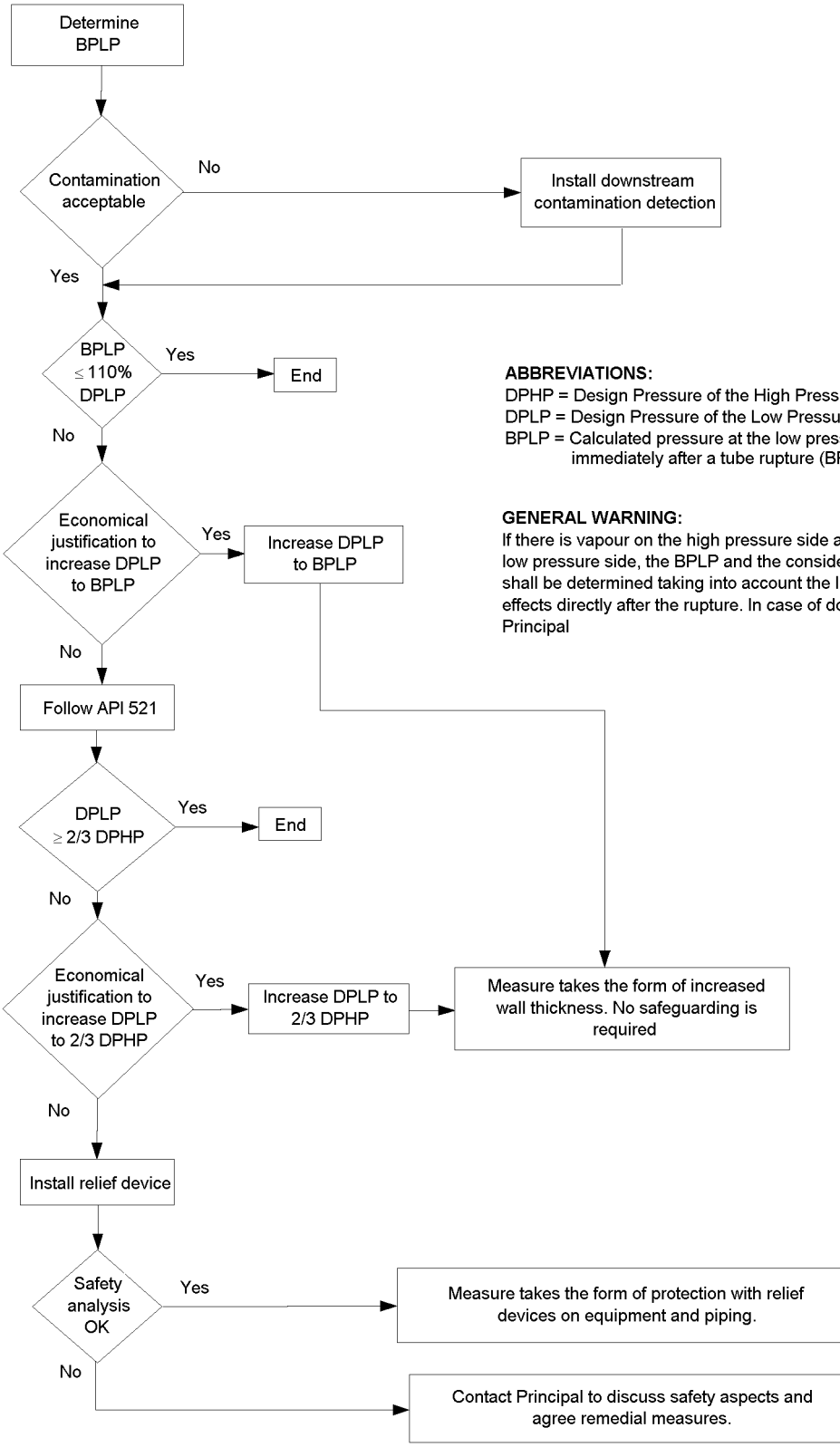
To be submitted during Project Specification phase (design phase) :

DEP 30.10.00.94-Gen., sheet 1	General data/requisition sheet
DEP 31.21.00.93-Gen., sheet 1	Process data
DEP 31.21.00.93-Gen., sheet 5	Mechanical data
DEP 31.21.00.93-Gen., sheet 6	Materials
DEP 30.10.00.94-Gen., sheet 2	Tubesheet lay-out drawing
DEP 31.22.00.94-Gen., sheet 3	Pressure vessels/nozzles

The following sheets may also be used when required :

DEP 31.27.30.93-Gen., sheets 1 / 2	Expansion joints
DEP 30.10.00.94-Gen., sheet 3	Suitable for notes
DEP 30.10.00.94-Gen., sheet 2	Suitable for detailed outline drawing of heat exchanger
DEP 31.21.06.93-Gen.	Outline drawing for horizontal heat exchanger
DEP 31.21.07.93-Gen.	Outline drawing for hairpin heat exchanger
DEP 31.21.12.93-Gen.	Outline drawing for vertical reboiler with floating head
DEP 31.21.20.93-Gen.	Outline drawing for horizontal cooler with welded channel
DEP 31.21.20.94-Gen.	Outline drawing for horizontal cooler with cast channel

APPENDIX B FLOWCHART FOR DESIGN PRESSURE LOW PRESSURE SIDE



ABBREVIATIONS:
DPHP = Design Pressure of the High Pressure side
DPLP = Design Pressure of the Low Pressure side
BPLP = Calculated pressure at the low pressure side immediately after a tube rupture (BPLP ≤ DPHP)

GENERAL WARNING:
If there is vapour on the high pressure side and a liquid on the low pressure side, the BPLP and the considered relief devices shall be determined taking into account the liquid acceleration effects directly after the rupture. In case of doubt, contact the Principal