

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

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

PTS 31.21.01.30

JANUARY 2009



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PTS Circular 2009 - 1	PETRONAS 
PTS No:	PTS 31.21.01.30
Publication Title:	SHELL AND TUBE HEAT EXCHANGERS (AMENDMENTS/SUPPLEMENTS TO ISO 16812)
Base PTS Version:	Release 13; May 2004

This revision of PTS 31.21.01.30, Release 13: May 2004 for SHELL AND TUBE HEAT EXCHANGERS (AMENDMENTS/SUPPLEMENTS TO ISO 16812) has been updated incorporating PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

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Revision History

Date	Version	Description of Updates	Author
05.01.09	Rev. 1	Revised per latest ISO 16812 :2007. Changes marked in italic	Ir. Zaini B Minin

PREFACE

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They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. 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 technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

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

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PART I INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design and construction of shell and tube heat exchangers having a bare tube surface area of greater than 0.5 m². Part V of this PTS has been written in the form of amendments and supplements to ISO 16812.

This PTS is a complete revision of the PTS of the same number dated *May 2004*; a summary of changes is given in (Part I-1.5). This PTS is primarily based on ISO 16812, whereas the previous version was exclusively based on TEMA standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part PETRONAS Group and to Contractors nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants and, where applicable, exploration and production facilities and supply/marketing installations. When PTS are applied, a Management of Change (MOC) process should 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 are more stringent than in this PTS, 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 PTS as closely as possible.

1.3 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 or maintenance 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.

The **Principal** is the party that 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 PTS are made, the referenced section number is shown in brackets.

Other documents referenced by this PTS are listed in Part VI.

1.5 CHANGES FROM PREVIOUS EDITION

The previous edition of this PTS was dated May 2004. The main changes are as follows:

Old section	New Section	Change
-	-	<i>The PTS is based on ISO 16812:2007</i>
Part III - 7	Part III - 7	Add new para : For offshore application where space is limited, the stacked exchangers shall be limited to two.
Part V – 3.12, 3.13	Part V – 3.14, 3.15	Revise clause numbering from 3.12 & 3.13 to 3.14 & 3.15 due to change in standard.
-	Part V – 4.6	Add new clause: Datasheet shall be in accordance with the requisition sheet PTS 40.10.01.93
Part V – 5.1	Part V – 5.1	Delete title – Purchaser Responsibility, due to change in standard.
Part V – 5.2	-	Delete title – Vendor Responsibility, due to change in standard.
Part V – 5.2.3, 5.2.4	Part V- 5.3, 5.4	Revise clause numbering from 5.2.3 & 5.2.4 to 5.3 & 5.3 due to change in standard.
Part V – 7.4.1	-	Delete clause due to change in standard.
Part V – 7.4.3	Part V – 7.4.2	Revise clause numbering from 7.4.3 to 7.4.2 due to change in standard.
Part V – 7.6.3	Part V – 7.6.3	Amend title to “Baffles and Support Plates” due to change in standard.
Part V – 7.7.4	Part V – 7.7.4	Revise clause to “Only forged long weld neck flanges shall be used for DN 40 and below”.
Part V – 7.7.9	Part V – 7.7.8	Revise clause numbering from 7.7.9 to 7.7.8 due to change in standard
Part V – 7.9.4	Part V–7.9.2 c)	Revise clause numbering from 7.9.4 to 7.9.2 c) due to change in standard.
Part V – 7.10.4	Part V – 7.10.5	Revise clause numbering from 7.10.10 to 7.10.11 due to change in standard
Part V – 9.9.4	Part V – 9.9.3	Revise clause numbering from 9.9.4 to 9.9.3 due to change in standard
Part V – 10.3.11	Part V – 10.3.12	Revise clause numbering from 10.3.11 to 10.3.12 due to change in standard
Annex A	Annex C	Revise annexes due to change in standard
Annex D	Annex A	Revise annexes due to change in standard. Also Annex D.2.6 is deleted.

PART II GENERAL INFORMATION AND DEFINITIONS

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 m² shall be based on this PTS.

For clarity and ease of reference, the section, paragraph and clause numbering of ISO 16812 has been followed throughout Part V of this PTS.

Clauses of ISO 16812 which are not referred to in this PTS shall apply as written.

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

1. the purchase order;
2. This PTS;
3. ISO 16812

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

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 PTS shall be used. Data/requisition sheet PTS 31.21.00.93., sheet 1, shall be completed in accordance with the guidelines given on its reverse side.

It shall be stated on the data/requisition sheets PTS 31.21.00.93 to which TEMA class the exchanger is to be designed and fabricated.

TEMA class 'R' shall be specified for all exchangers except that TEMA class 'C' may be selected for pressurized water-cooled seal-oil and lube-oil coolers for rotating equipment.

NOTE: TEMA Class 'R' shall apply even if TEMA class 'B' has been specified (e.g. as sometimes occurs with process licensors).

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 (BPTS) etc., shall be responsible for the thermal design.

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

2. PRESSURE DESIGN CODE

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

Unless otherwise specified, the pressure design code shall be PTS 31.22.20.31.

3. CATHODIC PROTECTION

The requirements for the cathodic protection of heat exchangers using sacrificial anodes, impressed current systems or internal coatings are given in PTS 30.10.73.10.

The 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.

4. UNITS OF MEASUREMENT

The SI unit system has been applied in this PTS 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.

5. END FLANGES

For the purpose of this PTS, end flanges shall include stationary head flanges, shell flanges, shell cover flanges and floating head cover flanges. Bolt count for end flanges shall be a multiple of four and nuts shall have a height at least equal to the bolt diameter.

6. EQUIPMENT NUMBERING

Heat transfer equipment shall be identified by a specific equipment number in accordance with PTS 31.10.03.10.

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

1. SELECTION OF TYPE

The following shall apply 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 may 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 adopted only if required by specific process requirements. U-tubes shall not be used if the fouling resistance exceeds $0.00052 \text{ m}^2.\text{K}/\text{W}$.
 - Tube-side fouling can be removed by chemical cleaning.
- Floating-head heat exchangers should be used in all other services.

2. SHELL SELECTION

TEMA nomenclature (TEMA Figure N-1.2) shall be used for describing the exchanger type.

Shell diameters exceeding 1524 mm shall be subject to the approval of the Principal.

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. However, Type F may be used if:
 - the longitudinal baffle is welded to the shell (maximum allowable shell side pressure drop to be less than 0.7 bar); and
 - for a removable bundle, (maximum allowable shell side pressure drop not to exceed 0.5 bar) the gap between the baffle and the shell is closed with a double-sided, multi-layered clip-on spring set; and
 - on the shell side the difference between the inlet and outlet temperature does not exceed 110°C .
- 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 % to 5 % entrainment) is required or where phase separation is required.

3. TUBE SELECTION

3.1 General

Table 1 below shows the outside tube diameters and minimum required nominal tube wall thickness for bare tubes of copper, carbon steel, aluminium and alloys.

TABLE 1 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. titanium tubes, the minimum wall thickness shall be 18 BWG/SWG, irrespective of whether mechanical cleaning of tubes is required or not.
 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.

3.2 Selection of bare tube diameter

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 where the tube-side medium has a fouling resistance of less than 0.00034 m².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 where the tube-side medium has a fouling resistance of 0.00034 m².K/W or higher.
2. Heat exchangers where it would be economical to use this size 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 inch) 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 these sizes because of process design restraints, e.g. pressure drop limitations.

3.3 Circumferentially-finned tubes

In general, finned tubing shall be used only in clean shell-side service (fouling resistance less than or equal to 0.00018 m².K/W) and non-abrasive services. Tubes shall have no more than 1181 fins per metre (30 fins per inch).

Circumferentially finned tubes shall not be finned at the U-bends.

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 TEMA 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.

Fin height and wall thickness under the fins determine the inside diameter. Wall thickness under the fin and diameter greatly affect the cost of finned tubes. Their minimum values are determined by the cleaning requirements of the tube-side fluid, as well as by the tube material selected.

Mechanical cleaning required	yes	no
Minimum inside tube diameter	15.0 mm	13.0 mm
Minimum wall thickness carbon steel under the fins	2.0 mm	1.6 mm
Minimum wall thickness non-ferrous and stainless steel under the fins (1)	1.6 mm	1.2 mm

Surface cracking at the fin or wall shall not be accepted.

Low finned tubes shall be eddy-current tested at the mill.

(1) Titanium low-finned tubes shall have a minimum bare end wall thickness 16 BWG/SWG so that the minimum thickness under the fins is not less than 0.9 mm – irrespective of tube-side mechanical cleaning requirements.

3.4 Longitudinally-finned tubes

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

3.5 U-tubes

Seamless tubes should 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.

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