



RP 26-1

HEAT EXCHANGE EQUIPMENT

February 1997

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SCOPE AND PURPOSE This Recommended Practice specifies BP's general requirements for the main types of heat exchanger it purchases. It gives guidance on heat exchanger selection, thermal and mechanical design, and materials. The units discussed in detail are: shell-and-tube, air-cooled, plate, plate-fin, diffusion bonded and double-pipe heat exchangers. Guidance is given on the limitations of each and reference is made to relevant standards and BP GS, where these are available.											
AMENDMENTS <table border="1"> <thead> <tr> <th>Amd.</th> <th>Date</th> <th>Pages</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td colspan="4"> </td> </tr> </tbody> </table>				Amd.	Date	Pages	Description				
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This Recommended Practice gives guidance to contractors, operating sites and vendors on the main aspects of heat exchanger selection and design. It covers the types of heat exchanger most commonly purchased by BP and references more detailed specification documents, where these are available. Its value lies in the information it contains.

Application

Text in *italics* is commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

This document has been revised to include comments from BP Chemicals and the contents of GS 126-4 (thermal design of offshore shell and tube exchangers), which is now deleted.

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

1.1.1 This Recommended Practice specifies BP's general requirements for heat exchangers. It provides guidance on heat exchanger selection, thermal and mechanical design, and materials. It gives information on the following types, some of which are further specified in BP GS as shown:

Shell-and-tube - BP Group [GS 126-1](#),
Air-cooled - BP Group [GS 126-2](#),
Plate and frame - BP Group [GS 126-5](#),
Plate-fin, Diffusion bonded and Double-pipe/multi-tubular hairpin.

The requirements are applicable to process heat exchanger equipment in all installations, except where specifically excluded by BP.

1.2 Application of this Recommended Practice

1.2.1 To apply this Recommended Practice to a specific project application, it is necessary for BP or the contractor, or both, to provide a supplementary specification.

2. GENERAL REQUIREMENTS

2.1 Heat exchanger selection

2.1.1 Table 1 gives the typical process design limits for the main types of heat exchangers.

Suitable lower cost alternatives to the shell-and-tube exchanger shall be considered. In particular compact and lighter types of heat exchanger, such as the plate and plate-fin, should be considered for economic reasons.

Heat Exchanger Type	Maximum Pressure bar abs.	Temperature range °C	Materials of construction	Cleaning & maintenance	Size limits per shell m ²
Shell & tube	Shell < 300 Tube < 1400	-25 to 600 *	CS, SS, Ti Exotics	Mechanical & chemical	3000
Air cooled	Tube < 250	tube 20 to 600 *	CS, SS, Ti, Exotics	Mechanical & chemical	500 per bundle
Plate & frame	< 25	-30 to 180	SS, Ti, Exotics Check gaskets	Mechanical & chemical	2200
Plate fin	<100 Al < 200 SS	-200 to 650 *	Al, SS	Chemical only	5000
Diffusion Bonded	< 700	-195 to 700 *	SS,Ti,Inconel	Chemical only	1000
Double pipe	Shell < 300 Tube < 1400	-100 to 600 *	CS, SS, Ti Exotics	Mechanical & Chemical	200
Graphite	< 10	-50 to 165	Check resin compatibility	Mechanical & chemical	300
Spiral	up to 18	-40 to 400	CS, SS, Ti, Exotics	Mechanical & chemical	500
Welded plate	< 60	-50 to 650 *	SS, Exotics, surrounding pressure vessel	Mechanical & chemical	1000

TABLE 1 - HEAT EXCHANGER SELECTION

* temperatures higher than 600°C shall be subject to approval by BP.

SS-Stainless steel CS-Carbon steel Ti-Titanium Al-Aluminium
Exotics include Inconel, Monel, Hastelloy but check with manufacturers data for exotics.

2.1.2 The vendor may use his own standard equipment specification sheets, providing they give all the information required by the relevant exchanger data sheets in BP Group [GS 126-1](#) for shell and tube

exchangers, BP Group [GS 126-2](#) for air cooled exchangers and Appendix C and D of this Recommended Practice for plate-fin and diffusion bonded heat exchangers.

2.2 Design and construction

- * 2.2.1 BP will specify details of the utilities for the site concerned.
- 2.2.2 General requirements for screening and treating cooling water are given in BP Group [RP 60-1](#)
- 2.2.3 Any piping and flanges associated with heat exchange equipment shall be in accordance with BP Group [RP 42-1](#).

Where the materials of interconnecting sea water piping and the mating surfaces of the heat exchanger are dissimilar, either rubber lined couplings, flange insulation kits or sacrificial spools shall be provided if galvanic corrosion could otherwise occur.

- 2.2.4 Pipework to and from heat exchangers shall be provided with connections for the measurement of temperature and pressure in accordance with BP Group [RP 30-2](#).

No thermowell connection shall be located in a pipe of less than NPS 4 (DN 100). For pipe sizes less than NPS 4 (DN 100) the connection shall be flanged

- 2.2.5 Nozzles and shell flange connections with bolting of nominal diameter 25 mm (1 in.) and over shall have sufficient clearance and access to allow the use of hydraulic tensioning equipment.

Nominal Bolt Diameter	Condition
50 mm (2 in.) and over	All joints
38 mm (1 1/2 in.) and over	(a) Class 600 and over (b) Hydrogen service
25 mm (1 in.) and over	(a) Joints subject to high temperatures or cyclic duties (b) Joints with leakage history (c) Joints where high accuracy of bolt load is required

TABLE 2 - DESIGNS REQUIRING BOLT TENSIONING

Stud bolts and nuts shall be designed to suit the chosen bolt tensioner. Excess thread should be protected by an additional nut or thread protector.

- 2.2.6 For any group of exchangers, the units shall be designed to permit, wherever practical, interchangeability of components.

2.3 Guarantees

The vendor responsible for the thermal design shall also guarantee the thermal performance of the unit. A vibration analysis shall be an integral part of the thermal guarantee.

The vendor responsible for the mechanical design shall provide appropriate guarantees.

3. SHELL-AND-TUBE HEAT EXCHANGERS

3.1 General

- 3.1.1 Shell-and-tube heat exchangers shall be mechanically designed and fabricated in accordance with BP [GS 126-1](#). Specific designs are classified to [TEMA](#) standard Figure N-1.2.

- 3.1.2 The design pressure shall be the highest pressure expected in the system plus a safety margin. If vacuum conditions can exist in the unit, it shall be designed for full vacuum.

- 3.1.3 Where a shell might be over-pressured in the event of a burst tube, a review of the need for over-pressure protection shall be carried out in accordance with BP Group [RP 44-1](#).

In some cases increasing the design pressure of the shell might be preferable to providing a relief system.

- 3.1.4 Provision shall be made in designs for any abnormal conditions, e.g. start-up, failure of steam desuperheater, by-passing of upstream banks, steam out and water boil.

3.2 Selection of TEMA type

The type of shell-and-tube exchanger chosen depends on: thermal design, the need to clean the tubes internally or externally, maintenance, materials, fabrication and cost.

- 3.2.1 Where the shellside fluid is clean and no mechanical cleaning of the shell side is required, a fixed tubesheet exchanger may be used.

- 3.2.2 Where the shellside requires mechanical cleaning but the tubeside does not, a U-tube bundle may be used.

3.2.3 If both sides of the exchanger need to be mechanically cleaned, a type S floating rear head would normally be specified. For situations where frequent shellside cleaning is required (severe fouling conditions) a type T rear head may be selected.

3.2.4 Special requirements for reboilers are given in 3.5 below.

3.3 Materials of construction

3.3.1 Material grades for shell and tube heat exchangers are tabled in BP [GS 126-1](#)

BP [GS 146-2](#) contains Appendices with BP requirements for fabrication in different materials. It also provides guidance on material requirements where the design temperature is below 0°C (32°F).

3.3.2 Materials for use in sour water service shall comply with BP [GS 136-1](#).

3.3.3 For water-cooled exchangers with water on the tube side, the following applies.

If the cooling water is treated so as to be non-corrosive to carbon steel, carbon steel tubes and tubesheets should be considered.

If cooling water is not treated as above, the following materials should be considered for the tubes, subject to their compatibility with the process side fluids:

- (a) Admiralty brass with fresh and recirculated fresh cooling water.
- (b) Aluminium brass with sea water and other corrosive waters. 90-10 Cu-Ni and 70-30 Cu-Ni may be used as alternatives.
- (c) Titanium for use with sea water and other corrosive waters.
- (d) With austenitic stainless steel, chloride stress corrosion cracking can occur. To avoid such cracking, the cooling water should be low chloride and the tube wall temperature less than 50°C. Type 316 gives the best resistance of the standard materials.
- (e) Standard duplex stainless steel gives better resistance to chloride stress corrosion cracking (than austenitic s.s.) but grade 2205 can pit in high chloride environments.
- (f) High alloy duplex stainless steel (e.g. grade 2507) and high molybdenum stainless steel may be used for seawater and other

corrosive waters. In their selection, account should be taken of the maximum temperature and the use of chlorination.

- (g) Header materials shall be compatible with the tubes. Linings of the headers may be considered. Cathodic protection by sacrificial anodes (see BP Group [GS 126-1](#)) shall be provided where necessary.

3.3.4 If the use of salt water or other aggressive water on the shell side of an exchanger is unavoidable, the shell shall be of corrosion-resistant material. Materials for the tube bundle and shell shall be selected to ensure galvanic compatibility.

3.3.3 On high pressure hydrogen service, seamless tubes shall be used.

For duties where corrosive attack could occur, seamless or longitudinally welded (seamed) tubes will be as specified by BP

3.4 Thermal design

3.4.1 Where possible, thermal design shall be performed using either [HTFS](#) or [HTRI](#) methods and software. Other software may only be used with BP approval.

3.4.2 Exchangers are normally specified with a bonnet type, [TEMA](#) type B head at the front end head and a type M head at the rear but exceptions are:

(a) To provide better access for tube cleaning, a type A may be specified for the front end. In that case, for fixed tubesheet heat exchangers, a type L head should be used at the rear.

(b) Exchangers with type D special high pressure closures.

3.4.3 Exchangers would normally be specified with a type E shell. However, in some cases shell types G, H, J or X may be a more suitable configuration, a typical case being a design requiring a very low shell side pressure drop.

For kettle (type K) reboilers and chillers (i.e. a kettle-type shell with no weir), with clean tubeside fluids but requiring removable bundles for inspection and access to shell side, U-tube bundles with a type B stationary head should normally be used.

If [TEMA](#) type F shells are proposed, they shall be subject to approval by BP. Typically they should only be used for relatively low fouling duties (i.e. fouling resistance less than $0.00088 \text{ (m}^2 \text{ }^\circ\text{C)/W}$ ($0.005 \text{ ((ft}^2 \text{ h$

°F)/Btu), and duties that would not normally require cleaning between shutdowns.

If an F shell is proposed specific measures should be taken to avoid fluid leakage past the longitudinal baffle. Flexible sealing devices are often used, but these are difficult to maintain. Any flexible sealing system should be replaced every time the bundle is removed. A better system is to cover the bundle in a shroud but this makes the construction more complex and hence expensive.

- 3.4.4 In general plain 19mm outside diameter (o.d.) tubes are preferred. Minimum thickness are shown in Table 3.

Tube Material	Minimum Thickness	
	mm (in)	BWG
Carbon steel	2.11 (0.083)	14
Low/Medium alloy Steels	2.11 (0.083)	14
Aluminium brass	2.11 (0.083)	14
Aluminium bronze	2.11 (0.083)	14
Aluminium	2.11 (0.083)	14
Austenitic stainless steels	1.65 (0.065)	16
Ni-Fe-Cr alloys	1.65 (0.065)	16
Admiralty brass	1.65 (0.065)	16
Cupro-Nickels	1.65 (0.065)	16
Copper	1.65 (0.065)	16
Monel/Zirconium/Hastelloy	1.22 (0.048)	18
Titanium	0.89 (0.035)	20

TABLE 3 - MINIMUM TUBE WALL THICKNESS

For other materials, thicknesses will be specified by BP.

Larger diameter tubes are preferred for fouling services (e.g. slurry oil).

Smaller diameter tubes may be used, when the tube side fluid has a low fouling tendency and there are significant economic benefits.

- 3.4.5 Low fin tubing should be considered when the shellside fluid heat transfer coefficient (including the fouling resistance) is less than half the tubeside coefficient on the same basis.

Enhanced boiling surfaces (high flux tube) may be proposed for non-fouling applications, such as refrigeration systems and some light hydrocarbon services (e.g. C4 splitter reboiler, toluene column reboiler etc.)

Devices to enhance the tube side heat transfer coefficient may also be used if the tubeside thermal resistance is controlling (e.g. tube inserts, internal fins)

- 3.4.6 When the shellside requires mechanical cleaning, the tubes should be laid out on a square pitch. If the tubes can be cleaned by water flushing or chemical means, a triangular pitch should be used.

For fixed tubesheet exchangers, tubes should be on a triangular pitch.

The minimum tube pitch/diameter ratio shall be 1.2 and the maximum 2.0, with a preferred range of 1.25 - 1.4.

- 3.4.7 For most applications, an even number of tube passes should be proposed, but single pass exchangers may be used for some duties, e.g. units that require pure counterflow.

In general single tube pass exchangers will be fixed tubesheet designs, but sometimes floating head designs are necessary. An even number of passes is usually chosen because it simplifies pipework design.

- 3.4.8 Tube lengths should preferably be one of the following, the longer being preferred, except where otherwise required for process reasons (e.g. vertical reboilers) The preferred tube lengths are:

2500, 3000, 3500, 5000 and 6000 mm.

Different tube lengths are permissible if they result in a more economical unit, and the plot requirements have not been exceeded.

Longer tube lengths are preferred because this reduces the cost of the exchanger for a given area.

- 3.4.9 For all cooling water applications, design operating velocities in tubes should be kept within the limits shown in Table 4.

Tube Material	Velocity limit m/s (ft/s)	
	Min.	Max.
Admiralty Brass	0.9 (3.0)	1.5 (5.0)
Aluminium or Copper	0.9 (3.0)	1.5 (5.0)
Aluminium Brass	0.9 (3.0)	2.4 (8.0)
Aluminium Bronze	0.9 (3.0)	3.0 (10.0)
Cupro-Nickel 70/30	0.9 (3.0)	3.0 (10.0)
Cupro-Nickel 90/10	0.9 (3.0)	2.4 (8.0)
Titanium	0.9 (3.0)	4.5 (15.0)
Monel	0.9 (3.0)	3.7 (12.0)
Austenitic Stainless Steel	0.9 (3.0)	4.6 (15.0)
Ni-Fe-Cr Alloys	0.9 (3.0)	4.6 (15.0)
Carbon steel with an organic protective lining	0.9 (3.0)	2.1 (7.0)
Carbon Steel	0.9 (3.0)	2.1 (7.0)

TABLE 4 - FLUID VELOCITY LIMITS WITH DIFFERENT TUBE MATERIALS

Design velocities for tube materials not included in the above table shall be specified by BP.

If the water contains suspended solids, the maximum velocity shall be 80% of the limits given above.

When cooling water has to be placed on the shellside of a baffled exchanger the cross flow velocity should be at least 0.7 m/s (2.3 ft/s). Large baffle pitches and baffle cuts should be avoided.

Designs based on higher water velocities may be proposed.

Minimum velocities are specified to help prevent excessive fouling and maximum velocities to reduce tube erosion.

If the cooling water flow is restricted to control the process stream temperature great care is required. Typically restricting the flow will reduce the velocity and increase the water outlet temperature, this can lead to accelerated fouling. In these circumstances consideration should be given to providing a bypass on the process side.

- 3.4.10 For offshore applications, the maximum temperature of the cooling water shall be limited to 50°C unless otherwise specified by BP.
- 3.4.11 With oil as a heating medium, the minimum tubeside velocity should be 0.9 m/s (3.0 ft/s). For slurry oil service, the velocity range should be 1.4 to 2.1 m/s (4.5 to 7.0 ft/s) within the constraints of the allowable pressure drop.

- 3.4.12 Baffles should be of the single or double segmental type. The baffle cut should be vertical for horizontal condensers and reboilers, and horizontal for single phase exchangers. For vertical exchangers, the baffle cut should be perpendicular to the nozzle centreline.

For heat exchangers with segmental baffles, the inlet, outlet and central baffle spacing should be restricted to less than 40% of the unsupported spans given in [TEMA](#) Table R-4.52, but for a No-Tube-In-Window (NTIW) design it is acceptable to have double this span.

U- tube bundles may require additional lacing of the U bends.

NTIW segmental baffles with intermediate supports provide good resistance to vibration but a Rod Baffle design may give a more economic solution.

- 3.4.13 Impingement protection should be provided according to [TEMA](#) RCB-4.6. Impingement plates are preferred but, where vibration is probable, rods should be used instead of plates.

Distribution belts should only be used when absolutely necessary because of their cost.

- 3.4.14 Sealing devices are not required if the shell side flow is axial.

Sealing devices should be considered when the radial clearance between the outermost tubes and the shell exceeds 19 mm. The number of devices shall be the greater of one pair per eight rows of tubes in the baffle overlap area, or two pairs coinciding with the baffle tips.

Sealing devices should be considered on the shell side of the bundle to block the pass partition lanes, the gap in U-tube bundles or other by-pass areas that are parallel to the direction of flow (see Figure 1).

- 3.4.15 All exchangers shall be free of damaging vibration. [HTFS](#) or [HTRI](#) software shall be used for vibration analysis unless otherwise agreed with BP.

- 3.4.16 Fouling resistances shall be specified by BP. In the absence of plant data or experience, [TEMA](#) (Section 10 RGP-T-2.4) fouling resistances should be used.

It is important to note that incorrect specification can lead to expensive heat exchangers that are not without operational problems.

- 3.4.17 Condensers/Steam Heaters

All condensers shall be fitted with inert gas vents. These should preferably be located just above the condensate level at the cold end of the shell.

3.5 **Reboilers**

For new process duties, the financial benefits of using different reboiler designs shall be considered (i.e. kettle, vertical and horizontal thermosiphons). Kettle reboilers should not be used to boil fluids with high fouling rates.

To reduce the risks of unstable operation, the maximum allowable vaporisation rate for natural circulation reboilers shall be limited to 30% weight for vertical and 50% weight for horizontal units.

For vertical thermosiphon units the mist flow regime should be avoided, and for fouling duties the vaporisation rate should be restricted to below 20% weight.

Horizontal thermosiphon designs should be based on an annular flow regime in the outlet pipework to prevent liquid separation.

The control response of all thermosiphon reboiler designs shall be checked over the entire operational range from the clean to the dirty condition. The inlet feed pipework to the reboiler should include a spool piece so that a valve can be installed, if necessary, at a later date to control the circulation rate.

Residence time for kettle reboilers shall be as specified in BP Group [RP 46-1](#), and an appropriate liquid surge section arrangement provided.

3.6 **Mechanical design**

3.6.1 The type of tube/tubesheet joint will be specified by BP.

BP GS 118-8 states BP requirements on tube end welding. BS 5500 contains a detailed Appendix T on tube end welding.

3.6.2 Tubesheets in fixed tubesheet exchangers shall be designed for the design cases given in Appendix E of this GS. All possible operating, failure and test conditions shall be taken into account during design.

The metal temperatures required for tubesheet mechanical design should preferably be obtained by using HTRI or HTFS software.

It is important to consider the exchanger in both the clean and fouled condition when assessing metal temperatures.

- 3.6.3 Bellows (in the shell of a fixed tubesheet exchanger or on the outlet of the floating head in a floating head heat exchanger) may be used to accommodate high differential thermal expansion but the design shall be subject to BP approval.
- 3.6.4 For heat exchangers that may be subject to severe tubeside fouling, the pass partition plate(s) shall be capable of withstanding, without permanent damage, a differential pressure calculated by taking into account the fouling layer thickness when determining the tubeside pressure drop.
- 3.6.5 All shell and tube exchangers shall be arranged so that they can be dismantled for cleaning and maintenance. The spacing between exchanger shells shall be adequate to allow sufficient unobstructed clearance for bundle withdrawal equipment, if required, and to permit access for shell flange gasket renewal.

BP sites normally have pulling and lifting equipment capable of handling bundles up to 15 tonnes weight. Where a contractor considers that heavier exchangers would be economical, his proposal shall be subject to approval by BP. In such cases special pulling and handling equipment shall be supplied by the contractor, and the structure supporting such bundles shall be designed to withstand the reaction forces incurred. Provision shall be made (where appropriate) for the removal of bundles from vertical exchangers, irrespective of weight.

4. AIR-COOLED HEAT EXCHANGERS

4.1 General Requirements

Air-cooled heat exchangers shall be generally in accordance with BP [GS 126-2](#). Reference shall also be made to BP Group [RP 4-4](#) for structural requirements, BP Group [RP 12-11](#) for electric motors and BP Group [RP 12-1](#) for electrical systems.

Unless otherwise agreed with BP, thermal design shall be performed using only [HTRI](#) or [HTFS](#) methods and software.

4.2 Materials of Construction

- 4.2.1 For high pressure air cooled heat exchangers on hydrogen service or other onerous duties tubes shall be seamless.



4.2.2 Where materials other than ferrous alloys are required for process side corrosion resistance, and such materials are incompatible with aluminium fins, either of the following may be used:

- (a) Bimetallic tubes or fins of compatible material.
- (b) Fins of L-shaped aluminium, provided that there is complete coverage of the tube.

4.2.3 The proposed finned tube construction shall be subject to approval by BP. The maximum material design temperatures for the main fin types shall be as follows:

Fin Type	Design Temperature °C (°F)
Embedded (G-fin)	400 C (752 F)
Integral	288 C (550 F)
Fins extruded from aluminium sheath	250 C (482 F)
Knurled overlapped footed	180 C (356 F)
Footed (L-shaped)	120 C (248 F)
Overlapped footed (L shaped)	120 C (248 F)

Other forms of finning or bonded construction together with temperature limitations, shall be submitted for approval by BP.

4.3 Thermal Design

4.3.1 Fouling resistances shall be specified by BP. In the absence of plant data or experience, [TEMA](#) (Section 10 RGP-T-2.4) fouling resistances should be used.

4.3.2 For air cooler applications, where very hot streams are cooled prior to storage or where there is a maximum allowable cooling rate (e.g. due to hydrate formation, the vendor shall determine the exchanger heat load under natural draft conditions.

4.3.3 Tubes

4.3.3.1 The recommended minimum bare tube size before finning is 25.4 mm o.d.. Use of any other size shall be subject to approval by BP.

4.3.3.2 Straight tube lengths should preferably be 9.2m, 12.2m or 15.2m. If required by a specific design, the use of other lengths may be proposed for approval by BP.

4.3.3.3 The wall thickness under any grooving or U bends after bending, for tubes or 25.4 mm o.d. shall not be less than the following:

Tube material	Wall thickness mm (in)
Carbon steel or ferritic low alloy steel (up to 9% chromium)	2.64 (0.104)
High-alloy ferritic steel (11/18% chromium)	2.23 (0.089)
Austenitic stainless steel	1.65 (0.065)
Copper alloys other than cupro-nickel	2.11 (0.083)
Titanium	1.24(0.049)
Cupro-nickel and nickel-copper alloy (alloy 400)	1.82 (0.072)
Incoly 800	1.65 (0.065)
Nickel-iron-chromium-molybdenum- copper alloy (alloy 825)	1.65 (0.065)

Where the use of tubes other than 25.4 mm o.d. is used, the wall thickness shall be subject to approval by BP.

- 4.3.3.4 For viscous process stream (e.g. oil coolers) the benefits of using tube inserts to increase the inside heat transfer coefficient and hence reduce the size of the exchanger should be considered.
- 4.3.3.5 Fins serrated on the outside edge shall not be used. Bare tubes are acceptable for process designs that require close control of the tube wall temperature.
- 4.3.4 Tube Velocity
- 4.3.4.1 Design velocities in the tubes shall be proposed by the vendor for approval by BP.
- 4.3.4.2 The maximum allowable tube-inlet design velocity for gas streams containing no liquid or solid shall be 30 m/s (98 ft/s). If the stream contains particles a velocity not exceeding 20 m/s (65.6 ft/s) shall be used. the vendor shall ensure that the velocity used does not lead to erosion of the header bores, tubes or tube end welds.
- 4.3.5 Tube Bundle
- 4.3.5.1 Bundles should be made up from straight tubes with a plug-type header at each end with the following exceptions:
- (a) For clean duties, U-tubes may be used.

- (b) For equipment operating at pressures above 50 barg (750 psig) on hydrogen, or where hydrogen sulphide is present, welded manifold headers may be used.

4.3.5.2 Multi-pass air cooler designs are preferred for duties with a wide condensing range (50°C). For straight tube bundles on multi-component condensing duties, only the first tube pass shall have more than 1 row of tubes. Single pass exchanger designs that have been checked for process flow distribution may be proposed, but are subject to approval by BP.

4.5.5.3 When heating coils are provided for protection against freeze-up, they shall be in a separate bundle, and not part of the process tube bundle.

4.3.5.4 Tube bundles shall not exceed 10 tonnes in weight unless approved by BP.

4.4 Air Side Design

4.4.1 Air-cooled heat exchangers shall be designed for both summer and winter conditions.

The summer design air temperature shall be the maximum of the dry bulb temperature which is equalled or exceeded in 1% of the hourly readings for the year, or the dry bulb temperature which is exceeded in 5% of the maximum daily readings for the year.

4.4.2 For operation at low air temperatures, provision shall be made, either in the process design or equipment design, to prevent overcooling.

The inside tube wall temperature shall be a minimum of 10°C (18°F) above the pour point of the process fluid. This condition shall be satisfied for the lowest part-load design case with the air entering at winter design temperature. The provision of counter or parallel flow piping arrangements, heating coils, or air recirculation may be necessary to achieve this.

In cases where the process fluid may solidify or become highly viscous when flow is interrupted, the purchaser shall specify the method of heating and control for use when starting-up and shutting-down. Steam heating is preferred. The use of electric heaters will require special precautions in hazardous areas.

4.4.3 Forced draught fans are preferred but induced draught type should be considered for the following situations:

- i) Where temperature control of the process stream is critical and sudden downpours of rain (i.e. excessive cooling) would cause operating problems.
- ii) To minimise the risk of hot air recirculation, especially for large installations and for services requiring a close approach of outlet process temperature to inlet air temperature.
- iii) On sites where air side fouling is a significant problem, requiring bundles to be washed.
- iv) To provide better thermal performance due to the stack effect in the event of fan failure.
- v) In hot climates, where the fan plenum chamber will shield the bundle from the sun.

4.4.4 Automatically controlled variable pitch fans or variable speed fan drives shall be specified in preference to louvers when the additional cost can be economically justified in terms of better control and lower fan power consumption.

When the unit is served by a number of fans, only that number of fans needed for control are required to have blades of the automatically adjustable type.

4.4.5 Common fans cooling more than one process duty should not be used except when close control of the cooling duties is not required.

4.5 Fan Design

4.5.1 Two or more fans aligned in the direction of tube length shall be provided for each bay. All fans in a bay shall be arranged for independent operation.

4.5.2 Specific attention shall be given to the additional cost and associated benefits of installing fan tip seals and centre hub discs to improve the fan efficiency.

4.5.3 Motors shall be sized for cold start-up under winter design conditions with fan blades set to deliver the required air movement at summer design air temperature without exceeding the motor current rating.

The size of steam turbine drives should be similarly determined.

4.5.4 Fan drivers should be capable of producing the required air flow-rate even when the outside of the tubes are dirty. The fan and motor shall

be sized so that the design air flowrate can be maintained when there is a uniform fouling layer thickness on the tubes and fins of 0.13 mm (0.005 in).

One of the main reasons for poor performance of air cooled heat exchangers is a reduced airside flowrate. Over a period of time the performance may degenerate significantly. The flowrate is often 20% or more below the design intent. Regular maintenance and cleaning of the airside is recommended to prevent such a deterioration.

4.6 Location

4.6.1 Air-cooled heat exchangers shall be located to ensure the emitted hot air is not a hazard or an inconvenience to personnel, nor adversely affects the operation of adjacent equipment.

4.6.2 Air-cooled heat exchangers shall be 21 m (70 ft) minimum horizontally from fired heaters to minimise the possibility of the circulation of hot air.

4.6.3 The height of the fan inlets (for forced draught units) or the underside of the bundle (for induced draught units) shall be at least one fan diameter above the nearest solid horizontal obstruction to air flow.

Air coolers of different fan intake elevations shall not be located adjacent to one another.

4.6.4 Air-cooled heat exchangers shall preferably be located above piperacks for space-saving and use of a common structure.

4.6.5 Air-cooled heat exchangers shall not be located above pumps handling volatile fluids or fluids above their auto-ignition temperature.

4.7 Mechanical Design

4.7.1 Where the fluid temperature differential between inlet and outlet is greater than 93°C (167°F), split headers or U-tube construction shall be considered in order to prevent excess warpage of the tubes and tube sheet. The tube bundle construction shall be such as to prevent sagging or snaking of tubes, or both.

Differential expansion between tube rows shall be checked for excessive stresses and distortion on all units.

4.7.2 Cover-plate type headers shall be used only on fouling duties and at pressures less than 10 barg (150 psig).

- 4.7.3 Piping on a mixed phase duty shall be arranged symmetrically in order to provide an even distribution to the header.
- 4.7.4 Platforms shall be provided for access to each header, each louver and mechanism (if any), each motor, and for the lubrication of all bearings. Where economical, access to motors and lubrication points may be made by installing a rolling platform.
- 4.7.5 Access for mobile lifting equipment shall be provided unless the need for compact layout makes this impracticable. In the later case, permanent maintenance handling facilities may be specified by BP.
- 4.7.6 To prevent the finned tubes being damaged during maintenance periods, all forced draught air coolers shall be fitted with protective mesh screens above the tube bundles.
- 4.7.7 Fan driver control stations and louvre operating controls at grade shall be located remote from hot oil pumps.
- The requirements for motor driver control stations are covered in BP Group [RP 12-7](#). The same requirements shall apply to any louvre-operating controls at grade level.
- 4.7.8 Consideration should be given to providing remote isolation of fans.
- 4.7.9 Vibration trips on fans and motors should be considered.

5. PLATE AND FRAME HEAT EXCHANGERS

5.1 General Requirements

- 5.1.1 BP Group [GS 126-5](#) should be used as a basis for specification.

5.2 Fluid Systems

- 5.2.1 In most cases the fluids should be single phase liquids.

Condensing and vaporising duties shall only be undertaken with BP approval.

Plate and frame exchangers are rarely used for vaporising duties, it is usually better to heat the liquid phase under pressure and then flash to produce the required vapour. The use of plate and frames for condensing duties, particularly steam, is becoming more widespread.

- 5.2.2 When specifying a plate and frame heat exchanger, the hazard resulting from fluid leakage shall be considered.



5.3 Plate Pass Arrangements

- 5.3.1 Whenever the thermal duty permits, single pass, counterflow types are preferred. All port connections shall be on one side of the plate pack (the fixed head plate) wherever possible.

Having all connections on the fixed head plate permits the unit to be dismantled without affecting the pipework. Very occasionally, usually for multi-pass units, it is necessary to have two connections on the fixed head plate and two on the floating head plate.

- 5.3.2 Usually only two streams are allowed, proposals for more than two streams are subject to BP approval.

In some rare circumstances there may be considerable economic benefits for having more than two streams in a single exchanger.

5.4 Flow Velocity/Pressure Drop Limits

- 5.4.1 The maximum pressure drop through the inlet and outlet ports should not exceed 10% of the allowable unit pressure drop.

5.5 Fouling Resistance

- 5.5.1 Fouling resistances will be specified by BP. Alternatively a percent excess area may be specified.

Fouling resistances are typically much lower in plate and frame exchangers than in shell and tube exchangers. If no reliable data are available it is recommended that a percent excess area be specified, a typical minimum value being 10%.

5.6 Mechanical Design

- 5.6.1 Gaskets shall be securely located at the plate edges and around the ports. The corner ports carrying a different process or service stream from that on the plate shall incorporate double gaskets with the space between the gaskets vented directly to atmosphere. Any gasket support bars not intended to hold pressure shall be open to atmosphere.

- 5.6.2 Each plate shall be stamped with the exchanger item number in addition to the code number to indicate identification of plate material and its position in the plate pack.

- 5.6.3 The plate shall be designed such that each stream can operate at the full design temperature and pressure with no pressure on the other stream.

- 5.6.4 If the process fluids handled in the exchanger are corrosive to the exchanger frame or foundations, drip trays in corrosion-resistant

material connected to the appropriate drainage system shall be provided. The plate pack compression bolts shall be in corrosion-resistant material and the proposed protection of the plate frame shall be submitted for approval by BP.

5.6.5 If any of the fluids handled in the exchanger are potentially hazardous, or could injure personnel or damage surrounding equipment in the event of gasket failure, the plate pack shall be enclosed on the top and sides by removable covers.

5.6.6 Frames shall not be plated to more than 90% of the maximum frame capacity unless approved by BP.

5.7 Materials

5.7.1 Materials for the plates will be specified by BP.

Carbon steel is not a suitable plate material.

5.7.2 Materials for plate gaskets shall be specified by the Vendor and shall be suitable for the service based on proven field experience. Plate gasket materials shall be subject to approval by BP.

5.8 Inspection and Testing

5.8.1 The exchanger shall be opened for inspection of the plates and the gaskets, to check the number of plates and the order of the plates against the manufacturer's plateage specifications and drawings.

5.8.2 After reassembly, the compressed plate pack dimension shall be checked and agreed with the manufacturer.

5.8.3 All exchangers shall be hydrostatically tested in accordance with the design code.

5.8.4 After testing, a band approximately 50 mm (2 in) wide shall be painted diagonally across the edges of the plate pack in order to ensure correct assembly during subsequent maintenance. Marking paint shall not contain materials (e.g. chlorides) which are incompatible with the materials of construction.

5.8.5 A random 10% of the plates shall be crack detected by applying fluorescent dye penetrant ink to one side of the plate, leaving to soak for a minimum of six hours, then examining the opposite side under ultra violet light. In the event of failures being found, the 10% shall be increased to 100% at the discretion of the purchaser's inspector.



6. PLATE-FIN HEAT EXCHANGERS

6.1 General Requirements

- 6.1.1 The use of plate-fin exchangers (PFHE) is subject to approval by BP.
- 6.1.2 In the absence of a BP Group Specification this section specifies BP's minimum requirements and sets out the principles used to thermally and mechanically design PFHE's. Reference should also be made to the HTFS Guide to the Specification and Use of Plate-Fin Heat Exchangers
- 6.1.3 A process data sheet for a PFHE is given in Appendix C. The purchaser should complete items 1 to 20 DATA FOR ONE TRAIN on the top part of the data sheet, and the vendor should complete items 21 to 45 DESIGN OF ONE TRAIN as appropriate, some items may be pre-specified by the purchaser.

Note that each stream can have an independent design pressure and temperature.

- 6.1.4 The purchaser shall specify all applicable physical properties, for each stream. This should include a heat release curve for multiphase streams (Appendix C).
- 6.1.5 The purchaser should specify his requirements for connection sizes, their type and orientation. Exchanger support and packaging requirements should also be defined.
- 6.1.6 If any alternative design cases have to be met by the PFHE, for example, turndown conditions or any other special operating conditions, the purchaser shall specify them in sufficient detail for the vendor to include in his performance guarantee.

6.2 Design Constraints

6.2.1 Materials

PFHE's are normally only made from aluminium or stainless steel.

The mechanical strength of aluminium falls rapidly as the design temperature increases. It is usually only used in PFHE's at sub-ambient temperatures.

6.2.2 Flow Arrangements

The cheaper cross-flow arrangement should be used if possible, but a counterflow arrangement may be proposed where necessary (e.g. for close temperature approaches).

6.2.3 Type of Fin Corrugation



The type of fin corrugations are generally selected by the manufacturer.

6.2.4 Fouling

PFHE's shall not be specified for fouling services.

Where liquid entrained in the vapour feed could cause freeze fouling a high efficiency separator shall be installed upstream of the exchanger.

Cooling water streams, and other streams that may contain particles, should be screened to at least half the smallest passage dimension.

6.2.5 Distributors

All distributors shall be designed to ensure that the fluid entering each layer is distributed uniformly across the full width of the heat transfer section.

For mixed liquid and vapour process streams, a separator shall be placed upstream of the PFHE, and the liquid and vapour shall be introduced through separate distributors.

6.2.6 Flow Distribution Between Fin Channels

The flow length of each channel from inlet to outlet should be the same to give similar pressure gradients and hence similar flowrates along each channel.

6.2.7 Thermal Transients

If any of the process streams can have temperature changes at a rate greater than 3°C/minute, the vendor shall be informed of the maximum rate, and the frequency of the occurrence. The vendor shall carry out a detailed stress analysis to ensure the stresses are acceptable, and shall inform the purchase of the expected fatigue life.

6.2.8 Corrosion

If the exchanger is constructed in aluminium, and is likely to be in a corrosive atmosphere (e.g. sea spray), the exchanger should be protected from the environment, or the outer plates shall be thickened to allow for the pitting that may occur.

7. DIFFUSION BONDED HEAT EXCHANGERS

7.1 General Requirements

7.1.1 The use of a diffusion bonded heat exchanger (DBHE) may be proposed where there is a significant cost and/or weight/space layout advantage for doing so.

DBHEs can withstand high pressures and are usually much smaller than comparable shell and tube units. They obtain high rates of heat transfer by passing the fluid down narrow passages at high speed. They offer minimal internal access for maintenance or cleaning. One design of DBHE is a printed circuit heat exchanger where plates are etched to create grooves and then diffusion bonded together. Another applies superplastic forming to diffusion bonded plates to create the heat exchanger.

7.1.2 In the absence of a BP Group Specification for DBHE's, this section gives BP's main requirements on the thermal and mechanical design of DBHE's.

7.1.3 A process and physical property data sheet for a DBHE is given in Appendix D. The purchaser shall specify all applicable phase properties, for each stream.

The purchaser should complete items 1 to 23, 'PROCESS DATA FOR ONE TRAIN', on the top part of the data sheet, and the vendor should complete items 25 to 51.



MECHANICAL DESIGN OF ONE TRAIN on the lower pail of the data sheet as appropriate (note some items may be pre-specified by purchaser).

Note that each stream can have an independent design pressure and temperature.

The purchaser should also specify his requirements for connection sizes, their type and orientation. Exchanger support and package requirements should also be defined.

If any alternative design cases have to be met by the DBHE, for example, turndown conditions or any other special operating conditions, the purchaser shall specify them in sufficient detail for the vendor to include in his performance guarantee.

7.2 Thermal Design

7.2.1 Calculations

Thermal design shall be based on the data sheet issued by the purchaser in the job specification. The Vendor shall carry out the thermal design and complete the design data sheet (Appendix D) or their own data sheet as appropriate (see 2.2.6).

The Vendor shall provide sufficient details of the thermal calculations and internal details of the exchanger to enable a cross check to be performed, if desired.

7.2.2 Fouling

DBHE's shall only be used for clean duties, or duties subject to low fouling. In general, an exchanger should have between 10-20% excess area to allow for fouling, where suitable fouling factors are not available.

7.2.3 Filters

Streams containing particulate debris (which may or may not specifically cause fouling) should be filtered to a particle size of less than 300 microns, prior to entering the exchanger.

7.3 Mechanical Design

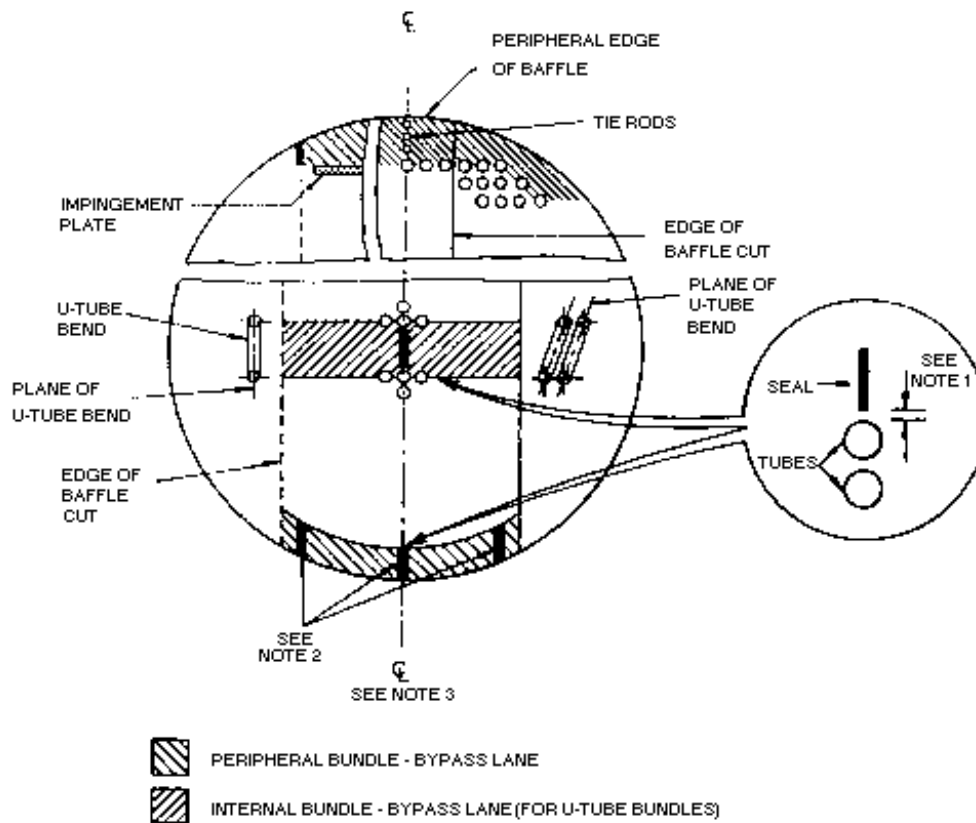
7.3.1 The exchanger should be designed to the rules of [ASME VIII](#) Division 1 or any internationally recognised pressure vessel code.

8. DOUBLE-PIPE/ MULTI TUBULAR HAIRPIN HEAT EXCHANGERS

8.1 General Requirements

- 8.1.1 Double-pipe heat exchangers may be used wherever justified for economic or space reasons. Where thin walled tubes are used, these shall be of one continuous length without welding.
- 8.1.2 Details shall be submitted for approval by the purchaser.
- 8.1.3 When preparing a detailed specification, relevant sections of BP Group [GS 126-1](#) will have to be included, e.g. bolting, welding, flanges, materials, gaskets, nameplates etc. The S&T data sheets and physical property datasheets given in BP Group [GS 126-1](#) can also be used for double pipe heat exchangers.





NOTES:

1. Clearance shall not exceed the nominal clearance between tubes.
2. Multiple seals shall be reasonable uniformly spaced.
3. Single seals shall be located on the centerline of the tube bundle.

FIGURE 1

TYPICAL CROSS SECTIONS OF TUBE BUNDLE SHOWING LOCATIONS OF SEALING DEVICES

DEFINITIONS AND ABBREVIATIONS**Definitions**

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BS	British Standard
DN	Nominal diameter
HEI	Heat Exchanger Institute
HTFS	Heat Transfer & Fluid Flow Service
HTRI	Heat Transfer Research Incorporated
NPS	Nominal pipe size
PCHE	Printed Circuit Heat Exchanger
PHFE	Plate-Fin Heat Exchanger
SI	Système International d'Unités
TEMA	Tubular Exchanger Manufacturers Association



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

ASME VIII	Pressure Vessels
TEMA	Standards of Tubular Exchanger Manufacturers Association
BS 5500	Pressure Vessels
HTFS	Guide to the Specification and Use of Plate-Fin Heat Exchangers
BP Group RP 12-1	Electrical Systems & Installation - General
BP Group RP 12-7	Electrical Systems and Installations - LV Switchgear
BP Group RP 30-2	Selection and Use of Measurement Instrumentation
BP Group RP 4-3	Civil Engineering
BP Group RP 4-4	Buildings
BP Group RP 42-1	Piping Systems
BP Group RP 44-1	Overpressure Protection Systems
BP Group RP 46-1	Unfired Pressure Vessels
BP Group RP 60-1	Cooling water treatment
BP Group GS 118-8	Tube end welding of heat exchanger tubes
BP Group GS 126-1	Shell and Tube Heat Exchangers - TEMA type
BP Group GS 126-2	Air-Cooled Heat Exchangers
BP Group GS 126-5	Design of Plate & Frame Heat Exchangers for Offshore Use
BP Group GS 136-1	Materials for Sour Service to NACE Std MR-01-75 (1994 Revision)



BP Group [GS 146-2](#)

Unfired Pressure Vessels, Ferritic Steels

BP Group [RP 12-11](#)

Electrical Systems & Installation - Motors



APPENDIX C

DATA SHEET

CLIENT				JOB NO.			
LOCATION		DESIGN DATA SHEET PLATE FIN HEAT EXCHANGER		ITEM NO.			
1	Service			No of trains/service			
2	No of process streams/block	Flow: cross/counter/cross-counter		No of blocks ser/per par train			
3	DATA FOR ONE TRAIN						
4	Stream Identification	Units	A	B	C	D	E
5	Fluid Name						
6	Quality w/w in/out						
7	Total Flowrate						
8	Operating Pressure						
9	Design Pressure						
10	Test Pressure						
11	Allowable Pressure Drop						
12	Temperature: In/Out						
13	Design Temp. Max./Min.						
14	Heat Load: Gas						
15	Latent						
16	Liquid						
17	Total						
18	Fouling Factor						
19	Design Code	Approval Authority		Inspection Organisation			
20	External Environment	External Protection		Insulation			
21	DESIGN OF ONE TRAIN						
22	Total Pressure Drop/Train						
23	Corrugation Code						
24	No. of Layers/Block						
25	Free Flow Area/Block						
26	Thermal Surface/Block						
28	Inlet Distributor Code						
29	Type/Position on Block						
30	Outlet Distributor Code						
31	Type/Position on Block						
32	Nozzle in: dia/sch/type						
33	Nozzle out: dia/sch/type						
34	Header Tank dia. in/out						
35	Manifold dia. in/out						
36	Stacking Arrangement (including dummies)						
37	Total Surface/Block	Thermal Margin		Sketch:			
38	Matls/Thick	- fins	- headers				
39		- parting sheets	- cap sheets				
40	Width of spacer bars	Total X sect Metal					
41	WxHxL of block	Free Volume of Block					
42	WxHxL of train						
43	Weight/Block - dry	- operating					
44	Weight/Train - operating	- max for shipping					
45	Notes:						
REV		Date	By	Checked	Appr'd		
0							
1							
2							
		Sheet					of



DATA SHEET

CLIENT				JOB NO.			
LOCATION		DESIGN DATA SHEET DIFFUSION BONDED HEAT EXCHANGER		ITEM NO.			
1	Service			No of trains/service			
2	No of process streams per core			No. Cores series/parallel per train/			
3	DATA FOR ONE TRAIN						
4	Stream Identification	Units	1	2	3	4	5
5	Fluid Name						
6	Quality w/w in/out						
7	Total Flowrate						
8	Operating Pressure						
9	Design Pressure						
10	Test Pressure						
11	Allowable Pressure Drop						
12	Temperature: In/Out						
13	Temperature: Outlet						
14	Design Temperature Max/Min						
15	Heat Load: Gas						
16	Latent						
17	Liquid						
18	Total						
19	Corrosion Allowance						
20	Fouling Factor						
21	Excess Duty / Area %						
22	Design Code	Approval Authority		Inspection Organisation			
23	External Environment	External Protection		Insulation			
24	DESIGN OF ONE TRAIN						
25	Total Pressure Drop/Train						
26	No. of Layers/Block						
27	Free Flow Area/Block						
28	Thermal Surface/Block						
29	Thermal Length/Block						
30	Nozzle diameter (NB) inlet						
31	Nozzle schedule inlet						
32	Nozzle diameter (NB) outlet						
33	Nozzle schedule outlet						
34	Overall Dimensions		Width	Height	Length		
35	WxHxL of core						
36	WxHxL of train						
37	WxHxL of train						
38	Weight/Core (Inc. headers, nozzles etc.)				Sketch:		
39	Dry						
40	Operating						
41	Excess Duty / Area %						
42	Materials						
43	Core						
44	Header						
45	Nozzle						
46	Flange						
47	Notes:						
48	(1)						
49	(2)						
50	(3)						
51	(4)						
REV			Date	By	Checked	Appr'd	
3							
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ASSESSMENT OF DESIGN CASES FOR TUBESHEET DESIGN

Introduction

The mechanical design methods for fixed tubesheets in [TEMA](#) and [BS5500](#) both require the specification of mean shell and tube metal temperatures and their coincident pressures. [TEMA](#) also states that all foreseeable modes of operation should be considered including the following:

- 1) normal operation under fouled conditions at the design flow rates and terminal temperatures;
- 2) operation at less than design fouling allowance;
- 3) alternative flow rates and or terminal temperatures;
- 4) flow of process fluid through one side but not the other.

However, it also states that other conditions should be considered were appropriate. It is clear from the above that for any fixed tubesheet design a large number of possible situations will need to be considered. Unfortunately it is not always possible to determine which cases will control without undertaking a full design. The following appendix gives guidance on the cases that might be considered.

Design cases for fixed tubesheets

The following is a list of possible cases.

- 1) Normal operating temperatures and pressures on both sides.

The mean metal temperatures for this case would be calculated by using an appropriate computer program to simulate the performance of the heat exchanger. The mean metal temperatures can then be calculated from the heat transfer coefficients or in some cases read direct from the computer output.

- 2) Shell side at design conditions tube side flow failure.

Such situations may occur at start up/shut down or when the tube side flow is lost. Consider the case of the tubes being at ambient temperature with no tube side flow, since the controlling resistance to heat transfer will be on the tube side the wall temperature will quickly approach the bulk shell fluid temperature. And, since there will be little heat transfer both the shell and tube metal temperatures should be set to the maximum shell fluid inlet temperature. For the case of loss of flow, the tube wall temperature would be at some initial value depending on the previous flow conditions, however, because the tube side heat transfer coefficient would be low the tube wall temperature would quickly approach that of the bulk shell fluid, again

because of the low rates of heat transfer this should be taken as the shell inlet temperature. It may be prudent to consider both the minimum as well as the maximum possible shell inlet temperatures.

3) Tube side at design conditions shell side flow failure

Again this could happen at start up/shut down or when the shell side flow is lost. If the shell were empty or full of static fluid it would eventually reach an equilibrium with the tube side fluid. Since the heat transfer rate is likely to be small and the shell side heat transfer coefficient low this could take some time, particularly if the shell side fluid is a liquid. In this case then the shell metal temperature will vary from its initial value to the tube inlet temperature. For gas on the shell side the time taken for this to happen is likely to be small whereas for liquids it may take considerably longer. In the case of gas on the shell side the shell mean metal temperature should be taken as the inlet temperature of the tube side fluid. For liquids it may be necessary to consider both the initial shell side fluid and the inlet tube side fluid temperature as the mean metal temperature. It may be prudent to consider both the minimum and maximum possible tube side inlet temperatures.

4) Maximum shell side pressure tube side normal

5) Maximum tube side pressure shell side normal

6) Maximum shell side temperature

7) Maximum tube side temperature

8) Hydraulic Pressure test

a) Tube side at test pressure shell side ambient, metal temperatures at ambient.

b) Shell side at test pressure tube side ambient, metal temperatures at ambient.

Mean Metal Temperatures

Those cases above that require the calculation of heat transfer coefficients in order to derive mean metal temperatures are 1), 4), 5) and 6). In the first instance these calculations should be undertaken using the design fouling resistance's. However, since it is unlikely that the units will foul for some time after they have been put into service, and even when they do the precise value of individual fouling resistance's is unknown it is necessary to consider various cases at the design stage.

If the shell and tube material expansion coefficients are the same then the maximum differential thermal expansion will be caused when the shell side is fouled and the tube side is clean.

If the expansion coefficients are different then there is no simple way of determining the controlling case and it would be necessary to simulate several different combinations of fouling.

Before embarking on detailed calculations of metal temperature the values of the various pressures to be used in the mechanical design calculations should be assessed to ensure that the effective pressure due to differential thermal expansion will have a significant influence on the design.

