h. Identification of materials and corrosion allowances.

i. Identification of special services and NDE requirements.

j. Identification of PMI requirements. (Refer to project specification BGS-MW-006 “Positive Material Identification of Equipment and Piping”)

9.2 TECHNICAL REQUIREMENTS

9.2.1 General Requirements

a. TEMA Class Selection

All shell and tube heat exchangers in process / hydrocarbon service, shall be in accordance with TEMA class ‘R’.

Heat exchangers in non-hazardous, non-process utility service as part of package may be supplied in accordance with TEMA class ‘C’ construction. TEMA Class type (R, C, B) shall be indicated on Data Sheets based on type of service and criticality rating of the equipment.

b. The thermal design and rating shall be based on the 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), and Heat Transfer and Fluid Flow Service (HTFS) are considered proven design methods.

9.2.2 Exchanger Type Selection

9.2.2.1 Front/Rear Head Selection

a. Type B front head shall be used for “clean service” and/or for design pressure above 9.95 barg. For “fouling service” and for design pressure less than or equal to 9.95 barg, Type A or B front head shall be used.

b. 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.

c. Rear end head Type S should be used for floating head type heat exchangers with a nominal shell diameter of more than DN 250. Alternative construction would need to be considered for diameters up to DN 250. Rear end head Type T shall be used for a kettle type heat exchanger with floating head.

d. Types P and N are not permitted.

e. High pressure or other design requirements may justify deviation from the guidelines shown.

9.2.2.2 Use of Fixed Tubesheet (nonremovable bundle) Exchangers

a. Use of fixed tubesheet exchangers requires prior approval by the COMPANY.

b. Non-removable bundle exchangers may be used in “clean” shellside service where a shellside expansion joint is not required. The use of shellside expansion joints is not permitted. Non-removable bundles may only be used when the shell side fouling factor does not exceed $0.00018 m^2 °C/W$.

c. The differential expansion between shell and tubes of a fixed tubesheet exchanger shall be based on the controlling metal temperatures, either clean or one side fouled.

d. The maximum controlling differential temperature between the tube and shellside during operation, start-up, shutdown or steamout shall be stated on the Data Sheet and used to determine the requirement for an expansion joint and tubesheet thickness on a fixed tubesheet heat exchanger. If design consideration result in

expansion joint being required, a removable bundle type exchanger shall be selected.

9.2.2.3 Use of U-Tube Bundles

U-tube bundles shall be used only for the "clean service" on the tubeside as defined in paragraph 9.1.1. Other design considerations may govern, but require prior approval by the COMPANY.

9.2.2.4 Shell Selection

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

a. Where the shellside pressure drop is a restricting factor, the divided flow shell Type J or cross-flow shell Type X or double-split flow shell Type H, should be considered. Divided flow shall be considered where tube vibration is a problem.

b. For horizontal shellside thermosyphon reboilers, Types G, H, J, or X should be selected.

c. The kettle type shell, Type K, should be selected for boiling where almost 100% vaporization (0-5% entrainment) or where a phase separation is required. Entrainment shall be a maximum of 2% for return to a tower or a K.O. drum. Elsewhere it shall be a maximum of 0.1%.

d. The use of TEMA type F shells with removable bundles is not permitted.

9.2.2.5 Horizontal and Vertical Exchangers

a. Heat exchangers should be of the horizontal type; however, for process requirements or where cleaning and other maintenance will be infrequent or space requirements make it more attractive, the vertical arrangement may be considered.

b. For thermosyphon reboilers, vertical orientation is preferred to horizontal orientation, even if the heating medium is fouling. However, all aspects of design, vibration, maintainability, and performance should be evaluated when making a selection.

c. When horizontal arrangements are preferred, the stacking of exchangers should be considered to conserve space in the structure. Preferred stacking should be 2 (two) shells high.

9.2.3 Tube Bundle

9.2.3.1 Design Considerations

a. Maximum Size

Maximum size shall be as shown below.

- The maximum straight length for tubes in removable bundles shall be 10362 mm (34 feet). Tube lengths for non-removable bundles may exceed 10362 mm, subject to COMPANY's approval on a case by case basis, but shall not exceed 12192mm. Total straight tube lengths on all exchangers shall be limited to a maximum of four different lengths for standardisation purposes.
- The maximum shell diameter shall be 2921 mm (115 inches).
- The maximum bundle diameter for removable bundle exchanges shall be 2032 mm (80 inches).
- The maximum removable bundle weight shall be 40,000 kg (88,184 lb).

b. Standard straight lengths for tubes shall be as follows:

Millimeters	2438	3048	3658	4877	6096	7315	10362
(Feet)	(8)	(10)	(12)	(16)	(20)	(24)	(34)

c. The ratio of tube length to bundle outer diameter for removable bundles shall be less than 10:1.

d. The maximum tube length for vertical thermosyphon reboilers shall be 6096 mm (20 ft).

e. Selection of different tube lengths than above for U-tubes may be considered when economically justified.

9.2.3.2 Tube Diameters and Gauges

The following table specifies bare tube diameters and minimum permissible gauges (BWG):

TUBE OD	CARBON STEEL AND LOW ALLOYS	COPPER, COPPER ALLOYS AND HIGH ALLOYS
	(MIN. WALL)	(MIN. WALL)
19.05 MM (0.75 IN.)	2.11 MM (0.083 IN.)	1.65 MM (0.065 IN.)
25.4 MM (1 IN.)	2.77 MM (0.109 IN.)	2.11 MM (0.083 IN.)
*31.75 MM (1.25 IN.)	3.40 MM (0.134 IN.)	2.77 MM (0.109 IN.)

* Use of 31.75 mm OD tubes requires prior approval by COMPANY.

- The minimum permissible gauge for titanium shall be 20 BWG. (0.9 mm)

9.2.3.3 Tube Diameter, Pitch and Layout

The following table defines criteria for selection of tube diameter, pitch and layout:

SHELLSIDE SERVICE	TUBESIDE FOULING M^2 ˚C/W (FT² HR°F/BTU)	MIN. TUBE O.D. MM (IN.)	PITCH, MM (IN.) AND LAYOUT
CLEAN*	UP TO AND INCLUDING 0.0005 (0.003)	19.05 (0.75)	25.4 (1.0) 30°/45°/90°
CLEAN*	OVER 0.0005 (0.003)	25.4 (1)	31.75 (1.25) 30°/45°/90°
FOULING*	UP TO AND INCLUDING 0.0005 (0.003)	19.05 (0.75)	25.4 (1) 45°/90°
FOULING*	OVER 0.0005 (0.003)	25.4 (1)	31.75 (1.25) 45°/90°

* As defined in paragraph 9.1.1.

Exceptions to the above table are as follows:

a. The pitch and layout guidelines shown above are the minimum starting points for economic design. Larger pitch or different layout patterns may be required to

d. High-finned tubing is not permitted.

e. Longitudinally-finned tubes are not allowed for shell and tube exchangers.

f. The minimum thickness at the plain end shall be in accordance with 9.2.3.2.

g. Finning to be skipped at baffles.

9.2.3.8 U-Tube Bundle Bend Radius and Thickness.

- Bends with radius R < 1.5 times nominal tube OD are not permitted.
- In high pressure designs inner tubes are to be increased one gauge to allow for thinning at the U-bend.

9.2.4 Water-Cooled Coolers

9.2.4.1 Cooling water shall be placed on the tubeside and should run upwards through the tubes in order to avoid gas build-up. The tubeside velocity should be as specified in this specification. The tubeside shall be maintained at a positive pressure so that air cannot separate from or be sucked into the water.

9.2.4.2 Cooling Water Velocity

a. Tubeside velocity range for seawater or brackish water shall be as follows:

Tube Material	Velocity m/s (FPS)	
Titanium	2.0 - 4.6	(6.6-15.1)
70-30 Cu-Ni	1.5 - 3.7	(4.9-12.1)
90-10 Cu-Ni	1.5 - 2.7	(4.9-8.9)
Al Brass, Al Bronze	1.5 - 2.0	(4.9-6.6)
Monel	1.5 - 3.7	(4.9-12.1)
Incoloy 825, Carpenter 20 CB3	1.5 - 3.7	(4.9-12.1)
Incoloy 625, Hastelloy C	1.5 - 3.7	(4.9-12.1)

b. Tubeside velocity range for treated/fresh cooling water shall be as follows:

Tube Material	Velocity m/s (FPS)	
Carbon and Low Alloy Steel	1.0 - 2.1	(3.3-6.9)
Austenitic Stainless Steel	2.0 - 4.5	(6.6 - 14.8)
Titanium	2.0 – 6.0	(6.6-19.7)
Inhibited Admiralty	1.0 - 2.7	(3.3-8.9)
70-30 Cu-Ni	1.5 – 7.0	(4.9-23.0)
90-10 Cu-Ni	1.5 – 7.0	(4.9-23.0)
Aluminum, Brass, Alum. Bronze	1.5 - 2.1	(4.9-6.9)
Monel	1.6 – 7.0	(5.2 – 23.0)
Incoloy 825, Carpenter 20 CB3	1.5 - 3.7	(4.9-12.1)

9.2.5 Tubeside/Shellside Selection

In general, tubeside/shellside selection shall be made to satisfy as many as possible of the following points, unless otherwise indicated on Data Sheets:

Service	Shellside	Tubeside
Seawater		X
Cooling Water		X
Condensing Vapors (except steam)	X	

j. Vent and drain connections shall be provided on the shellside inlet and outlet nozzles for purging during maintenance, when nozzles are blinded. Threaded connections are not permitted for vents and drains.

9.2.13 Saddles/Supports

a. Saddle design for horizontal exchangers shall comply with Project Standard Drawing STD-ME-00008.

b. Support design for vertical exchangers shall comply with Project Standard Drawing STD-ME-00001.

9.2.14 Baffle-to-Shell Clearance

For viscous fluids on shellside, with the dynamic viscosity above 2.0 cP at inlet or outlet temperature, the heat transfer coefficient shall be calculated with the baffle-to-shell clearance specified as "large". The shellside pressure drop, however, shall be calculated with the baffle-to-shell clearance specified as "standard/average".

9.2.15 Impingement

a. Impingement protection, in form of impingement plate or two rows of impingement rods, shall be specified for:

- Steam heaters with steam on shell side
- Two phase flow at inlet

b. For noncorrosive, nonabrasive fluids, nozzles shall be sized to avoid necessity of impingement protection. For designs with nozzles sized to avoid impingement protection, the shell entry area shall be sufficient to obtain comparable values of ρV^2 (within 15-40%) through the nozzle and corresponding shell entry area, but with larger deviations only permitted if ρV^2 is low, otherwise the preferred margin is 10%-15%.

9.2.16 Vibration

Thermal design and sizing process shall include analysis of all aspects of design to avoid or minimize the possibility of vibration.

9.2.17 Tubeside Performance

For gases and vapors, the ρV^2 in tubes shall be less than 7000 kg/m-s^2 (4700 lb/ft-s^2).

For water, the maximum velocities shall be as listed in paragraph 9.2.4.2.

For liquids (other than water), the ρV^2 shall not exceed 8900 kg/m-s^2 (5980 lb/ft-s^2).

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 homogenous gas/liquid mixture.

V is the linear velocity in m/s (ft/s) and ρ is the density in kg/m^3 (lb/ft^3).

10.0 MATERIALS

a. Materials selection shall be indicated on the Project Equipment Data Sheets.

b. Carbon steel tubesheets shall be SA 266 Gr. 2.

c. For exchangers in seawater service, tube and tubesheet / tubesheet cladding shall be the same metallurgy. A dissimilar metal interface is not acceptable.

d. Carbon steel tube shall be seamless (SA 179) and not welded (SA 214). Stainless steel tubes shall be seamless; however welded stainless steel tubes may be used if supplied by qualified manufacturer and/or respectively qualified tube bending subcontractors with prior company approval.

e. Titanium tubes may be seamless or welded. Inspection requirements as per B338 GR2.

f. For direct sea water cooling Al brass is not acceptable; tube and tube sheet shall be monel, titanium or Cu Ni.

11.0 FABRICATION

Equipment Data Sheets shall indicate any special fabrication requirements.

12.0 TESTING

Equipment Data Sheets shall indicate any special testing requirements.