



SHELL & TUBE HEAT EXCHANGERS PROCESS DESIGN STANDARD

FOR THE

CARTAGENA REFINERY EXPANSION PROJECT

CB&I CONTRACT NO. 166000

Prepared by: Process - CB&I

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1. Scope

This process design criteria section outlines the general process requirements for shell and tube heat exchangers.

2. Exchanger Design

- 1) Shell and tube exchangers shall be designed in accordance with TEMA (Tubular Exchanger Manufacturers Association) Standards (Class R) and Section VIII, Division I of the ASME (American Association of Mechanical Engineers) Boiler and Pressure Vessel Code.
- 2) When alternate operating conditions are specified, the exchanger unit shall be designed to handle either condition without exceeding the allowable pressure drop and the estimated pressure drop shall be stated by the vendor for all alternates.
- 3) Materials are specified in the Project Specifications in general terms.
- 4) Based on available bundle pulling and lifting equipment, the maximum bundle size should not exceed 60 inches diameter with a maximum weight of 44,000 lbs. Note: These limitations will not apply to vertical combined feed exchangers, vertical reboilers or fixed tubesheet type exchangers.
- 5) Contractor will provide DCS temperature indication at the inlet and outlet of each exchanger service on the process side. Local temperature gauges will be provided inlet and outlet of each exchanger shell (single shells) or at the inlet and outlet of each set of stacked exchangers (multi-shell exchangers). This applies to both process and utilities. These connections will typically be made on the piping, not on the exchanger nozzles. Measurement between stacked shells is not normally required. If measurement between stacked shells is required, the exchanger nozzle connections can be used. △2
- 6) Refer to the Mechanical Specification for Shell and Tube Heat Exchangers for details concerning connections on the inlet and outlet nozzles. △2
- 7) Deleted. △2
- 8) Deleted. △2

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- 9) The pressure gauge and thermowell connections on the inlet and outlet nozzles shall be shown on the P&ID's.

3. Exchanger Fouling Resistances

Fouling factor for fresh water, brackish, or sea water cooling should be 0.003 h-ft²-F/Btu.

In the absence of specific or client supplied data, TEMA typical fouling resistances shall be used as a guideline. Typically, corrosive, fouling, scaling, and high pressure fluids should be on tubeside.

A maximum heat flux for reboiler design is limited to 15,000 Btu/hr-ft² to minimize vapor blanketing or film boiling tendency.

4. Tube Dimensions

Killed carbon steel and low alloy steel (up to and including 5 Cr-1/2 Mo) tubes, the preferred OD is ¾ inch with a minimum wall thickness of 0.083 inch.

Alternatively, killed carbon steel and low alloy tubes may be 1.0 inch OD with a minimum wall thickness of 0.109 inch.

High alloy (above 5 Cr-1/2 Mo through austenitic stainless) tubes, the preferred OD is ¾ inch with a minimum wall thickness of 0.065 inch.

Non-ferrous (Admiralty, Cu-Ni, etc.) tubes, the preferred OD is ¾ inch with a minimum wall thickness of 0.083 inch.

Super high alloys (Incoloy, Titanium, etc.) tubes, the preferred OD is ¾ Inch with a minimum wall thickness of 0.065 inch.

For all applications not mentioned above consult with API 660 7.6.1.2

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5. Tube Pitch

Standard tube pitch is Triangular

Square pitch shall be specified when the shell side fouling factor is equal to or greater than 0.002 h-ft²-F/Btu. Center to center spacing of the tube should be at least 1.25 times the tube OD, which is the minimum spacing specified by TEMA for fouling service.

6. Tube Length

The preferred tube length for all horizontal exchangers is 20 feet. Alternate tube lengths may be used to improve design.

Vertical thermosyphons normally have a tube length of 8, 10, or 12 feet.

7. LMTD

The LMTD correction factor is calculated for multiple tube passes and if the value is less than 0.8, it is advised either to go to multiple shells or to make it a single tube pass.

8. Materials

Material selection, like any other equipment, is based on corrosion, design temperature and design pressure. When specifying multiple shell exchangers, the cold end exchangers may be of less expensive materials. If the shellside fluid determines the material for the tube (such as viscous and condensing fluids), the material for the channel may be different from the material for the tube.

Cast iron shall not be used.

The preferred tube metallurgy for treated and inhibited fresh cooling water is killed carbon steel.

Process licensor will specify the metallurgy for sea water or brackish water cooling services.

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9. TEMA Class

CB&I standard is TEMA “R” for all services.

10. Notes

The engineer should specify under the notes section at the bottom of the process data sheet asking the vendor to guarantee the exchanger thermally and mechanically. Expansion joint requirements, cyclic operation of the unit, or changes in materials for specific items may also be entered under Notes.

11. Baffles

The baffle cuts are normally specified as a percent of the diameter by the vendor. The following conversion chart shows the pct dia equivalents of percent area and vice-versa. The baffle cuts vary from 15% to 45% of the shell diameter, and maximum baffle cut is limited to 50%. The horizontal cut segmental baffles should not be used for fluids containing solids, condensing or vaporizing on the shell side. For all gas or liquid services, the vertical cut segmental baffles may be used.

pct area	pct dia	pct dia	pct area
15	20.8	15	9.4
25	29.8	25	19.6
35	38.1	35	31.2
45	46.1	45	43.6
50	50	50	50

Longitudinal baffles (F type) are not usually recommended mainly because they tend to leak and are prone to vibrating. However, longitudinal baffles are often considered for clean liquid service, such as BFW, where multiple shells would otherwise be required, but the shell pressure drop should be less than 7 psi.

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12. U Tubes

U tubes may be specified when the fouling factor on the tubeside is less than 0.002 h-ft²-F/btu. For fouling services (tube side $f > 0.002$ h-ft²-F/btu) floating head construction will normally be specified. Client approval will be required for U tube specification when the tubeside $f > 0.002$ h-ft²-F/btu.

13. Reboiler Section

- a. Reboiler selection shall be made from the following types:
 - Kettle
 - Horizontal once-through
 - Vertical thermosyphon – Use 25-30 wt.% vaporization.
 - Horizontal thermosyphon – Use 25-30 wt.% vaporization.
- b. Fired heater reboiler may be used when insufficient heat is available from other heating mediums. Refer to Standard 000-SP-PR07-0021, Fired Heaters.

14. Tube Side Velocity

	Velocity, ft/sec		
	Maximum	Minimum	Normal
Liquid			
BFW	10	---	---
Slurries	7	4	6
Cooling Water	8	3	6
Amine Solution	5	3	4
Other	6	---	---
Vapor			
Vacuum	250	---	---
0 – 500 psig	200	---	---
Above 500 psig	150	---	---

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15. Pressure Drop

The allowed tubeside pressure drop should allow for the drop through the inlet nozzle, the exchanger and the outlet nozzle. Tubeside nozzles should not exceed a ρV^2 of 4000 lb/ft-sec² (6000 Kg/m-sec²) based upon the actual ID.

Typical pressure drops are as follows:

	Allowed Pressure Drop, psi		
	Maximum	Minimum	Normal
Liquid			
BFW	10	5	10
Cooling Water	20	10	15
Amine Solution	10	5	10
Other	10	5	10
Vapor			
Vacuum (inches water)	(5)	(0.5)	(2.5)
H2 rich streams	6	2	3
Non H2 streams	6	5	5
Steam generation (shellside)	0.5	0.25	0.25

16. Exchanger Approach Temperatures

- a. Guidelines for setting the approach temperature follow. These guidelines do not apply to all cases. For example, there may be cases where there is not temperature cross and selecting an optimum approach temperature may depend on control requirements or other criteria. However, where the maximum economic heat transfer is desired, the guidelines are as follows:

Reboilers	Minimum Approach Temperature, °F
Steam	30
Hot Oil Loop	40

If a hot oil loop is not temperature controlled, e.g., when heat medium is pump around reflux from a column, extra surface and/or circulation should be specified.

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- b. Approach to cooling water or air temperature should generally be kept within the following limits:

	Cooling Water	Air
Condensers	20°F(*1)	40°F(*2)
Water Coolers	25°F	45°F
Oil Coolers	30°F	50°F

(*1) minimum 10 -15 °F

(*2) minimum 20 °F

- c. Refrigerants: 10°F

17. Amine Reboilers

Bulk Process Temperature: 365°F max (confirm w/ supplier)

18. Cooling Water Service

The maximum tube wall temperature for cooling water service is 130°F.

Valves and piping for backflushing of the exchanger are required. Valves should include a butterfly valve for regulating at the inlet of the exchanger and a block valve at the outlet (also typically a butterfly valve). An additional piping connection downstream of the butterfly valve on the cooling water supply is required routing the backflush to the Oil Water Sewer. This connection will include a block valve with blind. The size of the connection will be as follows:



Cooling Water Supply Lines 4" and Smaller	Line Size
Cooling Water Supply Lines 6" to and Including 10"	4"
Cooling Water Supply Lines 12" and Larger	6"

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19. Physical Properties and Heat Curves

For condensing or boiling, heat curves shall be included at three constant pressures between the inlet and expected outlet pressures on the datasheet.

For thermosyphon reboilers, heat curves should be included at three constant pressures. An intermediate curve is required in order to properly estimate the onset of boiling for the feed to the reboiler, which will always be subcooled, due to the head introduced by the elevation difference between the column and reboiler.