How to select the best reboiler for your processing operation

Guidelines streamline choosing a heat exchanger to maximize process efficiencies

B. TAMMAMI, Fluor Corp., Houston, Texas

Reboilers are used throughout refineries and are critical to reliable plant operation. They generate vapor, which drives fractional distillation separation. In traditional fractional distillation services, all vapor driving separation comes from the reboiler. Therefore, proper reboiler operation is vital to effective distillation.

The most critical element of reboiler design is selecting the proper type. Heat-transfer equipment, including stab-ins, plate-fins and spiral-plate, can be used for specific services. But the most common type used is the shell-and-tube reboiler. Several examples review the characteristics of various shell-and-tube reboiler designs and examine selection criteria for particular processing operations.

It is possible to operate multiple reboilers in one distillation column. Reboilers with the same operating temperature should be identical, installed in parallel formation with identical piping and balance line. The presented concepts will not go into the design details of various reboilers; we will define the characteristics of shell-and-tube reboilers and examine selection criteria that favor one configuration over another.

TYPES OF REBOILERS

Table 1 lists the various shell-and-tube reboilers that can be applied in various heat transfer operations in any hydrocarbon processing facility.

Kettle reboilers. Historically, the most common reboiler used in the refining industry is the kettle type. They often require pumping of the column bottoms liquid to deliver the liquid into the reboiler. Pool-boiling is a typical characteristic of kettle reboilers with 20% to 100% boil-up range. However, it is recommended to keep the vaporization rate at 80% and thus minimize excessive fouling.

In this reboiler type, steam flows through the tube bundle and exits as condensate (see Fig. 1). Liquid from the bottom of the tower, commonly called the bottoms, flows through the shell side. The reboiler construction may include a retaining wall, commonly referred to as "weir." The weir separates the tube bundle from the reboiler section, where residual reboiled liquid (bottoms product) is withdrawn. The liquid level should be maintained over the tube bundle, using a weir or controls to assure maximum heat-transfer efficiency and to avoid tube exposure by extreme heat that may result in dry out and tube damage.

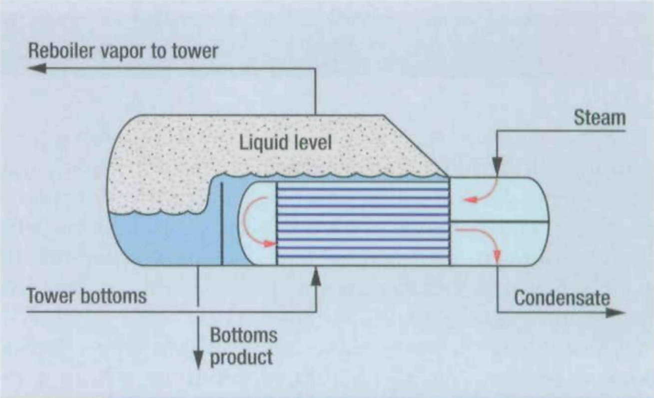

FIG. 1 A typical steam-heated kettle reboiler.

Size of the kettle reboiler depends on the required vapor disengagement and acceptable liquid entrainment, which is a function of corresponding vapor velocity (vertical and horizontal), liquid level, vapor load, etc.[1]

With the larger capital cost, we inherit a natural heat and thermal capacitance that withstands large process variations. That is the principal reason applied to select a kettle reboiler when future turndowns or turn ups are predicted and inevitable.

Thermosyphon reboilers. This reboiler does not require pumping of the column-bottoms liquid into the reboiler (see Table 1). Natural circulation is obtained by using the density difference between the reboiler inlet column bottoms liquid and reboiler outlet liquid-vapor mixture. This provides sufficient liquid head to deliver the tower bottoms into the reboiler.

Thermosyphon reboilers are more complex than kettle reboilers and require careful design and more attention from the plant operators (Fig. 2). There are many types of thermosyphon reboilers, which include vertical (updraft in-tube vaporization) or horizontal (in-shell vaporization). Reboilers can be once-through or recirculating in operations. The basic approach for designing thermosyphons is to:

- Estimate the fraction vaporized
- Determine the circulation rate from the piping layout and pressure drop
- Calculate the heat transfer rates.

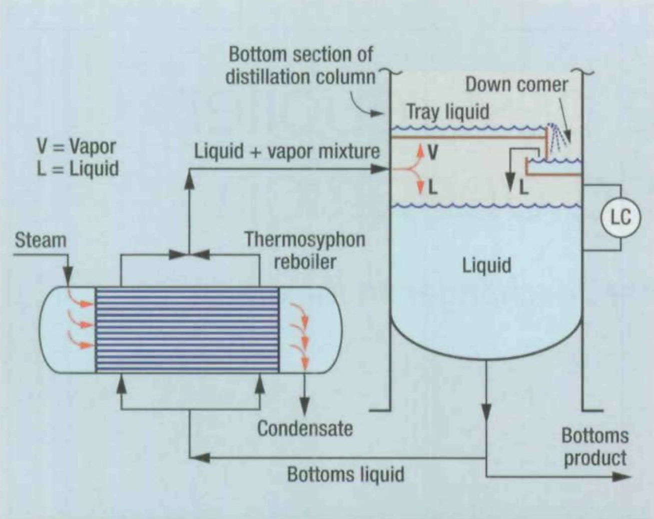

FIG. 2 A typical horizontal thermosyphon reboiler.

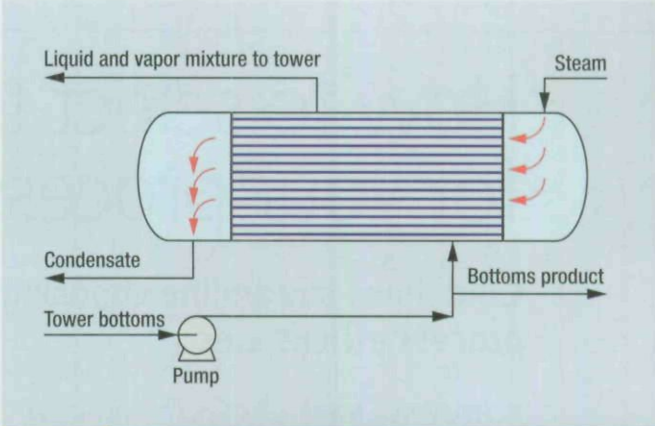

FIG. 3 A typical steam-heated forced circulation reboiler.

The calculations are repeated until the estimated vapor fraction and calculated fraction converge. The fraction vaporized is kept around 25% for vertical units; higher rates may be required for horizontal reboilers. The objective is to control the bottoms flowrate through the thermosyphon and vaporization rate. In general, higher vaporization results in a lower heat transfer coefficient due to lower vapor heat transfer rate.

Once-through thermosyphons can be used for heat-sensitive bottoms product recovery, but the vaporization rates are controlled better by using circulation operation. Accurate thermodynamics and transport properties of the boiling liquid are essential for proper sizing of thermosyphons.

Forced-circulation reboilers. These reboilers use a pump to force the liquid through the exchanger. They can be either vertical or horizontal with one or multi-pass construction (Fig. 3). The main process characteristic of a forced reboiler is low percentages of vaporization with high liquid circulation. Forced circulation is used especially when the viscosity of liquid is higher than 2 cp. The efficiency of forced reboilers is identical to that of natural circulation thermosyphon provided the liquid circulation is small, which is not always the case in most operations.

TABLE 1. Summary of the advantages and disadvantages for kettle and thermosyphon reboilers

Kettle reboilers	
Advantages	**Disadvantages**
Insensitive to hydrodynamics	Dirt collector; requires more frequent cleaning
Easy to size	Concentration effects may cause severe fouling or corrosion problems
Requires the lowest liquid driving head	
Good performance in deep vacuum and near critical	Wide boiling range mixtures and large bundles inhibit performance
Enhanced surfaces are most effective	
Could be used as waste-heat-recovery unit	Prone to vapor blanketing with high heat fluxes
Virtually no tube vibration	Liquid entrainment with high mass fluxes
Easy to operate	Higher capital cost
Horizontal thermosyphon reboilers	
Advantages	**Disadvantages**
Excellent performance at low temperature differences	Fouling on shell-side; hence difficult to clean
Ideal for wide boiling range mixtures	Vapor blanketing and localized dryout possible at high fluxes
Lower liquid driving head requirements than VTS*	Large units require multiple nozzle and expensive manifold piping
Higher circulation rates for the same liquid head	Improper exit piping design could lead to operational problems
Vertical thermosyphon reboilers	
Advantages	**Disadvantages**
High sheer rates reduce fouling tendencies	Difficult to operate in deep-vacuum and near-critical conditions
Fouling on tube-side; hence easier to clean	Prone to instability at low-pressure and high heat fluxes
Inexpensive shell and piping	Mist flow at high exit vapor fraction or low circulation rate
Better design possible with sensible heating mediums	Poor performance for low temperature difference

* Vertical thermosyphon reboilers

TABLE 2. Reboiler selection based on process conditions

	Reboiler selection				
	Reboiler type*				
Process conditions	KI	HTS	VTS	FRF	FAF
Operating pressure					
Moderate	OE	G	B	OE	OE
Near critical	B-OE	R	RD	OE	R
Deep vacuum	G	R	RD	OE	B
Design ΔT					
Moderate	OE	G	B	OE	OE
Large	B	R	G-RD	OE	P
Small	G-F	G	RD	RD	G
Very small	F-P	F	P	P	B
Fouling					
Clean	G	G	G	OE	OE
Moderate	RD	G	B	OE	G
Heavy	P	RD	B	G	G
Very heavy	P	P	RD	B	G-RD
Mixture					
Pure component	G	G	G	OE	G
Narrow	G	G	B	OE	G
Wide	F	B	G	OE	G-R
Very wide (viscous liquid)	F-P	G-RD	P	G	G-R

* Category abbreviations: B—best G—good operation F—fair but better choice possible RD—risky unless carefully designed R—risky due to insufficient data P—poor operation OE—operable but unnecessarily expensive

* Reboiler abbreviations: KI—kettle or internal HTS—horizontal thermosyphon VTS—vertical thermosyphon RFR—forced flow FAF—falling film

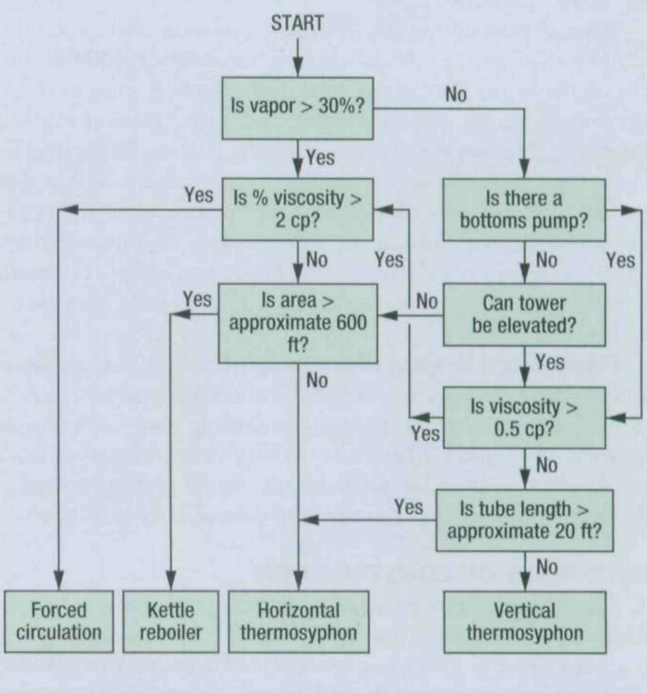

FIG. 4 Reboiler selection flowchart for varying conditions.

Falling film reboilers. This type of reboiler or evaporator can be vertical or horizontal:

Vertical tube falling film reboiler. The recirculating liquid is introduced at the top of a vertical tube bundle and it falls in a thin film down inside the tubes. The liquid absorbs heat from steam condensing on the outside of tubes and water, in liquid state, is vaporized. This evaporator type is usually selected for higher viscosity liquids and for concentrating heat-sensitive solutions that require low residence times. Evaporation occurs on the highly turbulent film and not on the tube surface. This heat-transfer operation requires that temperature differences be low. The main concern with falling film units is that liquids must be distributed evenly to all tubes.

Horizontal tube spray film reboiler. The recirculating liquor is heated and sprayed over the outside of a horizontal tube bundle carrying low-pressure steam, thus condensing water vapor inside the tube. Vapor from the evaporator chamber can be used as steam in a subsequent effect, or mechanically compressed and reused as the heating medium in the stage where it was generated.

MATERIALS OF CONSTRUCTION

The selection of materials of construction for reboilers is similar to the methodology used for standard heat exchangers. Mild steel alloys have excellent heat-transfer coefficient and long service life. Copper alloys are not generally recommended due to process compatibility concerns. Occasionally, operating companies may require using stainless steel tube bundles to reduce the possibility of tube failure from corrosion. This material may impact the design since the heat-transfer efficiency of stainless steel alloy is lower than mild steel alloys, especially when reboilers are operating at maximum throughput.

Selecting a reboiler. Many factors influence reboiler type selection. In the end, all these factors reduce to maximum efficiency, maintenance and economics. Every plant will weight the trade-offs between these factors differently as shown in Fig. 4. No "one-size-type fits all" selection exists. Table 2 summarizes the advantages and disadvantages for shell-and-tube reboilers. **HP**

LITERATURE CITED

[1] Tammani, B., "Simplifying reboiler entrainment calculations," *Oil & Gas Journal*, July 15, 1985.

Ben Tammami has over 29 years of experience in process, heat-transfer engineering and construction, as well as equipment specification and fabrication. As design engineer and engineering manager with shell-and-tube and pressure vessel fabricators, he gained the bulk of his experience in equipment design, estimating and manufacturing. He also has extensive engineering experience with several major engineering and construction firms on a variety of projects including gas, power and petrochemical projects. His heat-transfer experience includes nearly 6,500 shell-and-tube and air-cooler designs, over 2,700 of which are in operation worldwide. Mr. Tammani has authored several technical papers regarding heat transfer and fluid flow. He has developed several software products including thermal design and cost estimating for shell-and-tube heat exchangers. He holds a BS degree in chemical engineering from the University of Tulsa. He is a principal engineer with Fluor Corp. He is a member of AIChE and the heat transfer division of ASME. Mr. Tammani is a registered professional engineer in Texas.