5.8. Design Procedures

5.8.1. Selection of Reboiler Type

The following factors must be considered when the selection of a reboiler type is made.

1. Cleanability (Fouling) -Tube-side is easier to clean than shellside.

2. Corrosion - corrosion or process cleanliness may dictate the use of expensive alloys; therefore, these fluids are placed inside tubes in order to save the cost of an alloy shell.

3. Pressure - high pressure fluids are placed on tube side to avoid the expense of thick walled shells. For very low pressures (vacuum) other factors involved in the selection of reboiler type determines the tube-side fluid.

4. Temperatures - very hot fluids are placed inside tube to reduce shell costs. The lower stress limits at high temperatures affect shell design the same as high pressures.

5. Heating medium requirements may be more important than the boiling liquid requirements.

6. Boiling fluid characteristics: Temperature sensitive liquids require low holdup design. Boiling range and mixture concentration together with available ΔT affect circulation requirements to avoid stagnation. Foaming can be better handled inside tubes.

7. Temperature difference and type of boiling (film or nucleate) affects the selection.

8. Space constraints; e.g., if head room is limited then vertical units would be inappropriate or the limitation of space for internal reboilers.

9. Enhanced surfaces are suitable only for some types.

5.8.2. Pool Type Reboilers

The usual pool type (kettle) reboilers, Figure 5.9, have submerged tube bundles and a vapor disengaging space. Here the vapor leaves the reboiler at the saturation temperature and may have some entrained liquid. If a dry or superheated vapor is required as; e.g., feed to a compressor, then additional separators are used or tubes placed in the vapor space (Figure 5.10) to dry and superheat the vapor.

Typically the bundle diameter is about 6007o of the shell diameter and liquid level is sufficient to just submerge the bundle. The actual shell diameter is determined by the amount of acceptable entrainment and the corresponding vapor velocity. An empirical equation used to determine this velocity is

$$VL = 2290\,\rho_v \left[\frac{\sigma}{6.86(10^{-5})(\rho_\ell - \rho_v)} \right]^{0.5} \qquad (5.63)$$

where VL is vapor load lb/hr ft^3 (vapor rate divided by volume of vapor space), σ is surface tension lb/ft. Due to swelling of the liquid volume during boiling and to some foaming the surface area on which the above velocities are based is several (3-5) inches above the static level and the vapor volume is then calculated on this chord length. Entrainment is also effected by the vapor horizontal velocity in flowing to the vapor nozzles. As a rule of thumb the number of vapor nozzles are

$$N_n \approx L/(5\ D_s) \tag{5.64}$$

and an equal number of feed nozzles.

The tube diameters range from 5/8 to 1 inch with 3/4 and 1 inch being most common. Tube length is determined by the allowable pressure drop for the heating medium or space limitations. U-tubes are used to avoid an internal gasket but U-tubes are difficult to clean in the bend ends. Straight tubes with fixed tube sheets can be used if mechanical tube side cleaning is required.

Tube pattern depends upon the need for cleaning, a square pitch for fouling conditions, a triangular pitch for clean liquids. There is little agreement on the pitch ratios as both close, 1.2, and wide, 1.5 – 2.0, ratios are used. The best pitch ratio is a function of the amount of circulation and fraction vaporized, the effect of circulation on the coefficient, and the boiling range. Insufficient data exists to analyze the interaction of these factors and cur rent theory on circulation is in a developing stage (61). For pure single component liquids, as long as the tubes are wet, the heat transfer will be high, but multicomponent liquids will require adequate circulation to reduce the effect of boiling point elevation due to stripping of the light components. Also the relative contribution of nucleate and forced convection coefficients to the overall boiling coefficient will affect its response (slope of curve) to temperature difference. The maximum flux of the bundle (see eqn. 5.23) is affected by vapor blanketing. Sometimes, and based on the designer's intuition, vapor lanes are provided in large bundles to help improve circulation and vapor removal.

The liquid level can be controlled by external level controllers which measure the equivalent static level but the actual level can be higher because of the lower density of the vapor-liquid mixture in the reboiler. An overflow baffle in the end of the reboiler is used when there is a continuous bottoms withdrawal to control the kettle concentrations. This baffled zone allows separation of vapor and liquid and is sized to provide a sufficient (several minutes) holdup suitable for a bottoms pump control. This baffle then sets the level of the dynamic mix in the bundle. If the vapor release volume is marginal then a small (a few inches) change in liquid level can rapidly increase the entrainment such that the resulting increased two-phase flow pressure drop in the vapor line can reduce the feed rate especially if a gravity feed from a column is involved. These upsets seriously affect column performance.

5.8.3. In-tube or Thermosyphon Reboilers

The in-tube reboilers are vertical units with a condensing heat medium on the shell-side. The horizontal thermosyphons have a process stream or heating medium on the tube-side. Both thermosyphons depend upon a natural circulation induced by the density difference in the feed and exit streams. The vertical in-tube unit may, however, be operated as a once through vaporizer in which case the feed rate is controlled externally. In this discussion we limit ourselves to the thermosyphon action reboilers.

For in-tube vaporizers tube diameters range from 1 to 2 inches and tube lengths from 8 to 20 ft. although usually the shorter tubes are preferred where head room is limited. The horizontal vaporizers can use longer tubes.

The horizontal thermosyphon reboilers appear to have been developed in the petroleum industry and information and data on their design and performance are unavailable. However, the basic approach is to estimate the fraction vaporized, then determine the circulation rate from the piping layout and estimated exchanger pressure drop, and finally calculate the heat transfer rates using either convective liquid flow equations or, if desired, corrected for two-phase flow. The calculations are repeated and adjusted until the vapor fraction calculated and estimated agree within an acceptable limit. The fraction vaporized may be as large as 25%.

For the in-tube vaporizers a flow rate per tube is chosen and the calculations for heat transfer and pressure drop made for the chosen tube size and length. The total number of tubes for the required service can then be determined. The pressure drop in the piping is calculated and the total available head compared to the pressure drop. The flow rates are adjusted until a satisfactory agreement of the available and used pressures are obtained or a valve (or restriction) adjusted to balance the pressures.

In the application of reboilers to distillation columns the choice of reboiler type and the piping arrangement can affect the performance of the reboiler. Jacobs (71) describes various feed arrangements and column internal baffling. Considering only the simplest arrangements Figure 5.34 shows the column feed, G, mixes with the liquid discharge, L, from the reboiler and the mixture, F, is the feed to the reboiler. The effect of this arrangement is it produces the lowest AT in the reboiler, sacrifices a stripping plate, and is poor for thermal fouling because of a long holdup at high temperature. It is, however, a very simple arrangement. Figure 5.35 shows a gross bottom feed system where all the column downflow, G, flows directly through the reboiler in a once through manner. This results in the best average reboiler ΔT, has low holdup and, therefore, best for fouling liquids but because of the once through operation and to obtain the best reboiler performance this arrangement is limited to a maximum boil up of 30% of the feed, F. A combination of the two above methods is the mixed bottoms feed system shown in Figure 5.36. The average ΔT will be slightly less than the gross bottom feed (Fig. 5.35) but it is satisfactory for most fouling services and is a flexible system. The column baffling is more complex.

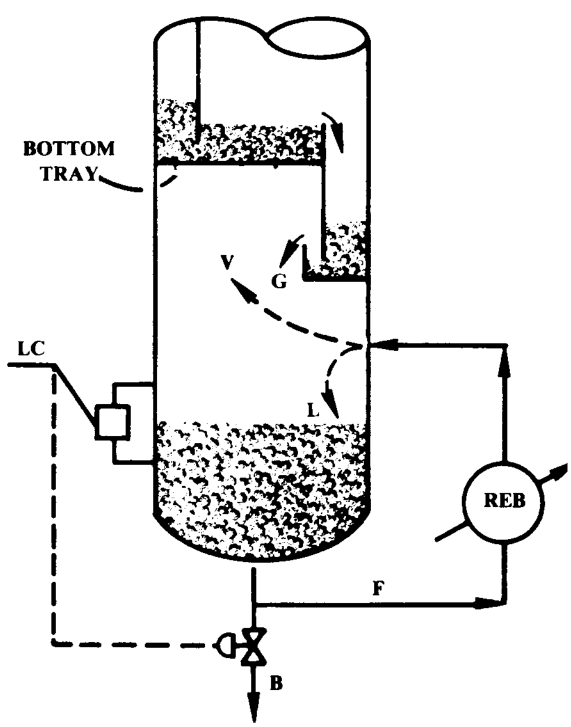

Fig. 5.34 Reboiler-distillation column arrangement. No internal baffle.

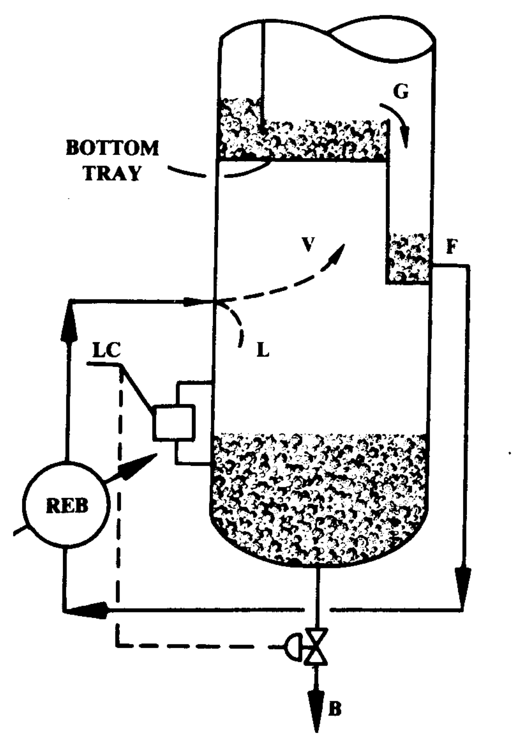

Fig. 5.35 Reboiler-distillation column arrangement. Baffled for once through flow.

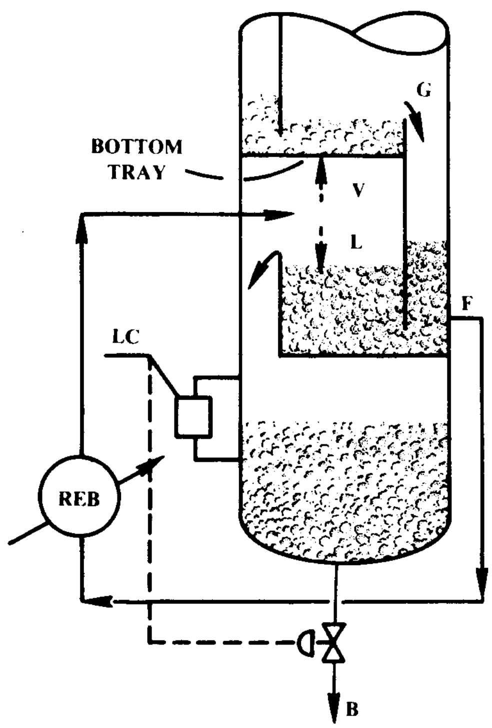

Fig. 5.36 Reboiler-distillation column arrangement. Horizontal baffle for mixed flow.