



WOLVERINE TUBE HEAT TRANSFER DATA BOOK

5.2. Vaporizers - Types and Usage

5.2.1. General

Vaporizers are constructed in numerous designs and operated in many modes. Depending upon the service application the design, construction, inspection, testing, operation, and maintenance are governed by various specifications, and by codes (national, state, and local government regulatory agencies.) The ultimate objective of all these rules is to insure the safety of the operators and community during the operation of the vaporizer. It is beyond the scope of this manual to discuss all these facets of vaporizers. Instead we will limit our discussion to the types of vaporizers frequently used in the process industries, specifically shell and tube exchangers. These can be broadly classified as those where the vaporization occurs (a) inside the tubes, or (b) outside the tubes.

The selection of the vaporizer type depends upon the evaluation of many factors such as; (1) the purpose of vaporization - to generate a vapor or to cool the heating medium, (2) the boiling fluid; single or multicomponent, and does it contain non-volatile liquids or dissolved solids, (3) the type of heating: liquid, gas, radiant, or electric, (4) the fouling characteristics and blow down requirements, (5) the operating pressures; this is especially important under vacuum or near critical pressure. In the following discussion tubes can be plain, finned, or enhanced to improve the nucleation and boiling coefficients, and/or to improve the heating media coefficients. The characteristics and application of Trufin tubes will be discussed later.

5.2.2. Boiling Outside Tubes

(a) Kettle Reboilers.

A kettle reboiler installation is shown in Figure 5.9 in simple line form. Here a horizontal U-bundle is placed at the bottom of an oversized shell. The liquid level over the bundle is controlled by means of a baffle. Excess liquid (bottoms or blow-down) overflows the baffle into the end section where the level is controlled by means of a level controller. The space above the baffle-liquid level is used to disengage the vapor from the splash and spray above the bundle. The recirculating liquid returns to the bundle in the eccentric annular space between the shell and the tube bundle. One or more (depending upon bundle length) vapor nozzles are used to remove the vapors. A U-tube bundle is frequently used thus eliminating the need for an internal floating head which could have gasket problems; also there are no stresses between tubes and shell. If a high velocity for liquid heating media is required additional passes can be formed.

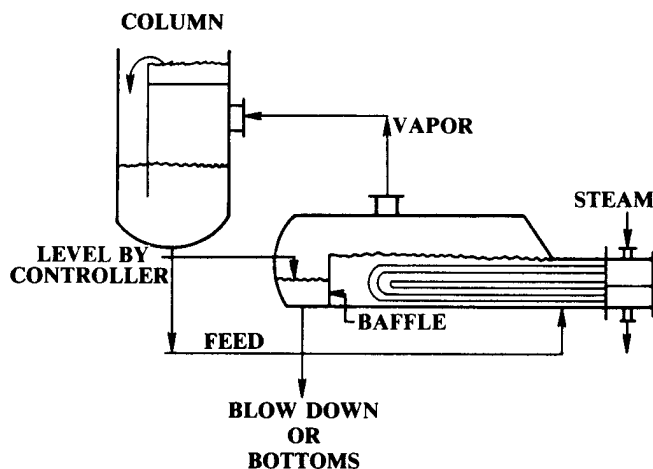


Fig. 5.9 Kettle type reboiler with U-tube bundle.

A U-tube bundle is frequently used thus eliminating the need for an internal floating head which could have gasket problems; also there are no stresses between tubes and shell. If a high velocity for liquid heating media is required additional passes can be formed.

Advantages are: insensitive to hydrodynamics and therefore reliable and easy to size. High heat fluxes are possible, can operate at low, ΔT , can handle high vaporization up to 80%, simple piping, unlimited area. Disadvantages are: all the dirt collects here and non-volatiles accumulate unless an adequate



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draw-off is maintained; shell side is difficult to clean; difficult to determine the degree of mixing and, thus, determine the correct ΔT for wide boiling range liquids; the oversize shell is expensive.

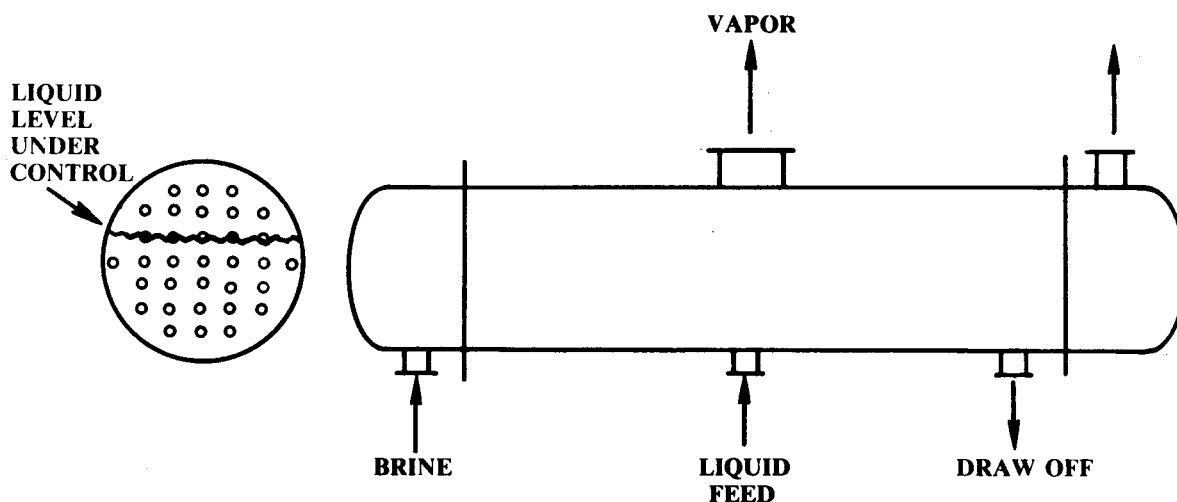


Fig. 5.10 Evaporator used in refrigeration type service.

Another version of the kettle reboiler, Figure 5.10, is a fixed tube sheet shell and tube exchanger with a full bundle but operated with a liquid level control on the shell side liquid. These types are used in large refrigeration and air conditioning plants. Here the refrigerant is clean, or at most contains traces of oils, and is completely evaporated. The tubes in the vapor space serve to dry and superheat the vapors for use in the compressors. A small draw off is occasionally used to keep the oil content low in the shell.

(b) Column Internal Reboiler.

Figure 5.11 shows a U-tube bundle inserted into the side of a column. It acts the same as a kettle reboiler but doesn't have the shell and connecting piping. There are fewer hydraulic problems as improper location and improper sizing of the feed and vapor lines in a kettle reboiler can cause operating problems. The disadvantages are the limited amount of surface area that can be installed, requires a large flange and internal supports, tubes are short hence a costly bundle, and the column must be shut down in order to clean as no alternate operation is possible.

(c) Horizontal Thermosyphon Reboilers.

A regular baffled shell and tube exchanger of the TEMA "X", "G", "H", OR "E" type is used as shown in Figure 5.12 with boiling occurring in the shell-side. By piping arrangement, a driving force for circulation is established by the density differences between the liquid in the column and the two-phase mixture in the exit piping. The heating medium flows in the tubes in single or multiple passes.

Advantages are: Higher circulation rate can give a better ΔT than a kettle reboiler; column skirt height is less than for a vertical thermosyphon; high velocity and low exit vapor fractions decrease the effect of residual high boilers and reduce fouling, unlimited area, can handle a fouling heating liquid. Disadvantages are: fouling on shell-side; baffling and tube supports may create vapor blankets and localized dryout; multiple nozzles and complicated piping is required; baffles may be needed to prevent



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flashing of low boilers near the inlets and concentration of heavies at the exchanger ends; very little design information is available and hydrodynamic problems are not well known or defined; requires large plot area, and high structural costs.

(d) Vertical Shell-Side Thermosyphon.

The vertical shell-side boiling exchanger is an unusual arrangement not used much in connection with columns but is often encountered in packed catalyst tube reactors. Here, because of the packing and the need for close temperature control, a vertical packed tube reactor of an arrangement shown in Figure 5.13 is used. Sometimes the catalyst bed is on the upper tube sheet when a fast reaction quench is required. Circulation is obtained through the use of an elevated steam drum. Depending upon the temperature conditions at the upper tube sheet, special problems may occur due to the tendency of the steam to form a vapor blanket underneath the tube sheet.

5.2.3. Boiling Inside Tubes

(a) Vertical Thermosyphon.

A single pass TEMA "E" type shell is used as shown in Figure 5.14. General characteristics of this vaporizer are a large exit pipe with a cross sectional area about equal to the total cross sectional area of the tubes and arranged to minimize the vertical distance between the top tube sheet and the column nozzle. The liquid level in the column is usually kept at the top tube sheet level in order to provide for maximum circulation. Better heat transfer coefficients are obtained if this level is dropped to 1/3 to 1/2 of the tube length; however, circulation is reduced and fouling may increase. For vacuum service where the hydrostatic head can significantly affect the local boiling point with a low ΔT , a lower tube submergence is often used. The driving head for circulation is the density difference between the liquid in the column and the two phase mixture in the tubes. These vaporizers frequently are constructed with 3/4 to 1 in. tubes, 8 to 12 ft. long. The exit vapor weight fraction for hydrocarbons ranges from 0.1 to 0.35 and for water about 0.02 to 0.1.

Advantages are: circulation is relatively high and

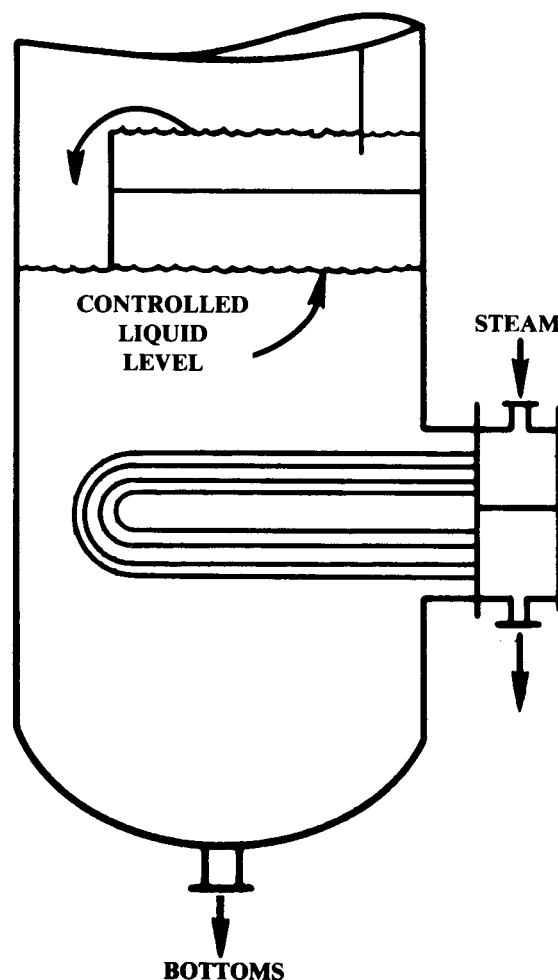


Fig. 5.11 Column internal reboiler.

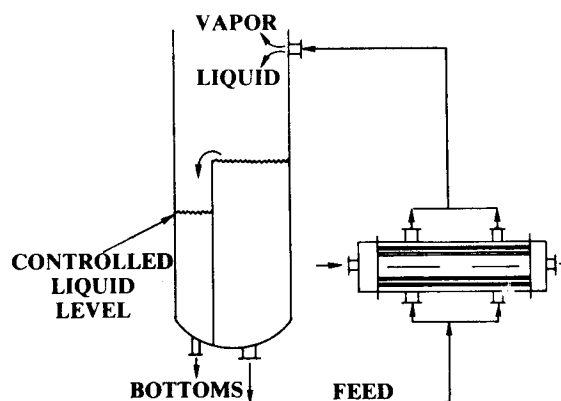


Fig. 5.12 Horizontal thermosyphon reboiler - with TEMA H shell.



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tends to minimize fouling; tube-side fouling is easier to clean; the "E" shell and connecting piping is relatively inexpensive, easily supported, and compact. The disadvantages are: requires more head room and column skirt height; maximum heat flux may be lower than kettle reboilers due to instability; the hydrostatic head effect on the boiling point may be a problem at low ΔT and/or vacuum service, maximum reboiler area is limited, and limited to about 30% vaporization.

Experience has shown that the instability encountered at high fluxes is very sensitive to the size, hence, pressure drop in the exit piping. However, stability can be regained by increasing the pressure drop in the liquid recirculation line by means of restrictions or valves.

(b) Vertical Long Tube Evaporators.

In these evaporators the arrangement is almost the same as in Figure 5.14 except that the recirculation line maybe omitted. Basically they are an once-through evaporator with the feed rate separately controlled. The weight fraction vapor can be very high, approaching 100%, depending upon boiling range and fouling characteristics of the feed. Recirculation, if any, is done by mixing the recirculated liquid with the fresh feed before pumping the mixture to the evaporator. The effective submergence is very low so that an annular climbing film or mist flow regime exists in the major portion of the tube. These evaporators can operate at relatively low pressures (down to 2 in. Hg abs.) and can handle viscous, wide boiling range mixtures; however, the ΔT used is moderate, about 15 °F. Although smaller tubes have been used many of these evaporators have tube diameters of 2 in. and tube lengths of 20 or more feet.

(c) Forced Circulation Evaporators.

These may be either vertical or horizontal exchangers and may be of multi-pass construction. Very little vaporization occurs in these tubes especially before the last pass. Essentially these units are treated as a heater and the liquid is flashed after passing through a restriction and then the separated liquid is returned to the pump suction.

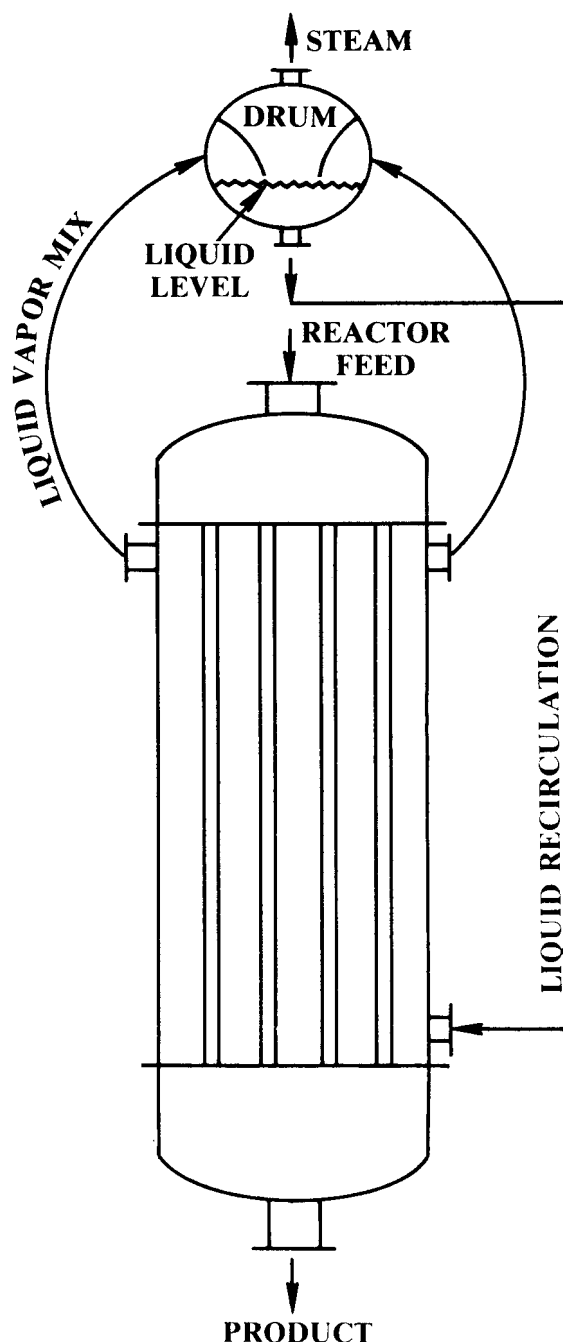


Fig. 5.13 Vertical shell-side thermosyphon - such as in reactor cooling.



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Advantages are: high velocity and no vaporization reduces fouling; high heat transfer rates; can be used for very low absolute pressures as hydrostatic head effects on boiling points is avoided, mandatory for viscous bottoms, can use standard exchangers, piping is smaller. Disadvantage is the cost of pumps and the power for their operation.

5.2.4. Other Types of Evaporators

(a) Fired Vaporizers.

In direct fired vaporizers such as steam generators and tube stills the major heat transfer problem is with the heat source and these are specialized designs with proprietary design methods and are beyond the scope of this manual.

(b) Film Vaporizers.

In falling film vaporizers a thin liquid film flows down the inside of vertical tubes, Figure 5.15, or can fall down across a bank of horizontal tubes. These films are thin so that the heat transfer coefficient is high and bubble formation is very low or non-existent. Since the pressure drops are low and the hydrostatic head is negligible, these vaporizers are well suited to operation at very low pressures as well as having high coefficients at low temperature differences. The hold-up is low and therefore can handle temperature sensitive liquids; also a stripping gas can be used to aid in reducing the temperature level. The disadvantages are: the difficulty of distributing the liquid uniformly on the tubes; the need to maintain an adequate film on all the surfaces; and the possibility to form dry patches when certain physical conditions are exceeded. In Figure 5.15, the tubes are extended above the tube sheet forming a suitable depth pool to aid in uniformly distributing the liquid. A primary overflow weir aids in distributing the feed around the bundle periphery. Each tube may be fabricated as in Figure 5.16 into additional distributing devices. Uniformity of distribution is very essential for vertical tube units.

On horizontal tubes the initial uniformity of distribution is not critical and simple overflow or spray devices are used. In horizontal units the bundles are rectangular, with staggered tube pitches, and relatively deep bundles. The major development of horizontal falling film vaporizers was government sponsored research by the Office of Saline Water and the DOE project Ocean Thermal Energy Conversion. Reports of various conferences of these projects contain references and data concerning these vaporizers.

In mechanically agitated film vaporizers a film is formed inside a large tube or vessel which has a close fitting agitator, or in some designs a scraper blade, rotating at speeds high enough to keep the liquid on

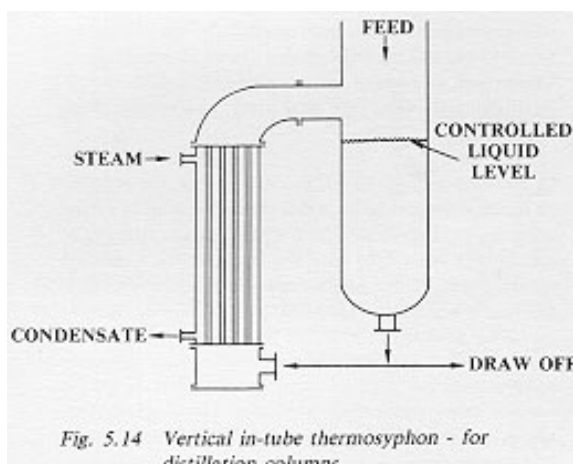


Fig. 5.14 Vertical in-tube thermosyphon - for distillation columns.

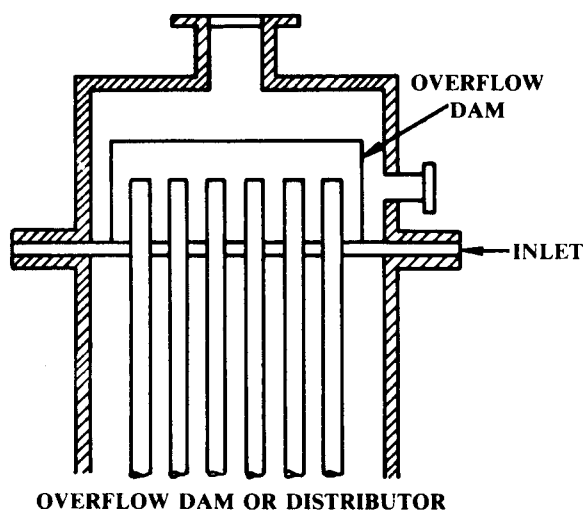


Fig. 5.15 Falling film evaporator - overflow distributors.
(COURTESY OF HEAT TRANSFER RESEARCH INC.)



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the walls and spread out in a film. Again these vaporizers are suitable for very low pressure (1 mm Hg) operation. The agitator performs several functions: it forms the liquid film; it prevents dry spots, provided sufficient liquid is fed; it agitates the film thus resulting in high heat and mass transfer rates; and fouling is reduced. The disadvantages are: power consumption for mechanical drives; problems with bearings and seals; very expensive design due to close tolerance required; and size and capacity is limited thus necessitating multiple units for large evaporation loads.

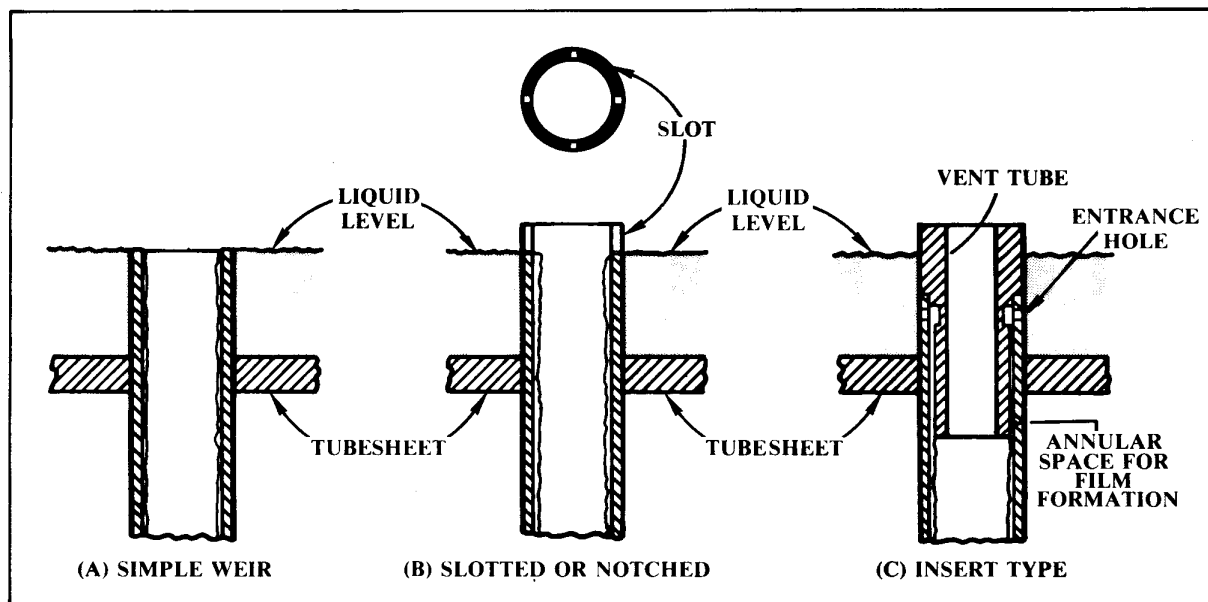


Fig. 5.16 Falling film evaporator - several tube-side distributor designs. (Courtesy of Heat Transfer Research Inc.)