5.5. Special Surfaces

Commercially available special surfaces used to enhance the boiling side heat transfer are finned surfaces, special plated surfaces, and porous surfaces produced by electroplating, sintering, or machining.

The Trufin tubes, used for boiling and condensation enhancement, usually have 16 to 40 fins/inch, approximately 1/16 inch high and resemble a screw thread. The basic purpose is to increase the surface per unit length that is exposed to the boiling liquid and an area ratio increase of 2.2 to 6.7 is obtained. The fins are formed by an extrusion process and are available in most metals. The finning process also changes the surface nucleation characteristics and an improved surface factor is reported by Palen et al. (49). Although the heat transfer coefficients are high the fin efficiency is still high because of the very short fin length. For the high conductivity metals, such as copper, the fin efficiency is almost 100% but for low conductivity metals such as stainless steel the efficiency may drop into the 70-80% range.

Surface enhancement is not a universally acceptable solution to the improved performance of reboilers. Careful consideration must be given to the particular operating conditions. Some of the factors to be evaluated are as follows. (1) These are expensive surfaces and cost comparisons should be made. (2) These surfaces are available only for a limited number of metals and the corrosion requirements of the system need evaluation. (3) The boiling range and fouling or corrosive characteristics of the liquids could significantly affect the final performance. Implied here is the ability to clean these surfaces. (4) The performance of a tube bundle can be significantly different from the performance of a single tube as described by Palen et al. (49). Here the relative effect of nucleate boiling to two-phase convection heat transfer needs to be determined. Further, apparent comparisons of tube bundle performance vs. single tubes needs a careful consideration of the effect of bundle layout, tube pitch, etc. on the circulation rate, hence two phase heat transfer, about which we are only beginning to understand. (5) The improvement of the boiling coefficient may not improve overall performance if the heating medium, fouling, or tube wall coefficients are limiting.

The major application of enhanced surfaces is in boiling clean liquids at low temperature differences. Trufin tubes depend more on surface increase and seem less subject to problems of fouling and wide boiling range liquids. The maximum heat flux appears to equal that of a plain tube based on the projected area.

Enhanced surfaces find industrial applications for two reasons: (a) For a given temperature difference the heat duty will be two or three times higher than for plain tubes at low ΔT. This can result in smaller reboilers with savings in space and weight. At high ΔT the relative performance of enhanced vs. plain tubes is less. (b) For a given duty the required temperature difference will be smaller than for plain tubes. This is of great importance when the cost of other equipment, such as compressors, and operating costs are considered. Heat transfer performance for some commercially available enhanced surface tubes are described by Yilmaz (50).

5.5.1. Boiling on Fins

One of the problems of boiling from fins is the determination of fin efficiency. As the nucleate boiling coefficient is strongly dependent upon the temperature difference, which in a fin is varying along its length, the calculation of a fin efficiency requires a stepwise computer program. Fin efficiency calculations with a linear variation along the length were derived by Han (51) and Chen (52). A closer approach to boiling conditions was made by Cumo (53) who made a numerical solution for the case where the heat flux was proportional to the third power of the local wall to liquid temperature difference. Haley and Westwater (54) solved a one dimensional general conduction equation.

The effect of fin clearances was studied by Westwater (55) who found that bubble size was a factor but a 1/16-in clearance at atmospheric pressure was sufficient to avoid interference.

5.5.2. Mean Temperature Difference

In all boiling processes the liquid is superheated with reference to the vapor saturation temperature but the effect of superheat on the temperature difference calculation is neglected. The amount of superheat cannot be predicted and is usually small compared to the ΔT_{sat}; thus this effect is ignored.

For in-tube boiling the heat transfer coefficient calculational procedure requires the division of the tube into zones for each flow regime which in turn requires calculating the heat transferred zone by zone and thus the temperature difference is also included in the calculations. The net result is no separate calculation of a mean temperature difference is made for in-tube vaporization.

For boiling outside of tubes the determination of a mean temperature difference is an arbitrary choice based on the amount of subcooling, the boiling range, and to some extent the geometry of the reboiler. The problem is the degree of mixing that occurs in the shell which depends on the circulation rate. Very little is presently known about shell-side circulation and methods for estimating the circulation rates are only in early stages of development. As shown by Palen et al. (32) in Figure 5.31 the bulk temperature within the tube bundle varies with length and the effective ΔT differs substantially from the assumed ΔT or the ΔT based on exit temperatures; thus depending upon the assumptions made, several methods of calculating the mean temperature difference can be used. Some of these choices are: (1) For a pure component or a narrow boiling range mixture, the vapor saturation temperature is used, and if a single component condensing vapor is the heating medium, the temperature difference is this difference. If the heating medium is transferring sensible heat, then a log mean of the vapor saturation temperature and the heating medium terminal temperatures is used. (2) For a wide boiling range mixture or where the sensible heat load is a substantial fraction of the total heat load, a counterflow log mean ΔT gives optimistic results (32, 34) and an LMTD based on exit vapor temperature is recommended. (3) When the effect of static head on the boiling point is significant; e.g., in large bundles and/or in vacuum service, then the boiling temperature should be based on the mean pressure in the bundle including the imposed static head. (4) When a horizontal thermosyphon reboiler is used, a counterflow LMTD is very optimistic and use of a cocurrent flow LMTD is suggested.

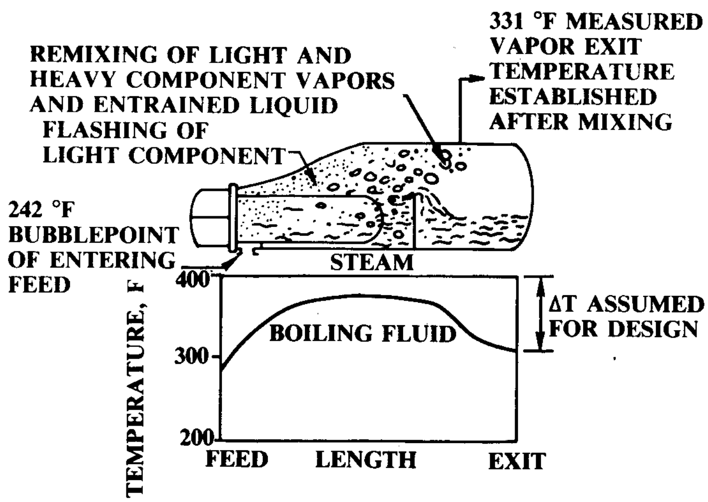

Fig. 5.31 Longitudinal temperature profile for wide range boiling mixtures [32].

Since experimentally measured boiling coefficients, and any resulting correlations, are dependent on the temperature differences used to calculate these coefficients from the basic data, then the same LMTD method should be used in the design of reboilers when using these data or correlations. However, the generalized correlations given above have such a spread of data that the temperature difference determination is a minor factor in the data spread and the MTD suggestions in the above paragraph should be followed.