3.1. Trufin Tubes in Condensing Heat Transfer

3.1.1. Modes of Condensation

Condensing is the heat transfer process by which a saturated vapor is changed into a liquid by means of removing the latent heat of condensation.

Four basic mechanisms of condensation are generally recognized: dropwise, filmwise, direct contact, and homogeneous. In dropwise condensation, the drops of liquid form from the vapor at particular nucleation sites on a solid surface, and the drops remain separate during growth until carried away by gravity or vapor shear. In filmwise condensation, the drops initially formed quickly coalesce to produce a continuous liquid film on the surface through which heat must be transferred to condense more liquid. In direct contact condensation, the vapor condenses directly on the (liquid) coolant surface which is sprayed into the vapor space. In homogeneous condensation, the liquid phase forms directly from super saturated vapor, away from any macroscopic surface; it is however generally assumed that, in practice, there are sufficient numbers of dirt or mist particles present in the vapor to serve as nucleation sites.

While dropwise condensation is alluring because of the high coefficients reported, it is not considered at this time to be suitable for deliberate employment in process equipment. Generally, contaminants must be continuously injected into the vapor, or special materials (often of low thermal conductivity) employed. Even so, the process is unstable and unpredictable, and of questionable efficacy under conditions of high vapor velocity and industrial practice.

Direct contact condensation is a very efficient process, but it results in mixing the condensate and coolant. Therefore, it is useful only in those cases where the condensate is easily separated, or where there is no desire to reuse the condensate, or where the coolant and condensate are the same substance. Homogeneous condensation is primarily of concern in fog formation in equipment and is not a design mode.

Therefore, all subsequent references to condensation will mean filmwise condensation, in which the heat transfer surface is covered with a thin film of condensate flowing under the influence of gravity, vapor shear, and/or surface tension forces.

The necessary equations for calculating the heat transfer and pressure drop for condensing will be developed later in this Chapter. The case for in-tube condensing will be studied first then extended to cover condensing outside Trufin tubes.

3.1.2. Areas of Application

In Chapter 1, it was pointed out that it is usually advantageous to use Trufin when one of the film heat transfer coefficients is significantly smaller than the other. The lower coefficient tends to control the magnitude of U, the overall heat transfer coefficient, and therefore the size of the heat exchanger. Hence, if Trufin is used, with the low coefficient fluid in contact with the higher heat transfer area of the fin, the total amount of tubing is reduced compared to the plain tube case; therefore the overall size of the heat exchanger is also reduced.

The best design is generally obtained if the thermal resistances of the two fluid heat transfer processes are approximately equal. This condition is obtained when:

$$\frac{1}{h_i A_i} \approx \frac{1}{h_o A_o}$$

$$\frac{A_o}{A_i} \approx \frac{h_i}{h_o}$$

In a large number of condensing applications in the process and refrigeration industries, especially where water cooling is used, the value of h_i/h_o ranges from 2 to 5 or even 10. Since low- and medium-finned Trufin have A_o/A_i values from about 3 to 7, these tubes are often found to afford substantial savings in overall heat exchanger size and cost. In these applications the condensation takes place on the outside (fins) of the tubes.

In other applications where air is used as the cooling medium, the air side heat transfer coefficients are much lower than the condensing coefficients. High-fin Trufin is used in these cases with the condensing taking place inside the tubes and the high outside area placed on the air side.

3.1.3. Types of Tubes Available

1. Type S/T Trufin® Low-Finned Tube
   Tubes of this type are made with 16 to 40 fins per inch and fin heights of approximately 1/16 inch. The diameter over the fins is equal to or less than the plain end diameter to allow the tube to be inserted through a tubesheet.

2. Medium-Finned Trufin
   These tubes are characterized by having 11 fins per inch and fin heights of 1/8 inch. The tubes can be supplied with plain ends of a smaller diameter than the finned section (type W/H) or with belled ends suitable for rolling into tubesheets (type S/T).

3. Type S/T Turbo-Chil® Finned Tubes
   The outer surface of these tubes is similar to standard type S/T Trufin. In addition, the inner surface of the tube is provided with integral spiral ridges which enhance the internal heat transfer coefficient.

4. Koro-dense®
   This tube is a corrugated rather than a finned tube but is mentioned here because of its advantageous application in steam condensing. Two types are available: MHT, a medium corrugation severity affording maximum tube side performance if pressure drop permits, and LPD, a low corrugation severity for use when tube-side pressure drop is limiting.

   Condensation generally takes place on the outside surface of the above tubes.

5. High-finned Trufin
   Tubes of this type are made in both copper and aluminum. Fin counts range from 5 to 11 fins per inch with fin heights as high as 5/8 inch. The aluminum finned tube can be supplied with liners of various other metals.