where

U = overall coefficient of heat transfer, Btu per (hour) (square foot external surface) (Fahrenheit degree mean temperature difference between air and fluid within the coil).

f_i = film coefficient of heat transfer between the internal surface of the coil and the fluid flowing within the coil, Btu per (hour) (square foot internal surface) (Fahrenheit degree mean temperature difference between that surface and the average fluid temperature).

f_o = film coefficient of heat transfer between air and the external surface of the coil, Btu per (hour) (square foot external surface) (Fahrenheit degree mean temperature difference between the mass of air and the external surface).

k = conductivity of material from which the bare pipe is constructed, Btu per (hour) (square foot) (Fahrenheit degree per inch thickness).

L = thickness of tube wall, inches.

R = ratio between external and internal surface of the bare tube, usually varying from 1.03 to 1.15 for the tube used in typical heating or cooling coils. This ratio R is inserted in the formula in order to place internal fluid coefficient of heat transfer on the basis of external surface.

Frequently, when pipe or tube walls are thin and of material having high conductivity (as is the case in construction of typical heating and cooling coils) the term L/k in Equation 2 becomes negligible and is generally disregarded. (The effect of the term L/k in typical bare pipe heating or cooling coils seldom exceeds 1 to 2 percent of the overall coefficient). Thus, in its simplest form, for bare pipe:

$$U = \frac{1}{\frac{R}{f_i} + \frac{1}{f_o}} \tag{3}$$

For finned coils the formula[2] for the overall coefficient of heat transfer can be conveniently written:

$$U = \frac{1}{\frac{R}{f_i} + \frac{1}{\eta f_o}} \tag{4}$$

in which the term η, called the *fin efficiency*, is introduced to allow for the resistance to heat flow encountered in the fins.

The term R, in this case, is the ratio of *total* external surface to internal surface. For typical designs of finned coils for heating or cooling, this ratio varies from 10 to 30. Term R is again introduced to place the internal surface coefficient of heat transfer on a basis of external surface. In the discussions which follow, coefficients f_i and ηf_o will be considered separately, and also various ways of combining them will be outlined.

The performances of all heating and dry cooling coils are influenced by these same factors. But, when cooling coils operate wet or act as dehumidifying coils, the performance cannot be predicted on the basis of overall coefficients, and an analysis must be made on the basis of individual film coefficients as will be explained.

PERFORMANCE OF DEHUMIDIFYING COILS

When a cooling coil operates with a surface temperature which is below the dew-point of the air entering the coil, moisture is condensed and the air leaves the coil with a humidity ratio lower than it had when it entered the coil. To understand the performance of surface coils under such conditions, assume that air enters a cooling coil at conditions corresponding to point 1 in Fig. 12. As long as the surface temperature of the coil is above the dew-point, the air is cooled without dehumidification, and its condition leaving the coil will be somewhere on line 1-A. Its exact position on this line depends on the air velocity and the external film coefficient, as well as upon the surface temperature. When the surface temperature just equals the dew-point, the air leaves with conditions represented by point A. If the surface temperature is below the dew-point, condensation takes place, and the air has a final condition somewhere along the line A-2-3 which is a

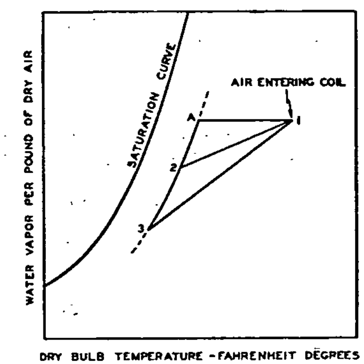

FIG. 12. PERFORMANCE OF DEHUMIDIFYING COIL

line at a constant horizontal distance from the saturation curve. It should be understood that the line 1-A-2-3 is not intended to represent the path of the condition of the air as it passes through the coil from row to row. It is simply the path traced by the exit air conditions as the surface temperature is gradually reduced, with other conditions remaining constant.[8]

In the process of dehumidification, since heat is being transferred to the coil surface by two different mechanisms (convection and condensation), it is evident that an overall coefficient of heat transfer cannot be determined by the same method used for heating and for dry cooling coils. However, if it is assumed that the sensible heat transfer of a dehumidifying coil is unaffected by the presence of moisture on its surface, Equation 5 may be obtained to express this part of the heat transfer in terms of the external film coefficient and the surface temperature.

$$q_s = f_o \times A \times N \times (\Delta t_o) \tag{5}$$

where

q_s = sensible heat transferred, Btu per (hour) (square foot of coil face area).
t_1 = dry-bulb temperature of air entering coil, Fahrenheit degrees.
t_2 = dry-bulb temperature of air leaving coil, Fahrenheit degrees.
t_s = average temperature of coil external surface, Fahrenheit degrees.