BUBBLE-CAP TRAY HYDRAULICS

Theory

A schematic of a bubble-cap tray is given in Figure 1 of the schematics.

The pressure drop for vapor flow from one tray to the next is designated h_t and has the value that would be read from a manometer tapped to the vapor space of adjacent trays (see Figure 1) h_t is segregated into the following resistances:

$$h_t = h_{cd} + h_{so} + h_l \qquad (1)$$

where

h_{cd} = drop through dry caps, in. liquid

h_{so} = drop through wet slots, in. liquid

h_l = drop through aerated mass over and around bubble cap, in. liquid

Equations used for calculating the various terms in Eq. (1) are:

$$h_{so} = 1.20\left(\frac{\rho_g}{\rho_l - \rho_g}\right)^{1/5} h_{sh}^{4/5}\ U_s^{2/5} \qquad (2)$$

where ρ_g = gas density, lb/ft^3

ρ_l = liquid density, lb/ft^3

h_{sh} = slot height, in.

U_s = linear gas velocity through slots, ft/s

= volumetric vapor flow rate/slot area per tray

$$h_{cd} = k_2 \frac{\rho_g}{\rho_l} U_h^2 \qquad (3)$$

where k_2 is called a dry-cap head-loss coefficient. It is a function of the annular/riser area and can be found in references like those listed below. (If you have trouble locating this or any other correlation, see the teaching assistant.)

U_h = linear gas velocity through risers, ft/s

= volumetric vapor flow rate/total riser area per tray

$$h_l = b\left(h_s + h_{ow} + \frac{h_{hg}}{2}\right) \tag{4}$$

where b = aeration factor, dimensionless. Again, found in references as a function of $U_a \rho_g^{1/2}$ where U_a is the linear gas velocity through active area, ft/s.

h_s = static slot seal (weir height minus height of top of slot above plate floor), in.

h_{ow} = height of crest over weir, in. clear liquid

h_{hg} = hydraulic gradient across plate, in. clear liquid

The Francis equation:

$$h_{ow} = 0.48\left(\frac{q'}{L_w}\right)^{2/3} \tag{5}$$

where q' = liquid flow rate, gal/min

L_w = length of weir, in.

Hydraulic gradient data, h_{hg} are again found in correlations in the references. These have to be corrected for gas flow effects using another correlation which gives the correction factor C_{vf}. Thus

$$h_{hg} = C_{vf} h'_{hg} \tag{6}$$

References

1. Smith, B. D., "Design of Equilibrium Stage Processes," McGraw-Hill, 1963.

2. Robinson, C. S. and E. R. Filliland, "Elements of Fractional Distillation," 5th ed., McGraw-Hill, 1952.

3. Perry's Chemical Engineers' Handbook, 5th edition, 1973.

Parameters needed for the theoretical calculations

Tower diameter	60 cm
air channel diameter	31.4 cm
downcomer area	0.026 m^2
weir length	0.43 m
weir height	5.0 cm
skirt clearance	1.25 cm
slot height	15 mm
slot width	3 mm
number of slots	24
riser area	2.07 in^2/cap
reversal area	1.914 in^2/cap
annulus area	2.153 in^2/cap
ρ_v (air)	1.185 g/cm^3
ρ_e (water)	1000 g/cm^3
static slot seal	27 mm