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:

$$h_t = h_{cd} + h_{so} + h_l$$

(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:

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

(2)

where

$\rho_g = $ gas density, lb/ft$^3$

$\rho_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

$$h_{cd} = k_2 \frac{\rho_g}{\rho_l} U_h^2$$

(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
Bubble-Cap Tray Hydraulics

this or any other correlation, see the teaching assistant.)

\[ U_g = \text{linear gas velocity through risers, ft/s} \]

\[ h_i = \text{volumetric vapor flow rate/total riser area per tray} \]

\[ h_i = \beta \left( h_s + h_{ow} + \frac{h_{hg}}{2} \right) \]  \hspace{1cm} (4)

where \( \beta = \text{aeration factor, dimensionless. Again, found in references as a function of} \)

\[ U_a \rho_g^{1/2} \text{ where } U_a \text{ is the linear gas velocity through active area, ft/s.} \]

\[ h_s = \text{static slot seal (weir height minus height of top of slot above plate floor), in.} \]

\[ h_{ow} = \text{height of crest over weir, in. clear liquid} \]

\[ h_{hg} = \text{hydraulic gradient across plate, in. clear liquid} \]

The Francis equation:

\[ h_{ow} = 0.48 \left( \frac{q'}{L_w} \right)^{2/3} \]  \hspace{1cm} (5)

where \( q' = \text{liquid flow rate, gal/min} \)

\[ L_w = \text{length of weir, in.} \]

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 \( C_{sf} \). Thus

\[ h_{hg} = C_{sf} h'_{hg} \]  \hspace{1cm} (6)

References


Parameters needed for the theoretical calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower diameter</td>
<td>60 cm</td>
</tr>
<tr>
<td>air channel diameter</td>
<td>31.4 cm</td>
</tr>
<tr>
<td>downcomer area</td>
<td>0.026 m²</td>
</tr>
<tr>
<td>weir length</td>
<td>0.43 m</td>
</tr>
<tr>
<td>weir height</td>
<td>5.0 cm</td>
</tr>
<tr>
<td>skirt clearance</td>
<td>1.25 cm</td>
</tr>
<tr>
<td>slot height</td>
<td>15 mm</td>
</tr>
<tr>
<td>slot width</td>
<td>3 mm</td>
</tr>
<tr>
<td>number of slots</td>
<td>24</td>
</tr>
<tr>
<td>riser area</td>
<td>2.07 in²/cap</td>
</tr>
<tr>
<td>reversal area</td>
<td>1.914 in²/cap</td>
</tr>
<tr>
<td>annulus area</td>
<td>2.153 in²/cap</td>
</tr>
<tr>
<td>( \rho_v ) (air)</td>
<td>1.185 g/cm³</td>
</tr>
<tr>
<td>( \rho_e ) (water)</td>
<td>1000 g/cm³</td>
</tr>
<tr>
<td>static slot seal</td>
<td>27 mm</td>
</tr>
</tbody>
</table>