"DESIGNING OF SIEVE TRAY"

A FINAL PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF TECHNOLOGY (APPLIED PETROLEUM ENGINEERING)

Submitted To

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

Guided by

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CERTIFICATE

This is to certify that the Project Report on **"DESIGNING OF SIEVE TRAY"** submitted to University of Petroleum & Energy Studies, Dehradun, by **JAVED KHAN SHERVANI** in partial fulfillment of the requirements for the award of Degree of **Bachelor of Technology** in **Applied Petroleum Engineering** (Academic Session 2003 – 07) is a bonafide work carried out by him under my supervision and guidance. This work has not been submitted anywhere else for any other degree or diploma.

Date: May 8, 2007

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INTRODUCTION:

TRAY TOWERS

Tray towers are vertical cylinders in which the liquid and gas are contacted in stepwise fashion on trays or plates, as shown schematically for one type (bubble-cap trays) . The liquid enters at the top and flows downward by gravity. On the way, it flows across each tray and through a downspout to the tray below. The gas passes upward through openings of one sort or another in the tray, then bubbles through the liquid to form a froth, disengages from the froth, and passes on to the next tray above. The overall effect is a multiple countercurrent contact of gas and liquid, although each tray is characterized by a cross flow of the two. Each tray of the tower is a stage, since on the tray the fluids are brought into intimate contact, interphase diffusion occurs, and the fluids are separated. The number of equilibrium stages (theoretical trays) in a column tower is dependent only upon the difficulty of the separation to be carried out and is determined solely from material balances and equilibrium considerations. The stage or tray efficiency, and therefore the number of real trays, is determined by the mechanical design used and the conditions of operation. The diameter of thetower,on the other hand, depends upon the quantities of liquid and gas flowing through the tower per unit time. Once the number of equilibrium stages, or theoretical trays, required has been detennined, the principal problem in thedesign of the tower is to choose dimensions and arrangements which willrepresent the best compromise between several opposing tendencies, since it is generally found that conditions leading to high tray efficiencies will ultimatelylead to operational difficulties.For stage or tray efficiencies to be high the time of contact should be long toPermit it the diffusion to occur, the interfacial surface between phases must bemade large, and a relatively high intensity of turbulence is required to obtainhigh mass-transfer coefficients. In order to provide long contact time, the liquidpool on each tray should be deep, so that bubbles of gas will require a relativelylong time to rise through the liquid. When the gas bubbles only slowly throughthe openings on the tray, the bubbles are large, the interfacial surface per unit ofgas volume is small, the liquid is relatively quiescent, and much of it may evenpass over the tray without having contacted the gas. On the other hand,whenthe gas velocity is relatively high, it is dispersed very thoroughly into the liquid,which in turn is agitated into a. froth. This provides large interfacial surfaceareas. For high tray efficiencies, therefore, we require deep pools of liquid andrelatively high gas velocities.These conditions, however, lead to a number of difficulties. One is the

mechanical entrainment of droplets of liquid in the rising gas stream. At highgas velocities,when the gas is disengaged from the froth, small droplets of liquidwill be carried by the gas to the tray above. Liquid carried up the tower in thismanner reduces the concentration change brought about by the mass transfer

and consequently adversely affects the tray efficiency. And so the gas velocitymay be limited by the reduction in tray efficiency due to liquid entrainment.Furthermore, great liquid depths on the tray and high gas velocitiesbothresult in high pressure drop for the gas in flowing through the tray, and this in turn leads to a number of difficulties. In the case of absorbers and humidifiers,high pressure drop results in high fan power to blow or draw the gas through the tower, and consequently high operating cost. In the case of distillation, highpressure at the bottom of the tower results in high boiling temperatures, which in turn may lead to heating difficulties and possibly damage to heat-sensitivecompounds.Ultimately, purely mechanical difficulties arise. High pressure drop maylead directly to a condition of *flooding*. With a large pressure difference in thespace between trays, the level of liquid leaving a tray at relatively low pressure and entering one of high pressure must necessarily assume an elevated positionin the downspouts, as . As the pressure difference is increaseddue to the increased rate of flow of either gas or liquid, the level in thedownspout will rise further to permit the liquid to enter the lower tray.Ultimately the liquid level may reach that on the tray above. Further increase in either flow rate then aggravates the condition rapidly, and the liquid will fill the entire space between the trays. The tower is then flooded, the tray efficiency falls to a low value, the flow of gas is erratic, and liquid may be forced out of the exit pipe at the top of the tower. For liquid-gas combinations which tend to foam excessively, high gas velocities may lead to a condition of *priming*, which is also an inoperativesituation. Here the foam persists throughout the space between trays, and a great deal of liquid is carried by the gas from one tray to the tray above. This is an exaggerated condition of entrainment. The liquid so carried recirculates between trays, and the added liquid-handling load increases the gas pressure drop sufficiently to lead to flooding. We can summarize these opposing tendencies as follows. Great depths of liquid on the trays lead to high tray efficiencies through long contact time but alsoto high pressure drop per tray. High gas velocities,within limits, provide goodvapor-liquid contact through excellence of dispersion but lead to excessive entrainment and high pressure drop. Several other undesirable conditions may occur.If liquid rates are too low, the gas rising through the openings of the tray maypush the liquid away *(coning),* and contact of the gas and liquid is poor. If thegas rate is too low, much of the liquid may rain down through the openings ofthe tray *(weeping),* thus failing to obtain the benefit of complete flow over the trays; and at very low gas rates, none of the liquid reaches the downspouts *(dumping).* The relations between these conditions are shown schematically in Fig.6.9,and all types of trays are subject to these difficulties in some form.The various form The various arrangements, dimensions, and operating conditions chosen for design are those whichexperience has proved to be reasonably good compromises. The general design procedure involves a somewhat empirical application of them,followedby computational check to ensure that pressure drop and flexibility,i.e.,ability of the tower to handle more or less than the immediately expected flow quantities, ~e satisfactory. A great variety of tray designs have been and are being used. .The various form practically all towers were fitted with bubble-cap trays, but new installations now use either sieve trays or one of the proprietary designs whichhave proliferated since 1950.

GeneralCharacteristics

Certain design features common to the most frequently used tray designs will bedealt with first.

Shell and trays The tower may be made of any number of materials, depending upon the corrosion conditions expected. Glass, glass-lined metal, impervious carbon,plastics, even wood but most frequently metals are used. Fór metal towers,the shells are usually cylindrical for reasons of cost. In order to facilitate
cleaning,small-diameter towers are fitted with hand holes, large towers with manwaysabout every tenth tray . The trays are usuallymade of sheet metals, of special alloys if necessary, the thickness governed by the anticipated corrosion rate. The trays must be stiffened and supported (see, for example, and must be fastened to the shell to prevent movement owing to to surges of gas, with.allowance for thermal expansion. This can be arranged by use of tray-support rings with slotted bolt holes to which the trays are bolted. Large trays must be fitted with manways so that a person can climb from one tray to another during repair and cleaning.Trays should be installed level to within 6 mm (~ in) to promote good liquid distribution.

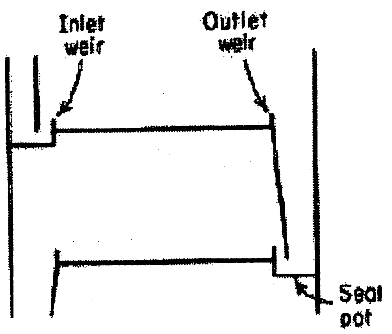
Tray spacing Tray spacing is usually chosen on the basis of expediency in construction, maintenance, and cost and later checked to be certain that adequate insurance against flooding and excessive entrainment is present. For special cases where tower height is an important consideration, spacings of 15 cm (6 in) have been used. For all except the smallest tower diameters, 50 cm(20 in) would seem to be a more workable minimum from the point of view ofcleaning the trays..

TowerdiameterThe tower diameter and consequently its cross-sectional area must be sufficientlylarge to handle the gas and liquid rates within the region of satisfactory operation For a given type of tray at flooding, th superficial velocity of the gas V_F (volumetric rate of gas flow Q per net crossection for flow An) is related to fluid densities by

$$V_F = C_F\left(\frac{\rho_L - \rho_G}{\rho_G}\right)^{1/2}$$

The net cross section An is the tower cross section A_t minus the area taken up by the downspouts (A_d in the case of a cross-flow tray as in CF is an empirical constant, the value of which depends on the tray design. Some appropriately smaller value of V is used for actual design; for non foaming liquid this is typically 80 to 85 percent of V_F(75 percent or less for foaming liquids),subject to check for entrainment and pressure-drop characteristics

DownspoutsThe liquid is led from one tray to the next by means of downspouts, or downcomers. These may be circular pipes or preferably portions of the tower cross section set aside for liquid flow by vertical plates, Sincethe liquid is agitated into a froth on the tray, adequate residence time must be allowed in the downspout to permit disengaging the gas from the liquid, so that only clear liquid enters the tray below. The downspout must be brought close enough to the tray below to seal into the liquid on that tray , thus preventing gas from rising up the downspout to short-circuit the tray above. Seal pots and seal-pot dams (inlet weirs) may be used , but they are best avoided (see below), especially if there is a tendency to accumulate sediment. If they are used, weep holes (small holes through the tray) in the seal pot should be used to facilitate draining the tower on shutdown. Weirs The depth of liquid on the tray required for gas contacting is maintained by an overflow (outlet) weir, which mayor may not be a continuation of the downspout plate. Straight weirs are most common; multiple V-notch weirs maintain a liquid depth which is less sensitive to variations in liquid flow rate and consequently also from departure of the tray from levelness; circular weirs, which are extensions of circular pipes used as downspouts, are not recommended. Inlet weirs may result in a hydraulic jump of the liquid and are not generally recommended. In order to ensure reasonably uniform distribution of liquid flow on a single-pass tray, a weir length of from 60 to 80 percent of the tower diameter is used. lists the percentage of the tower cross section taken up by downspouts formed from such weir plates.



Downspout

Sieve (perforated) trays

These trays have been known almost as long as bubble-cap trays, but they fell out of favor during the first half of this century. Their low cost, however, has now made them the most important of tray devices.The principal part of the tray is a horizontal sheet of perforated metal, across which the liquid flows,with the gas passing upward through the perforations. The gas, dispersed by the perforations, expands the liquid into a turbulent froth, characterized by a very large interfacial surface for mass transfer. The trays are subject to flooding because of backup of liquid in the downspouts or excessive entrainment (priming),as described earlier.

DesIgn of Sieve Trays

The diameter of the tower must be chosen to accommodate the flow rates, the details of the tray layout must be selected, estimates must be made of the gas-pressure drop and approach to flooding & and assurance against excessive weeping and entrainment must be established.

Tower diameter The flooding constant C_F of has been correlated for the data available on flooding .The original curves can be represented b

$$C_F = \left[\alpha \log \frac{1}{(L'/G')(\rho_G/\rho_L)^{0.5}} + \beta\right]\left(\frac{\sigma}{0.020}\right)^{0.2}$$

perforation and active area Hole diameters from 3 to 12 mm 0 to ! in) are commonly used, 4.5 mm(k in) most frequently although holes as large as 25 mm have been successful For installations, stainless steel or other alloy perforated sheet is used, rather than carbon steel, even though not necessarily required for corrosion resistance. Sheet thickness is usually less than one half than on the hole diameter for stainless steel, less than one diameter for carbon steel or copper alloys.
Table lists typical values.
The holes are placed in the comers of equilateral triangles at distances between centers (pitch) of from 2.5 to 5 hole diameters. For such an arrangement

$$\frac{A_o}{A_a} = \frac{\text{hole area}}{\text{active area}} = 0.907\left(\frac{d_0}{p'}\right)^2$$

Typically, the peripheral tray support, 25 to 50 mm (I to 2 in) wide, and the beam supports will occupy up to 15 percent of the cross-sectional area of the tower; the distribution zone for liquid entering the tray and the disengagement zone for disengaging foam (which are sometimes omitted) use 5 percent or more [47, 66]; and downspouts require additional area The remainder is available for active perforations (active area A_d),

Liquid depths Liquid depths should not ordinarily be less than 50 mm (2 in), *to* ensure good froth formaton These limits refer to the sum *of* the weir height h_w plus the crest over the weir $h_l$calculated as clear liquid although in the perforated area the equivalent clear-liquid depth will be smaller than this.

Weirs The crest of liquid over a straight rectangular weir can be estimated by the well-known Francis formula

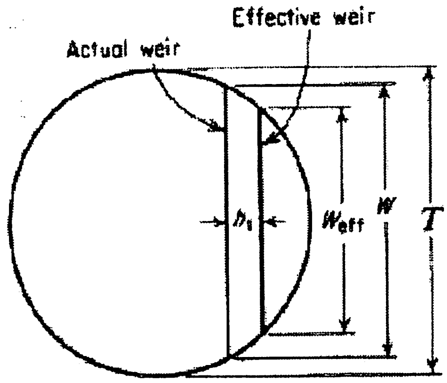
$$\frac{q}{W_{eff}} = 1.839h_1^{3/2}$$

where q - rate of liquid flow, m3Is
W_{eff} - effective length of the weir, m
H_l - liquid crest over the weir, m
Because the weir action is hampered by the curved sides of the circular tower, it is recommended that W_{eff} be represented as a chord of the circle of diameter *T,* a distance *h*l farther from the center than the actual weir, as in can then be rearranged tot

$$h_1 = 0.666\left(\frac{q}{W}\right)^{2/3}\left(\frac{W}{W_{eff}}\right)^{2/3}$$

$$\left(\frac{W_{eff}}{W}\right)^2 = \left(\frac{T}{W}\right)^2 - \left\{\left[\left(\frac{T}{W}\right)^2 - 1\right]^{0.5} + \frac{2h_1}{T}\frac{T}{W}\right\}^2$$

For *WIT* - 0.7, which is typical, can be used with Well- *W* for *hl/W* - 0.055 or less with a maximum error of only 2 percent in *hi,* which is negligible.



Effective Weir Length

Pressure drop for the gas For convenience, all gas-pressure drops will be expressed as heads of clear
liquid of density PLon the tray. The pressure drop for the gas he; is the sum of the effects for flow of gas through the dry plate and those caused by the presence of liquid:

$$h_G = h_D + h_L + h_R$$

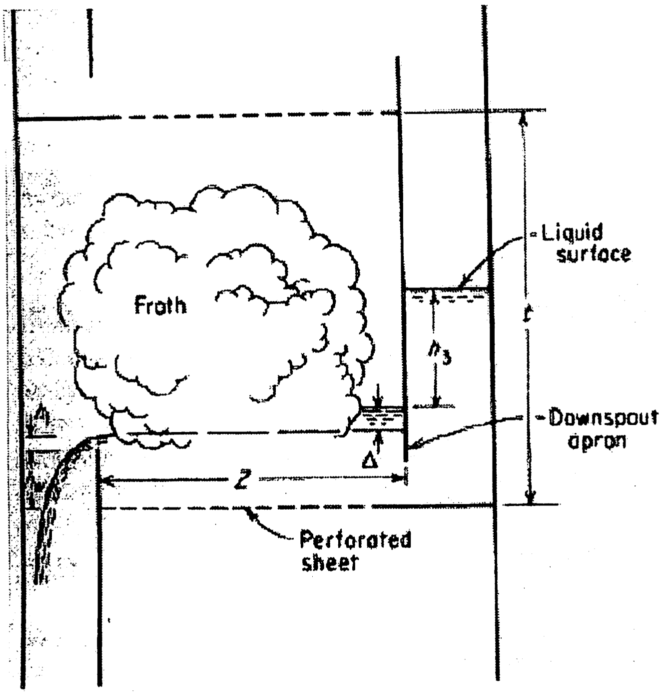
where h_D = dry-plate pressure drop
h_L = pressure drop resulting from depth of liquid on tray
h_R = residual pressure drop

Dry pressure drop h_D This is calculated on the basis that it is the result to a loss in pressure on entrance to the perforations, friction within the short tube formed by the perforation owing to plate thickness, and an exit loss

$$\frac{2h_D g \rho_L}{V_o^2 \rho_G} = C_o\left[0.40\left(1.25 - \frac{A_o}{A_n}\right) + \frac{4lf}{d_o} + \left(1 - \frac{A_o}{A_n}\right)^2\right]$$

The Fanning friction factor *f* is taken from a standard chart *Co* is an orifice coefficient which depends upon the ratio of plate thickness to hole diameter . Over the range *1/ do* - 0.2 to 2.0

$$C_o = 1.09\left(\frac{d_o}{l}\right)^{0.25}$$



Scheamitic diagram of sieve tray

Hydraulicbead h_L In the perforated region of the tray, the liquid is in the form of a froth. The equivalent depth of clear liquid *hL* is an estimate of that which would obtain if the froth collapsed. That is usually less than the height of the outlet weir, decreasing with increased gas rate. Some methods of estimating *hL* use a specific *aeration factor* to describe this In which is the recommended relationship the effect of the factor is included as a function of the variables which influence it

$$h_L = 6.10 \times 10^{-3} + 0.725 h_W - 0.238 h_W V_a \rho_G^{0.5} + 1.225 \frac{q}{z}$$

where z is the average flow width. which can he taken as *(T + W)/2.*

Residual gas pressure drop h_R This is believed to he largely the result of overcoming surface tension as the gas issues from a perforation. A balance of the internal force in a static bubble required to overcome surface tension is

$$\frac{\pi d_p^2}{4} \Delta p_B = \pi d_p \sigma$$

$$\Delta p_B = \frac{4\sigma}{d_p}$$

where Δp_B is the excess pressure in the bubble due to surface tension. But the bubble of gas grows over a finite time when the gas flows. and by averaging over time , it develops that the appropriate value is Δp_R

$$\Delta p_R = \frac{6\sigma}{d_p}$$

Since the bubbles do not really issue singly from the perforations into relatively quiet liquid, we substitute as an approximation the diameter of the perforations d_o which leads to

$$h_R = \frac{\Delta p_R\, g_c}{\rho_L g} = \frac{6\sigma g_c}{\rho_L d_o g}$$

Pressure loss at liquid entrance *h2* The flow of liquid under the downspout apron as it entersthe tray results in a pressure loss which can he estimated as equivalent to three velocity heads

$$h_2 = \frac{3}{2g}\left(\frac{q}{A_{da}}\right)^2$$

where A_{da} is the smaller of two areas, the downspout cross section or the free area between the downspout apron and the tray. Friction in the downspout is negligible.

Backup in the downspout The distance h_3. the difference in liquid level inside and immediately outside the downspout, will he the sum of the pressure losses resulting from liquid and gas flow for the tray above Since the mass in the downspout will he partly froth carried over the weir from the tray above, not ye"t disengaged, whose average density can usually he estimated roughly as half that of the clear liquid, safe design requires that the level of equivalent clear liquid in the downspout he no more than half the tray spacing. Neglecting A. the requirement is

$$h_W + h_1 + h_3 < \frac{t}{2}$$

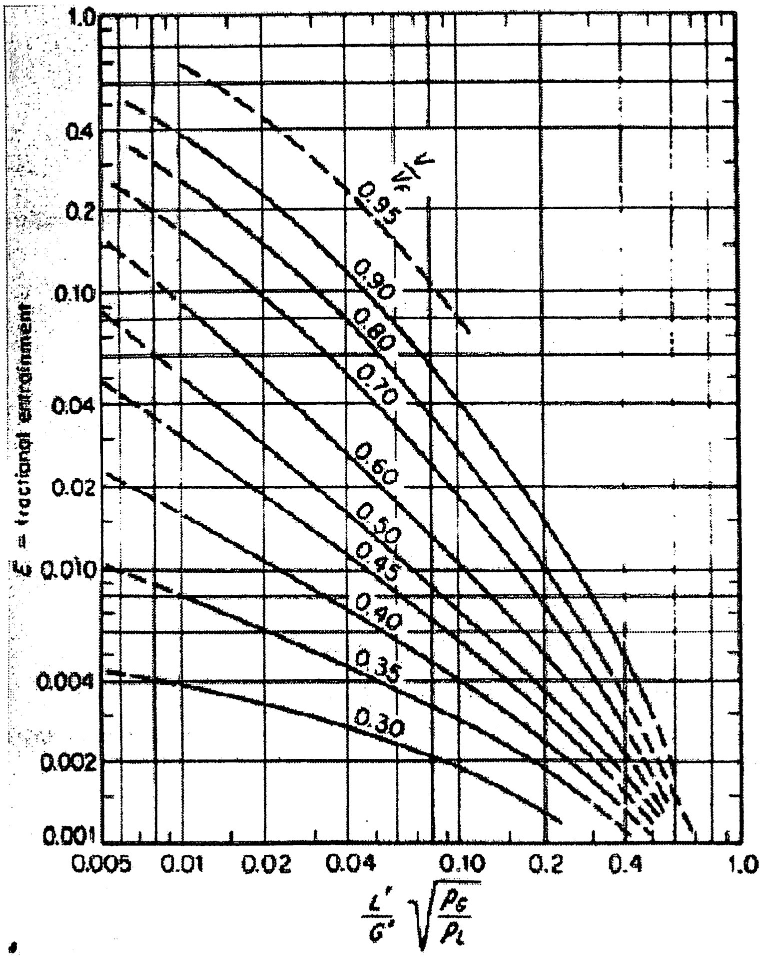
l

Weeping if the gas velocity through the holes is too small, liquid will drain through them andcontact on the tray for that liquid will be lost. In addition, for cross-flow trays, such liquid does not flow the full length of the tray below. The data on incipient weeping are meager, particularly for large liquid depths, and in all likelihood there will always be *some* weeping.

$$\frac{V_{ow}\mu_G}{\sigma g_c} = 0.0229\left(\frac{\mu_G^2}{\sigma g_c \rho_G d_o}\frac{\rho_L}{\rho_G}\right)^{0.379}\left(\frac{l}{d_o}\right)^{0.293}\left(\frac{2A_a d_o}{\sqrt{3}\,p'^3}\right)^{2.8/(Z/d_o)^{0.724}}$$

Liquid entrainment When liquid is carried by the gas up to the tray above, the entrained liquid is Caught in the liquid on the upper tray. The effect is cumulative, and liquid loads on the upper trays of a lower can become excessive. A convenient definition of the degree of entrainment is the fractionofthe liquid entering a tray which is carried to the tray above

$$\text{Fractional entrainment} = E = \frac{\text{moles liquid entrained/(area)(time)}}{L + \text{moles liquid entrained/(area)(time)}}$$



Entrainment graph

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Designing for stripping an aniline water solution with steam

Given :

At the top of the tower :

Temperature =98.5°C

Pressure = 745mmHgabs

Liquid :

Composition =7 mass% aniline

Rate =6.3 Kg/s

Density(=961Kg/m3

Viscosity =$3*10^{-4}$ Kg/m.s

Surface tension =0.058 N/m

Aniline diffusivity =$52*10^{-10}$ m2/s

Molecular wt. of H_2O = 18

Molecular wt of aniline = 93

Average molecular wt = 0.07*93+(1-0.07)*18

=23.25 Kg/Kmol

Volume flow rate (q) = 6.3/961= 6.55*10-3 m3/s

Vapour :

Composition =3.6 mole%aniline

Rate =3.15 Kg/s

Aniline diffusivity = $1.261*10^{-5}$ m2/s

Average molecular wt = 0.036*93 +(1-0.036)*18

= 20.7 Kg/Kmol

Gas density = 20.7*273/22.4*(273+98.5) =0.679 Kg/m3

Gas flow rate (Q) = 3.15/0.679 = 4.64 m3/s

1. **perforation**

   stainless steel

   take do = 4.5 mm

   equilateral triangle pitch =12 mm between hole centre

   plate thickness/hole diameter =0.43

   plate thickness(l) =0.43*4.5 = 2mm

$$\frac{A_o}{A_a} = \frac{\text{hole area}}{\text{active area}} = 0.907\left(\frac{d_0}{p'}\right)^2$$

$$=0.907(4.5/12)^2$$

$$=0.1275$$

2. **tower diameter**

   take t = 0.50 m tray spacing

$$\frac{L'}{G'}\left(\frac{\rho_G}{\rho_L}\right)^{0.5}$$

$= (6.55*10^{-3}*(961/0.679)^{0.5}) /4.64$
$=0.053$

$\alpha = 0.0744(0.50)+0.01173 = 0.0489$

$\beta = 0.0304(0.50) +0.015 = 0.0302$

$$C_F = \left[\alpha \log \frac{1}{(L'/G')(\rho_G/\rho_L)^{0.5}} + \beta\right]\left(\frac{\sigma}{0.020}\right)^{0.2}$$

$=0.1145$

$$V_F = C_F\left(\frac{\rho_L - \rho_G}{\rho_G}\right)^{1/2}$$

$= 4.31$ m/s

V= 0.75*4.31
= 3.23 m/s

An = At –Ad
Let weir lenth W = 0.75T
Ad = 11.255%
At = 1
An = 1-(11.255/100)
= 0.88745
An = Q/V =4.64/3.23= 1.437 m2

0.88745At = 1.437
At = 1.619 m2
$T = (At*4/\pi)^{0.5}$
=1.44 m
Corrected At = $\pi*T^2/4$
= 1.629 m2
W = 0.75(1.44) = 1.08 M
Ad = 0.11255 * 1.629 = 0.1833 m2
Area taken by [tray support + disengaging and distribution zone]
40 mm wide support ring

50mm wide disengaging and distribution zone
=2*[0.040*1.44]+ 2*[0.050*1.44]
=0.2592 m2

Aa =At- 2Ad – area taken by [tray support + disengaging and distribution zone]
= 1.629- 2(0.1833)-0.2592
= 1.0032 m2

3. weir crest h_1 and weir height hw

let h1 = 25 mm= 0.025 m
h1/T = 0.025/1.44 = 0.02
T/W =1.44/1.08 = 1.333
q/W = 6.55* 10^{-3}/1.08 = 6.06 *10^{-3} m2/s

$$\left(\frac{W_{eff}}{W}\right)^2 = \left(\frac{T}{W}\right)^2 - \left\{\left[\left(\frac{T}{W}\right)^2 - 1\right]^{0.5} + \frac{2h_1}{T}\frac{T}{W}\right\}^2$$

= 0.918

$$h_1 = 0.666\left(\frac{q}{W}\right)^{2/3}\left(\frac{W}{W_{eff}}\right)^{2/3}$$

= 0.0209 m
Let h_2 =0.0209 m
h_2/ T =0.0209/1.44= 0.015
Weff/ W = 0.9279
h_2 =0.02105
let h_3 =0.02195
h_3/ T= 0.02105/1.44 = 0.02105/1.44 = 0.0146
Weff/W =0.9299
h_3 = 0.02109
let h_4 = 0.02109
h_4/T =0.02109/1.44 = 0.0146
Weff/W = 0.929
Taking:
Weff/W =0.9299
h_1 = 0.02109 m
let weir height hw = 50 mm = 0.05m

4. Pressure drop for the gas

a. determination of h_D

$$C_o = 1.09\left(\frac{d_o}{l}\right)^{0.25}$$

$= 1.09(4.5/2)^{0.25}$
$= 1.335$

Ao =0.1275 Aa
$= 0.1275(1.0032)$
$= 0.128$ m2

Vo=Q/Ao = 4.64/0.128 = 36.25 m/s

Re = 0.0045*36.25*0.679/1.25*10^{-5} =8860
f =0.009

$$\frac{2h_D g \rho_L}{V_o^2 \rho_G} = C_o\left[0.40\left(1.25 - \frac{A_o}{A_n}\right) + \frac{4lf}{d_o} + \left(1 - \frac{A_o}{A_n}\right)^2\right]$$

h_d =0.0828 m

b. determination of h_l
Va = Q/Aa =4.64/1.0032=4.625 m/s
Z = T+W/2 = 1.44 +1.08/2 = 1.26m

$$h_L = 6.10 \times 10^{-3} + 0.725 h_W - 0.238 h_W V_a \rho_G^{0.5} + 1.225 \frac{q}{z}$$

= 0.0033 m

c. determination of h_R

$$h_R = \frac{\Delta p_R\, g_c}{\rho_L g} = \frac{6\sigma g_c}{\rho_L d_o g}$$

=6*0.058/961*0.0045*9.807
= 8.2*10^{-3}

$h_G = h_d + h_L + h_R$ =0.0828 +0.0033 +8.2*10^{-3} =0.0943 m

Pressure loss at liquid entrance : h_2
The down spout aprox. will be set out at =hw -0.025 = 0.025
The area for liquid flow under approx.
= 0.025*W
= 0.025*1.08
= 0.027 m2
Ada= 0.027 m2

$$h_2 = \frac{3}{2g}\left(\frac{q}{A_{da}}\right)^2$$

$= 9.001 * 10^{-3}$ m
Back up in the down spout
$h_3 = h_G + h_2$
$= 9.001 * 10^{-3} + 0.0943$
= 0.1033 m

Check on flooding :

$h_W + h_l + h_3 < t/2$

$h_W + h_l + h_3 = 0.05 + 0.02109 + 0.1033 = 0.17439$
t/2 = 0.50/2 = 0.25

hence chosen t is satisfactory

4. Weeping velocity :

For W/T= 0.75
Distance from the centre of the tower = 0.3296*T
= 0.3296*1.44
= 0.475
Z = 2*0.475
= 0.95

$$\frac{V_{ow}\mu_G}{\sigma g_c} = 0.0229\left(\frac{\mu_G^2}{\sigma g_c \rho_G d_o}\frac{\rho_L}{\rho_G}\right)^{0.379}\left(\frac{l}{d_o}\right)^{0.293}\left(\frac{2A_a d_o}{\sqrt{3}\,p'^3}\right)^{2.8/(Z/d_o)^{0.724}}$$

Vow = 5.14 m/s

5. Entrainment :

$V/V_F = 3.23/4.31 = 0.7$

$$\frac{L'}{G'}\left(\frac{\rho_G}{\rho_L}\right)^{0.5}$$

= 0.053

E = 0.038

6. Determination efficiency of sieve tray

Y_{n+1} = 3.6 mole % aniline

$\mu_{1g} = \Pi\, \mu_{1gi}\, y_i\, Mi^{0.5} / \Pi y_i\, Mi^{0.5}$

$= (0.82*0.036*93^{0.5} +0.27*0.964*18^{0.5}) /(0.036* 93^{0.5} +0.964*18^{0.5})$

= 0.313 cp

$Sc = \mu_g / D_G\ \rho_g$

$= 0.313*10^{-3} / 0.679*1.261*10^{-5}$

= 36.55

$$\theta_L = \frac{\text{vol liquid on tray}}{\text{vol liquid rate}} = \frac{h_L z Z}{q}$$

$= 0.0033*1.26*0.95 /6.55*10^{-3}$

=0.603

$$D_E = \left(3.93 \times 10^{-3} + 0.0171\, V_a + \frac{3.67q}{Z} + 0.1800 h_W\right)^2$$

= 0.0137 m2/ s

$$N_{tL} = 40\,000\, D_L^{0.5}(0.213\, V_a \rho_G^{0.5} + 0.15)\theta_L$$

= 1.67

$$N_{tG} = \frac{0.776 + 4.57 h_W - 0.238\, V_a \rho_G^{0.5} + 104.6q/Z}{Sc_G^{0.5}}$$

= 0.135

For 7% aniline

$X_{Local} = (7/93)/(7/93+93/18)$

$= 0.0143$

Plotting of equilibrium curve aniline -water

Antonie constant for aniline

A =6.4450

B =1731.50

C= -67.0500

$\log_{10} P_A = A - B/(T + C)$

$= 6.4450 - 1731.50/(371.5 - 67.0500)$

$= 0.7576$

$P_A = 5.72$ kpas

Antonie constant for water

A =7.0733

B=1686.40

C= -46.2500

$\log_{10} P_w = A - B/(T + C)$

$= 1.888$

$P_w = 77.26$kpas

Bubble point calculation :

$P = P_w + [P_A - P_w] Xi$

$Yi = Xi\, P_A / P$

1. $X_1 = 0$
   P =77.26
   $Y_1 = 0$
2. $X_1 = 0.1$
   P =70.106
   $Y_1 = 0.0163$
3. $X_1 = 0.2$
   P = 62.952
   $Y_1 = 0.0181$
4 $X_1 = 0.3$
   P = 55.798
   $Y_1 = 0.0308$
5..$X_1 = 0.5$
   P =48.64
   $Y_1 = 0.047$
6. $X_1 = 0.5$
   P =41.49
   $Y_1 = 0.0689$

7. X_1 =0.6
P =34.336
Y_1 =0.0689
8. X_1 =0.7
P =27.182
Y_1 =0.1473
9. X_1 =0.8
P = 20.028
Y_1 =0.228

10. . X_1 =0.9
P = 12.874
Y_1 =0.399

11 X_1 =1
P =5.72
Y_1 =1

Line AC is drawn with slope :

- N_{tL} *L/N_{tG} *G = - 1.67 *0.271 /0.135 *0.152
- Θ = (-22.05)tan⁻
- = -87.40

L = 6.3 Kg /s
= 6.3/23.23 Kmol/s
= 0.271 Kmol/s
G = 3.15/20.7 Kmol/s
= 0.152 Kmol/s
Slope = tan 17° = 0.306

$$\frac{1}{N_{tOG}} = \frac{1}{N_{tG}} + \frac{mG}{L}\frac{1}{N_{tL}}$$

$1/N_{toG} = 0.1332$

$N_{toG} = 0.1332$

Point efficiency (E_{OG}) = $1-e^{NtoG}$

= $1-e^{0.1332}$
= 0.414

Notation :

Q	volumetric flowrate
q	volumetric liquid flowrate
do	perforation diameter
l	plate thickness
Ao	area of perforation
Aa	active area
t	tray spacing
L'	superficial liquid mass velocity
G'	superficial gas mass velocity
C_F	flooding constant
V_F	flooding velocity
An	net tower cross-sectional area for gas flow
Ad	downspout cross-sectional area
At	tower cross-sectional area
T	tower diameter
W	weir length
h_l	weir crest
Weff	effective weir length
h_W	weir height
Co	orifce coefficient
Ao	area of perforation
Vo	velocity through an orifice

Re	reynold number
f	frictional factor
h_D	dry plate gas pressure drop as head
h_L	gas pressure drop due to liquid hold up
h_R	residual gas pressure drop
h_G	gas pressrure drop as head
Ada	smaller of two area
Vow	weeping velocity
E	entrainment
h_3	back up of liquid in downspout
h_2	head loss owing to liquidflow under down spout
Y_{n+1}	mass fraction in gas phase
Sc	schimdt number
θ_L	time of residence of liquid on tray
D_E	eddy diffsivity
X_{Local}	mass fraction in liquid phase
P_w	vapour pressure of water
P_A	vapour pressure of aniline
N_{tL}	number of liquid phase transfer unit
N_{tG}	number of gas phase transfer unit
N_{toG}	number of overall gas phase transfer unit
X_{Local}	mass fraction in liquid phase
A ,B,C	antonie constant

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