Mass Transfer

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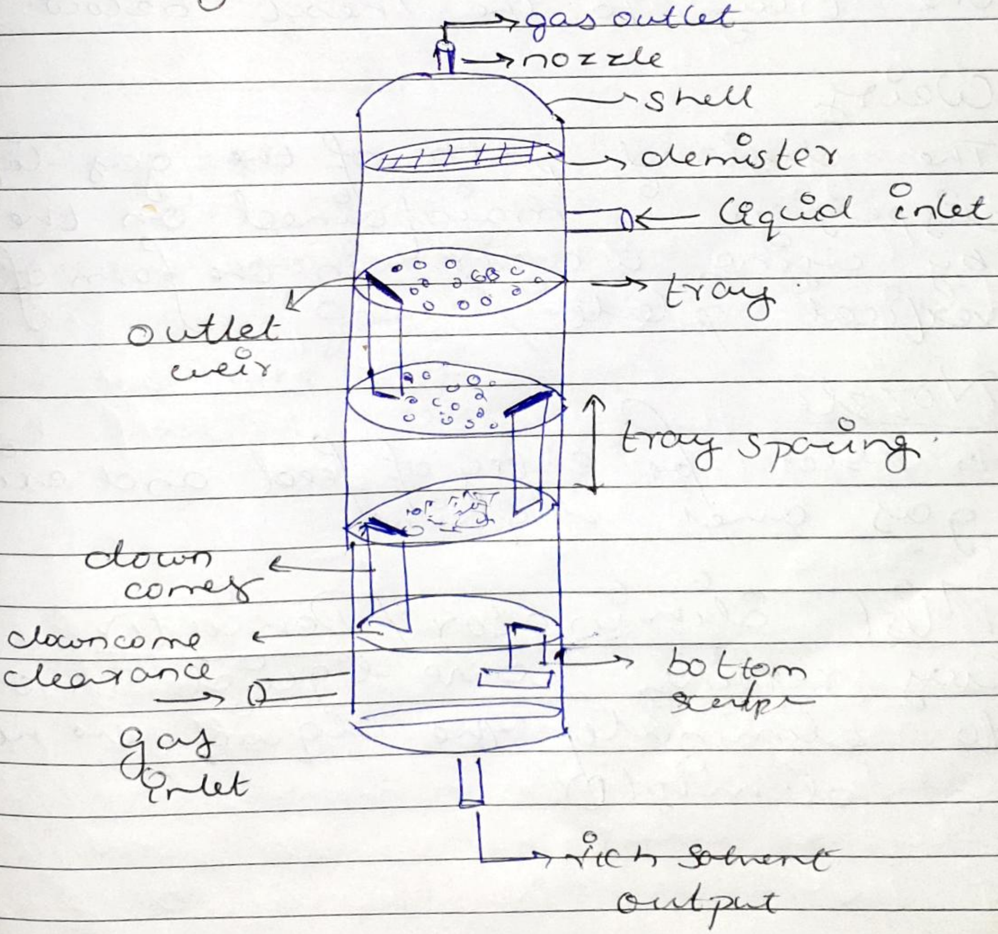
Q.1) <u>Gas is dispersed</u>
① Tray towers
② Bubble columns
③ Mechanically agitated vessels

<u>Liquid is dispersed</u>
① Spray towers
② Packed towers
③ Venturi scrubbers

Q.2) <u>Tray Columns</u>



Date
Page

Tray

① Allows gas to flow through the holes or passages. Gas bubbles through the liquid forming gas liquid dispersion

② Mass transfer between the phases occurs on the trays

Downcomer

Downcomer is a passage through which the liquid flows down from one tray to the next below.

Weirs

The desired path of the gas-liquid dispersion is maintained on the tray by using a weir in the form of a vertical plate

Nozzle

→ used for entry of feed and exit of gas and liquid.

Mist Eliminator / Demister

Gas retains some liquid. In order to eliminate the liquid we need a demister.

Q.3 Types of trays

① Bubble cap trays

A bubble cap consists of two major components - a bell shaped cap and a "riser". The riser is installed through a hole on the tray floor and the bell-shaped cap is bolted to it. A ring gasket is used below the nut. The riser is a piece of tube with a flared or expanded bottom end. The riser acts as the vapour passage and also holds the cap.

② Sieve tray

Simplest type of tray in which bubble caps are replaced by holes or perforations for the entrance of the gas into liquid. The holes are of relatively small diameter - usually ranging from 1/8 - 1/2 inch. This is why it is called the "sieve tray".

③ Valve tray

It provides variable area for the gas or vapour flow depending upon the flow rate or throughput. Hence it is called the valve tray.

→ Valve tray is a good choice for highly fouling services. It offers lower pressure drop than bubble type and is also cheaper. It is preffered if a high turndown is anticipated

→ Sieve trays are the cheapest. They are used if high turndown is not important

→ Bubble cap trays should only be used when very low vapour rates have to be handled and a positive liquid seal is essential at all flow rates.

Q. 4. Dumping

Extreme case of leakage through the tray deck if the vapour velocity is low & the vapour pressure drop across the tray is not suff. to hold the liquid.

Weeping

If a very small fraction of the liquid flows from a tray to lower one through perforations of the tray deck, this phenomenon is called weeping. Weeping causes some reduction of the tray efficiency because the liquid dripping down to the tray below through perforations has not been in full contact with the gas or vapour. In practice a small amount of weeping is un-avoidable.

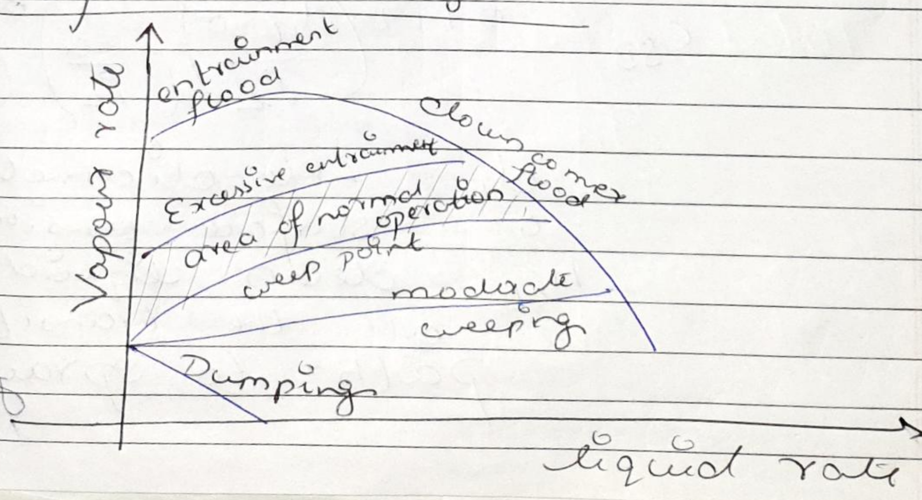
Entrainment

Gas bubbles through the liquid pool vigourously. Liquid is carried by gas up to the tray due to high gas flow rate

Flooding

Flooding is an abnormal condition of excessive accumulation of liquid & simultanious excessive pressure drop across the flooded tray.

Q.5 Performance diagram



Q.6 Tray diameter

Tray diameter is determined from flooding considerations. The flooding velocity corresponds to the max. capacity.

① Fair's method

$$u_{s,fl} = C_{SB}\left(\frac{\rho_L - \rho_G}{\rho_G}\right)^{1/2}$$

$u_{s,fl}$ → superficial velocity at flooding

C_{SB} → Saunders - Brown flooding coeff. Given by →

$$C_{SB} = 0.03445 + 5.421\times10^{-3} \cdot S^{0.755} \times e^{-1.463 \cdot F_{lv}^{0.842}}$$

$\frac{ft}{s}$

S = tray spacing (inches)

② Kister & Maas Method

$$C_{SB} = 0.144\left(\frac{d_H^2 \cdot \sigma}{\rho_L}\right)^{0.125}\left(\frac{\rho_G}{\rho_L}\right)^{0.1}\left(\frac{S}{h_{ct}}\right)^{0.5}$$

d_H = hole diameter
σ = surface tension
h_{ct} = clean liquid height at the transition from path to spray regime

$$h_{ct} = (h_{ct})_w \left(\frac{62.2}{\rho_L}\right)^{0.5(1-n)}$$

where $n = 0.0231 \frac{d_H}{f_h}$,

and $(h_{ct})_w = \dfrac{0.29\, f_h^{-0.791} \cdot d_H^{0.833}}{1 + 0.0036\, Q_L^{-0.59} \cdot f_h^{-1.79}}$

f_h = fractional area.

$$A_T = \frac{G_v}{(f_{fl}\, u_{s,fl})(1-f_d)} = \frac{A_a}{1-f_d} = \frac{A_a}{f_a}$$

G_v = volumetric gas flow rate
f_{fl} = fractional approach to the flooding velocity.
f_a = fractional active area
A_T = tower cross section

Q.7 Packed tower

① support plate

1) Supports weight of packing and the liquid held up in the packing during the operation.

2) Allows the gas to flow through & get distributed

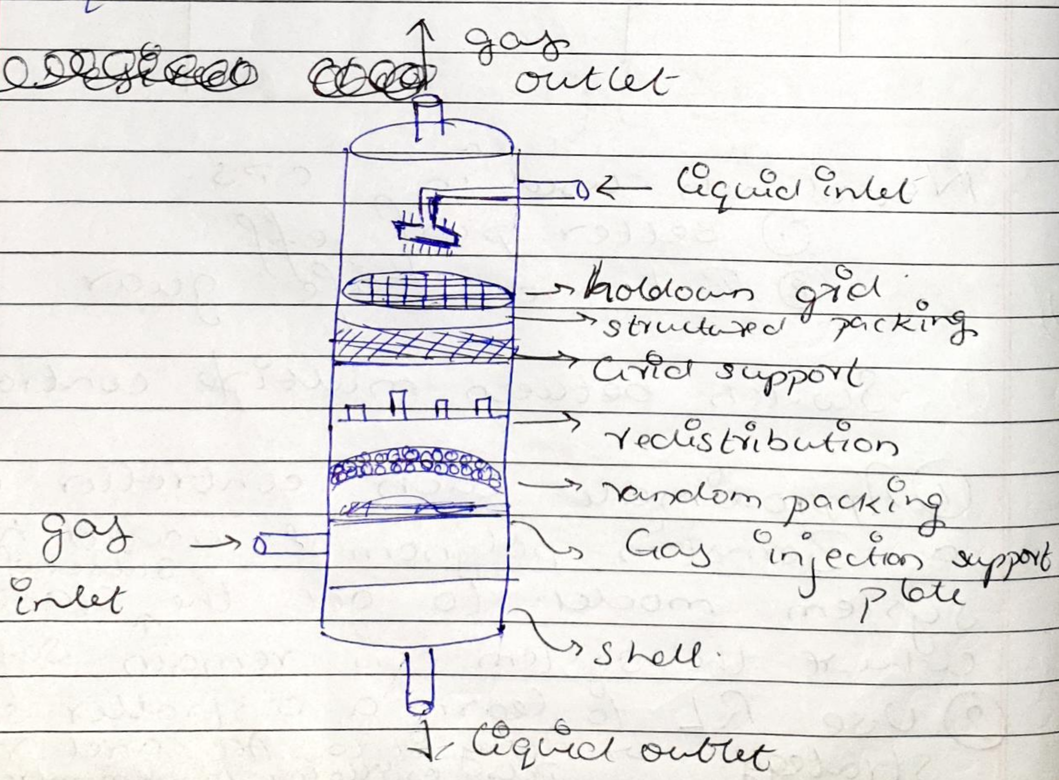
3) It allows the liquid to leave the bed.

Redistribution

Proper distribution of the feed liquid over the bed is essential for the satisfactory performance. Liquid distributor feeds the bed at a pretty large number of points at equal rates

Holddown Plate

A sudden surge in the gas flow rate in a tower may physically lift the packing and may even fluidize a layer of packing at the top. Therefore, a hold down plate is required.



Q.8 Desired characteristics of packing

① large surface area
→ Interfacial area of contact between the gas and the liquid is created in a packed bed by spreading of the liquid on the surface of the packing.

② Uniform flow of gas & liquid

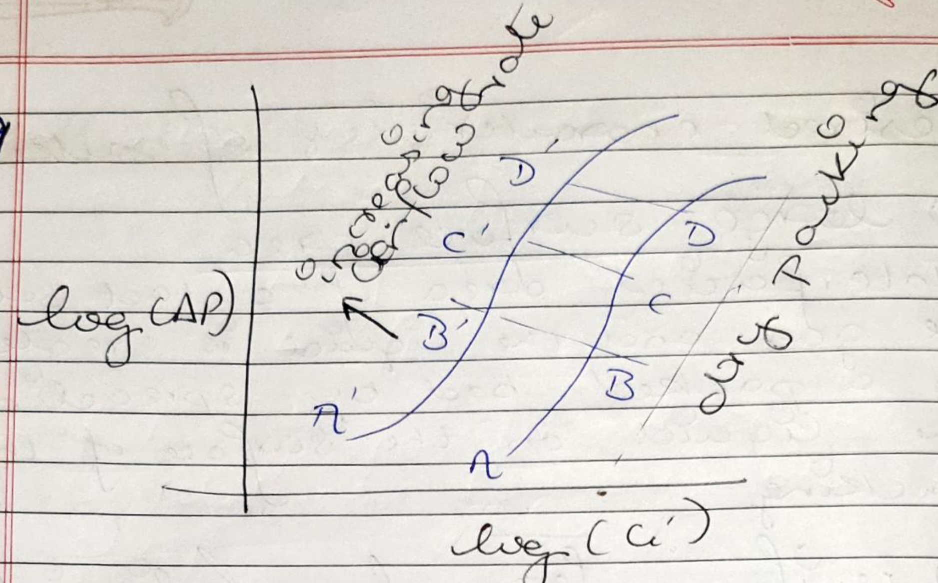
The packed bed must have a uniform voidage so that a uniform flow of gas & liquid can occur.

③ Void Volume
A packed bed should have a high fractional voidage so that pressure drop is low.

④ Mechanical Strength
The packing material should have sufficient mechanical strength so that it does not break or deform.

⑤ Fouling resistance
Packing should not trap fine solid particles that may be present in the liquid. Bigger packings are less susceptible to fouling.

Q.9



The slope of the straight section decreases slightly at higher liquid flow rates. If the gas rate is increased at const liquid rate, the drag of the gas impedes the downwards liquid velocity. The liquid hold up in the bed increases. This steady increase in the pressure drop ~~continues~~ continues till point B. Beyond B upflowing gas interferes strongly with the draining liquid.

Over region BC accumulation or loading of liquid starts. The point C is called incipient flooding. If the gas flow rate is further increased, liquid accumulates more in the upper region of the bed almost preventing the flow of the gas. This is called flooding (point D)

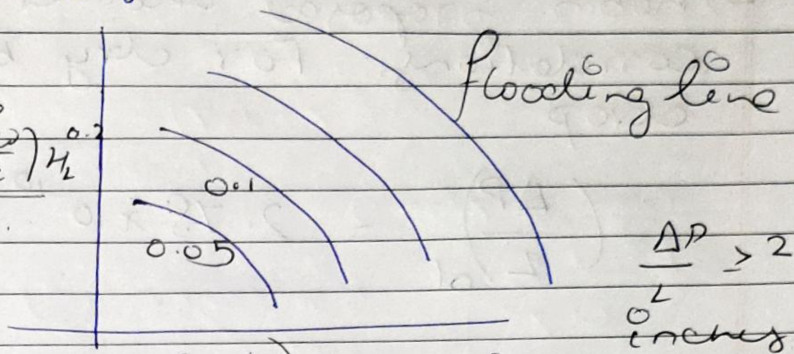
Q.10 Pressure drop correlation (GPDC)

→ Developed for all of the random packings.

→ Proposed by Eckert.

→ widely used in packed tower design.

$$\frac{G'^2 \cdot F_p \cdot \left(\frac{\rho_G}{\rho_L}\right) \mu_L^{0.2}}{\rho_G \cdot \rho_L \, g_c}$$



$\frac{\Delta P}{L} \geq 2$ inches of water per foot packed height makes incipient flooding

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

flow parameter → $F_{lv} = \frac{L'}{G'} \cdot \left(\frac{\rho_G}{\rho_L}\right)^{0.5}$

capacity parameter → $C_S \cdot F_p^{0.5} \cdot \nu^{0.05}$

$$C_S = u_{sg} \cdot \left(\frac{\rho_G}{\rho_L - \rho_G}\right)^{1/2}$$

→ F_p is the char. parameter of packing called packing factor.

→ C_S may be corrected for changes in the interfacial ~~system~~ tension and viscosity

$$(C_S)_{corr} = C_S \cdot \left(\frac{\sigma}{20}\right)^{0.16} \cdot \left(\frac{\mu}{0.2}\right)^{-0.11}$$

→ Kister and gill proposed a correlation for the flood point

$$\left(\frac{\Delta P}{L}\right)_{fl} = 0.115\, F_p^{0.7}$$

→ Robin proposed another set of correlations. For dry bed pressure drop

$$\left(\frac{\Delta P}{L}\right)_d = 2.78 \times 10^{-10} \cdot F_{pd}\left(\frac{G'}{\rho_G}\right)^2$$

Q. 11	Tray tower	Packed tower
① Gas pressure drop.	large	Smaller
② liquid hold up.	relatively larger	substancially smaller
③ liquid/gas ratio	very low	high
④ liquid cooling	suitable	–
⑤ Side streams	readily removed	–
⑥ Foaming systems	–	more suitable
⑦ Corrosion	–	more suitable
⑧ Cleaning	easier	–