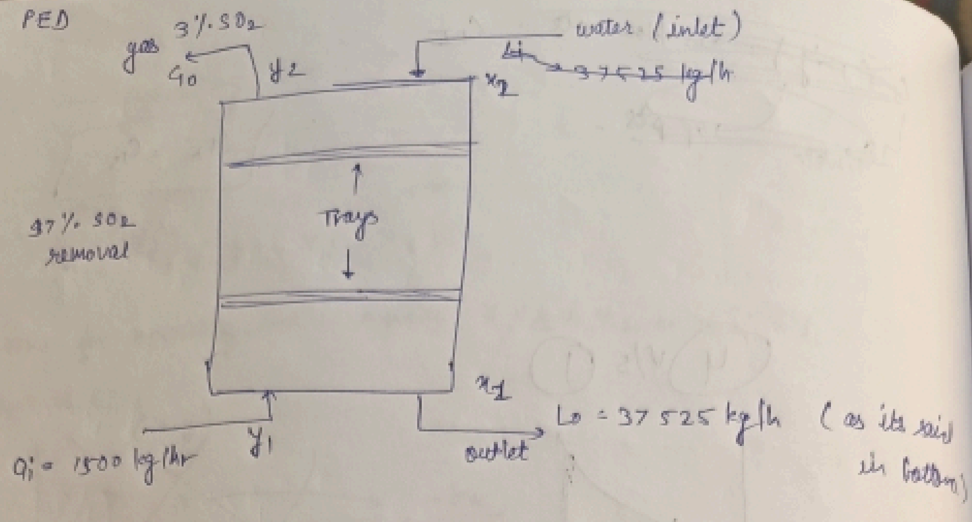
PED

(Q)



given 10% SO_2 90% air 1atm total pressure, 30°C

Average molecular weight $= \underset{(SO_2)}{(0.1)(64)} + \underset{(air)}{(0.9)(28.8)} = 32.3$ g

Rasching Ring 1½ inch or 50 mm.

Step 1 Assuming ideal gas $PV = nRT$

$PV = \frac{m}{(M_w)_{avg}} RT \qquad \frac{P(M_w)_{avg}}{RT} = \frac{m}{V} = \rho_G$ (gas density)

$$\rho_G = \frac{\overset{(P_a)}{101325} \times 32.3}{\underset{8.314\ J/molK}{R}(30+273)} = 1.298\ kg/m^3$$

Assumption liq is pure (if not given)

take $\rho_w = 1000\ kg/m^3$ always as the temp. doesn't fluctuate as much in questions. (~20-30°C)

* $\frac{\text{Flow rate}}{\text{avg. wt}}$ = Molar flow rate.

$G_s = \underset{\text{molar} \to 1500/32.3}{G_i}(1 - \underset{0.1}{y_1}) = G_0(1 - y_2)$

$L_s = L_0(1 - x_1) = L_i(1 - x_2)$

$G_s(Y_1 - Y_2) = L_s(X_1 - X_2) \qquad X_1 = \frac{x_1}{1-x_1}$

$L_i \times 18 \longrightarrow$ kg/hr (min) (for water)

(find) $L_0 = L_i + (SO_2)_{abs} \times 64$ kg/h

$G_i = 1500$ kg/hr

$L_0 = 37525$ kg/h (min).

$y_1 = 0.1$

step 2 fluid properties

liquid viscosity $\mu_L = 0.81$ cp (if not given we have to find out from the viscosity wala table)

liq density $\rho_L = 1000$ kg/m³

step 3 flooding line

→ for absorption, take bottom ~~and~~ L_0 & G_i

→ for stripping take upper L_i & G_0 (less likely to occur).

Now its absorption (given in question)

$L' = L_0 \quad G' = G_i$

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

$$\Rightarrow \left(\frac{37525}{1500}\right)\left(\frac{1.298}{1{,}000}\right)^{0.5} = 0.9.$$ → this is the value of x axis in fig 5.33 & 5.34.

→ for Rasching Ring, Berl ring } 1st gen. use Fig 5.33 GPDC (generalized pressure drop correlation)

→ for pal ring } 2nd gen use Fig 5.34

→ Now, draw perpendicular and find the pt where it intersects flooding line

here for $x = 0.9$ $y = 0.025$.

using 70% safety/ stability criteria

$y = y_F \times 70\% = 0.025 \times 0.7$

$\boxed{y = 0.0175}$.

Now draw a horizontal line from $y = 0.0175$ where it intersects $x = 0.9$' line

→ for verifying

$(\Delta P/L) = 0.115 f_p^{0.7}$ ↳ packing factor

↳ the only value of y

↳ for Raschig → Table 5.9

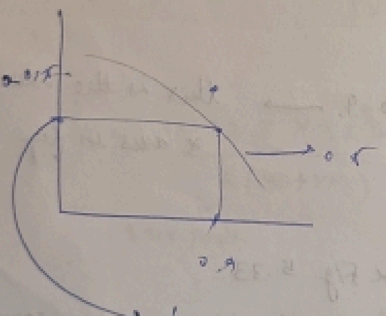
→ $y = 0.0175$

$x = 0.9$

and then find ~~Y~~ corresponding ~~y~~ coordinate value ~~of~~

for $x = 0.9$ so curve which is best fit is $(\Delta P/L) = 0.5$

$y' = 0.016$



→ $y' = 0.016$

$$y' = \frac{\overbrace{(G')^2}^{lb/ft^2hr} f_p (\rho_w/\rho_L) \mu_L^{0.2}}{\underbrace{\rho_G \rho_L}_{lb/ft^3} g_c}$$

we'll find G'.

$\mu_L = 0.81$ cp $\quad f_p = 945\ ft^{-1}$

$g_c = 9.81 m/s^2 = 4.18 \times 10^8$ ft/hr^2

we'll get G' from this

$G' = 607.6\ lb/ft^2h$ (here)

$G = G_1' = 1500 kg/hr = 1500/0.4536$

$= 3306.87\ lb/ft^2h$

$\text{area} = \dfrac{G}{G'} = \dfrac{3306.87}{607.6} = 5.44 ft^2$

$\text{area} = \dfrac{\pi D^2}{4} = 5.44\ ft^2 \Rightarrow \boxed{D = 2.63 ft}$

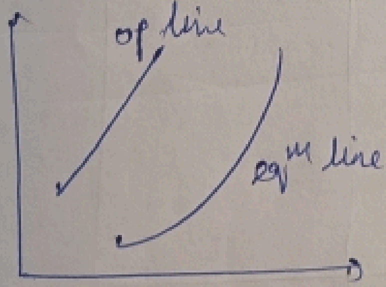
next step Packed bed height

$$h_T = \int_{y_2}^{y_1} \frac{G' dy}{k_y \bar{a}\,(1-y)(y-y_i)}$$

G' = gas flow rate per unit area (lb/ft^2h)

y_i = mol frac of solute at interface (eqm.)(line)

if k_x & k_y not given find using Sh formula



→ plot first

to generate op. line

PTO

0.14

air me SO_2 bacha

$$\boxed{y_2 = \frac{0.14}{41.79}}$$

→ air

y_1

0.0033

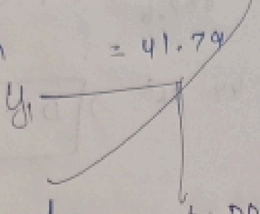
③ Calculation of mol fraction of SO_2 at exit of gas

$$\text{moles} = \frac{1500}{32.3} = 46.44 \text{ kmol/hr}$$

SO_2 inlet

10% of total mass = 4.64 kmol/hr

90% air = 41.79 (46.44 × 0.9)



y_1

0.0027

Outlet

97% removed

SO_2 conc^n (moles) = 4.64 (1 − 0.97) = 0.14 kmol/hr

SO_2 removed & added to liq = 4.64 (0.97) = 4.5

air will remain const

$G_s \rightarrow$ = 41.79 kmol/hr

(air pure) → ($k_x a$/k_y) slope ka value → will be const.

y	y_i	$G' = \frac{G_S}{(1-y)\,\text{area}}$	$\frac{G'}{k_y \bar{a}\,(1-y)(y-y_i)}$
0.1 ← 10%			
0.00335			

97% udd gya

3% bacha

$G_s = G_o (1 - y_2)$

$G_i (1 - y_1)$

$(1 - 0.1)$

→ kmol/hr

or

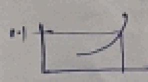
depends on $k_y \bar{a}$

$$\frac{y_1}{1-y_1}$$

2083.6

$$G_s (Y_1 - Y_2) = L_s (X_1 - X_2)$$

$Y \to \frac{y}{1-y}$ $\quad$ $X \to \frac{x}{1-x}$



0.1

0.027

→ as $y = 0.1$ $\quad$ 0.0033 $\quad$ 2083.69 $\quad$ → 0.0027

y_2 $\quad$ not

$x_2 = 0$ cuz pure water.

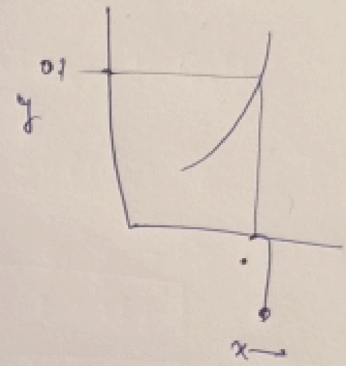
$$G_s \left(0.11 - \frac{y}{1-y}\right) = L_s \left(X_1 - \frac{x}{1-x}\right)$$

→ put y_2

$$\overset{0.111}{G_s\left(\frac{y_1}{1-y_1} - 0.0053\right)} = L_s\left(x_1 - \cancel{x_2}\right) \rightarrow 0$$

inlet

initial



① get x

② put in eqn

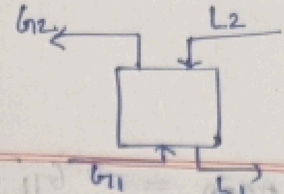
③ get Ls

~~pt~~

Now Ls × 1.25

$$G_s\left(0.111 - \frac{y}{1-y}\right) = L_s \times 1.25\left(0.00215 - \frac{x}{1-x}\right)$$

x & y.



Date / /

6.5 ⇒ $G_1 = 515$ kmol/h

$y_1 = 0.015$

Solute in the feed = 515 (0.015) = 7.8 kmol/h

carrier gas = 515 − 7.8 = 507.2 kmol

Moles solute absorbed = $7.8 - (0.0001 \times 507.2)$ ~~$7.8(1 - 0.0001)$~~ = 7.749 ~~7.799~~ kmol/h

$x_1^* = y_1/1.07 = 0.01402$ (For Min. liq. rate)

$x_{1\,max}$ lies on Equi. line

$y_2 = 0.0001 \approx 0$ $\quad x_2 = 0$ (Pure Water)

$$G_1 y_1 - G_2 y_2 = L_1 x_1^* - L_2 x_2$$

$$L_1 = \frac{G_1 y_1}{x_1^*} = \frac{515 \times 0.015}{0.01402} = 550.99 \approx 551$$

~~$L_1 = L_S = L_2(1-$~~ $\quad L_2 = L_S = L_1(1 - x_1^*)$

$$L_2 = (L_S)_{min} = 543.3 \text{ Kmol/h}$$

Actual $L_S = (1.3) \times (L_S)_{min} = 1.3 \times 543.3 = 706.3$

Total liquid rate at bottom = L_S + Moles Solute Absorbed

= 706.3 + 7.749

= 714.049 kmol/h

= 12853.782 kg/h

⇒ $F_{LV} = \frac{L_1}{G_1}\left(\frac{\rho_G}{\rho_L}\right)^{0.5} = 0.0947$

take $\frac{\Delta P}{L} = 0.5$ If not given

From Figure 5.34 $\quad$ y-axis $= 0.92 = C_S F_P^{0.5} (V_L)^{0.05}$

$F_P = 27 ft^{-1}$ $\quad V_L = \frac{\mu}{\rho} = \frac{0.86}{996} \times 100 = 0.86$

C_S = we will find C_S

$C_S = U_G \left[\frac{\rho_G}{\rho_L - \rho_G}\right]^{0.5}$ we will find U_G

Date / /

$$\text{tower Area } (ft^2) = \frac{G_1}{\rho_G \times u_G} \rightarrow lb/s$$

$$\frac{\pi}{4} d^2 = \text{area} \Rightarrow d = \_\_ \; ft$$

$$u_L = \frac{L_1}{\rho_L \times \text{area}} = \_\_$$

Re_G $\quad Re_L$ $\quad Sc_G$ $\quad Sc_L$ $\quad We_L$ $\quad Fr_L$

$h_L =$

$$k_L = (12)^{1/6} C_L \left(\frac{u_L D_L}{h_L l_\tau}\right)^{1/2} \qquad l_\tau = \frac{4\varepsilon}{a_p}$$

$$k_G = C_G \left(\frac{a_p}{l_\tau}\right)^{1/2} \frac{D_G}{(\varepsilon - h_L)^{1/2}} (Re_G)^{3/4} (Sc_G)^{1/3}$$

$$\frac{\bar{a}_{eff}}{a_p} = 3(\varepsilon)^{0.5} (Re_L)^{-0.2} (Fr_L)^{-0.45} (We_L)^{0.75}$$

$$k_x = k_L \times C$$

$$C = \frac{\text{Liq. at bottom}}{\text{area} \times u_L} = \frac{714.049 \text{ kmol} \times 10^3}{3600 \text{ s} \times 7.693 \, ft^2 \times 5} = 55$$

$$k_y = \frac{k_G P}{RT}$$

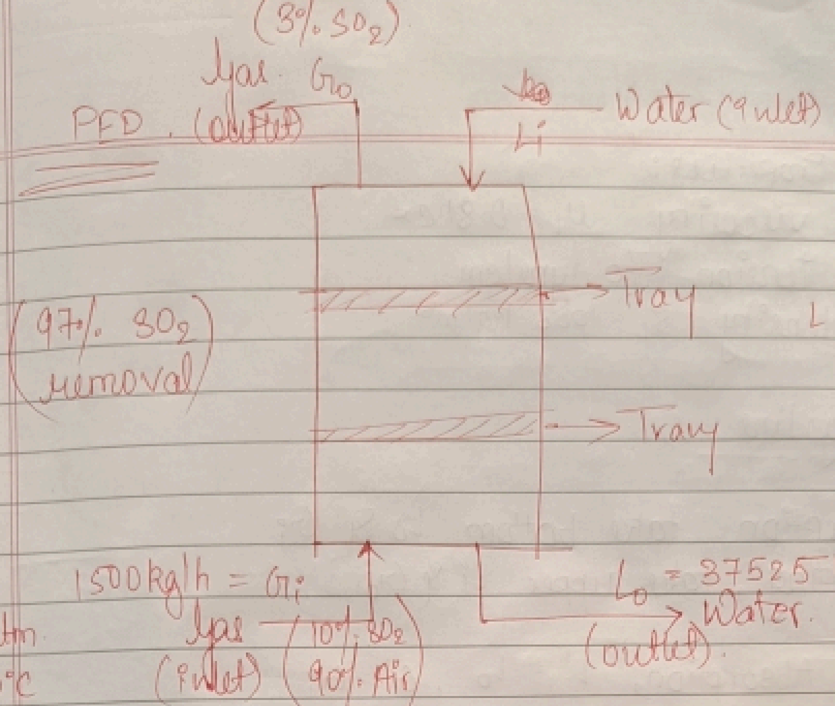
$$H_{tG} = \frac{G'}{k_y \bar{a}_{eff}} = \frac{G_1}{\text{area} \times k_y \bar{a}_{eff}}$$

$$H_{tL} = \frac{L_1}{\text{area} \times k_x \times \bar{a}_{eff}} \qquad l_\tau = \frac{4\varepsilon}{a_p}$$

$$\bar{S} = \frac{m G_1}{L}$$

$$\boxed{H_{tOG} = H_{tG} + \bar{S} H_{tL}}$$

PFD



P = 1 atm
T = 30°C

Q1

Given : For 1½ Raschig Rings

To find : (i) Diameter = ?
(ii) Height = 5 m.
(iii) ~~Blower~~ ~~= ?~~
(iv) ~~ΔP~~ ~~= ?~~

STEP 1: Assuming ideal gas law, [Gas density & molecular weight]

$$PV = nRT$$

$$PV = \frac{m}{(M_w)_{avg}} RT \Rightarrow \frac{P \cdot (M_w)_{avg}}{RT} = \frac{m}{V} = \rho_G \text{ (gas density)}$$

NOTE $\boxed{(M_w)_{avg} = \sum_{i=1}^{n} y_i M_{w_i}} \Rightarrow (M_w)'_{avg} = (0.9 \times 28.8) + (0.1 \times 64)$
$= 32.3 g$

~~STEP 2~~ $\rho_G = \frac{101325 \times 32.3}{R(30+273)} = 1.298 \text{ kg/m}^3$

$\rho_G = 1.298 \text{ kg/m}^3$
~~$\rho_L = 1000 \text{ kg/m}^3$~~

GPDC - Generalized Pressure drop correlation.

STEP 2: Fluid Properties:
~~STEP 2~~: Liquid viscosity $\mu_L = 0.81$ cP.
Surface tension 70 dyne/cm.
Liquid density $\rho_L = 1000$ kg/m³.

STEP 3: Flooding Line.

→ For absorption, take bottom L_o & G_i.
→ For stripping, take upper L_i & G_o

- This is Absorption, $L' = L_o$, $G' = G_i$

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

$$\Rightarrow \left(\frac{37525}{1500}\right)\left(\frac{1.298}{1000}\right)^{0.5} = 0.9 \quad \text{--- (i)}$$

- For Raschig Rings, Berl Saddles } 1st Generation, use Fig 5.33 Pg 245 (GPDC).

- For Pall Ring } 2nd generation, use Fig 5.34 Pg. 246. (GPDC)

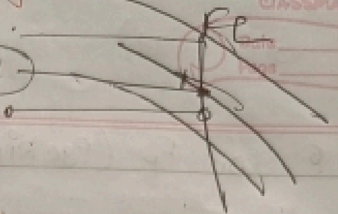
For 1½ Raschig Rings, use Fig. 5.33, & (i) as x-axis.

draw a vertical line till the point where it intersects the flooding line, ~~find~~ mark the value at y-axis.

here, for $x = 0.9$
$y_F = 0.025$

use 70% property to for stability maintenance

$y = y_F \times 70\% = 0.025 \times 0.7$



$$\boxed{y = 0.0175}$$

Now, draw a horizontal line from $y = 0.0175$ where it intersects '$x = 0.9$' line

* To select the correct or most accurate curve:

Use $\longrightarrow$ for verification

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

only value of f_l ; F_p from table

F_p: Packing ~~Efficiency~~ Factor ; $(\Delta P/L)_{fl} \Rightarrow$ value of different curve & choose the closest curve

OR

Choose the curve closest to that point on the graph

For $y = 0.0175$ & $x = 0.9$
closest curve $= 0.5$
& so, now, for $x = 0.9$ draw a straight line till curve 0.5 $(=\Delta P/L)$

and then find the corresponding y-coordinate value at for $x = 0.9$ & curve $(\Delta P/L) = 0.5$

$y' = 0.016$

$$y' = \frac{(G')^2 F_p (\rho_w/\rho_l)\, \mu_L^{0.2}}{\rho_G \rho_l g_c}$$

G' → lb/ft² hr ; μ_L → 0.81 cp ; g_c → 4.18×10^8 (ft/hr²) or 9.81 m/s² ; $\rho_G \rho_l$ → lb/ft³

ρ_w = density of water
ρ_l = density of liquid
ρ_G = density of gas

$F_p \rightarrow$ Table 5.9
Pg. 246

$\rho_w/\rho_l = 1$ $\quad \mu_L = 0.81\,cp$ $\quad F_p = 94.5\ ft^{-1}$
$g_c = 9.81\ m/s^2$

* For F_P (Packing Factor):

Raschig Ring $1\frac{1}{2}$ inch

Table 5.4, Page 247, find F_P

OR if not found use:
Treybal, Table 6.3, Pg 210: (i) find the desired Nominal size (packing)
(ii) find C_f (Packing factor)

$F_p = C_f = 95$ (from Treybal)

STEP 4: DIAMETER (D)

$$y' = \frac{(G')^2 F_P (\rho_w/\rho_L)\mu_L^{0.2}}{\rho_G \rho_L g_c}$$

conversion factor

$\frac{kg}{h} \cdot \frac{kg}{h \cdot m^2}$

at $G' = 607.6\ lb/ft^2 \cdot h$ = ~~0.4536 kg/m^2.h~~

in $G = 1500\ kg/h = 1500/0.4536 = 3306.87\ lb/h$

$$\text{Area} = \frac{G}{G'} \Rightarrow \frac{3306.87}{607.6} \Rightarrow 5.44\ ft^2$$

$$\text{Area} = \frac{\pi D^2}{4} = 5.44\ ft^2 \Rightarrow \boxed{D = 2.63\ ft}$$

STEP 5: Packed Bed Height

$$h_T = \int_{y_2}^{y_1} \frac{G'dy}{k_y\bar{a}(1-y)(y-y_i)}$$