CE 407 11/7/17

PACKED TOWERS, CONTINUED

WE HAVE SEEN HOW TO CALCULATE TOWER HEIGHT, Z_T
WHEN WE HAVE GAS FILM TRANSFER HEIGHT, H_y
AND LIQUID FILM TRANSFER HEIGHT, H_x
or MASS TRANSFER COEFFICIENTS, $k_x a$ and $k_y a$

IN GENERAL THESE WILL NOT BE AVAILABLE!
WHAT DO WE DO?

- FIRST PRINCIPLE CALCULATIONS WOULD BE EXTREMELY COMPLICATED

- EXPERIMENTAL MEASUREMENTS OF TRANSFER RATES WOULD NEED TO BE DONE FOR EACH SYSTEM OVER A HUGE NUMBER OF CONDITIONS

☆ CORRELATIONS ☆

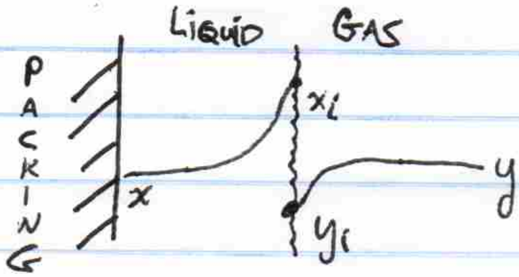
Gas Film $H_y = \frac{V/S}{k_y a}$ $N_y = \int \frac{dy}{y - y_i}$

Liquid Film $H_x = \frac{L/S}{k_x a}$ $N_x = \int \frac{dx}{x_i - x}$

Overall Gas $H_{Oy} = \frac{V/S}{K_y a}$ $N_{Oy} = \int \frac{dy}{y - y^*}$

Overall Liquid $H_{Ox} = \frac{L/S}{K_x a}$ $N_{Ox} = \int \frac{dx}{x^* - x}$

EXPERIMENTAL MEASUREMENTS



VARIABLES: Packing Type
GAS FLOW
LIQUID FLOW
CONCENTRATIONS

Any measurement will include both liquid $k_x a$ and gas $k_y a$, BUT WE WISH TO SEPARATE THE TWO

SPECIAL CASES WHERE RESISTANCE IN ONE PHASE RULES

- Desorption of O_2 or CO_2 from WATER
  LOW SOLUBILITY MAKES GAS FILM RESISTANCE NEGLIGIBLE SO $H_{Ox} \approx H_x$
  measured ↗ ↖ DESIRED

- ABSORPTION OF NH_3 IN WATER
  LIQUID FILM RESISTANCE LOW COMPARED TO OVERALL RESISTANCE H_y can be determined from H_{Oy}

CASES LIKE THIS ARE THE BASELINE MEASUREMENTS TO BUILD OFF OF FOR USING CORRELATIONS.

THERE IS A BODY of EXPERIMENTAL DATA WHICH CORRECTS FOR FLOWS, VISCOSITY, Diffusivity, density, packing type

LIQUID FILM

$$H_x \propto \left(\frac{G_x}{\mu}\right)^n \left(\frac{\mu}{\rho D_v}\right)^{0.5} \qquad n = 0.3 \text{ typical}$$

$$\propto \left(\frac{G_x}{\mu}\right)^{0.3} \left(S_c\right)^{0.5}$$

USE w/WATER SYSTEMS
BE CAUTIOS w/OTHER LIQUIDS

OBTAINED FROM CORRELATION of DATA

GAS FILM

$$H_y \propto G_y^{0.3} G_x^{-0.4} S_c^{1/2}$$

Typical exponents for G_y, G_x

Note: G_y does not appear in Liquid Film correlation because GAS FLOW RATES ARE DESIGNED TO AVOID FLOODING OF TOWER AND TEND TO BE SET AT A PARTICULAR RANGE FOR A GIVEN TOWER

PACKING TYPE

TABLE 18.1 HAS DATA on VARIOUS PACKINGS

PACKING FACTOR f_p FOR VARIOUS PACKINGS

$$H_x \propto \frac{1}{f_p} \quad \text{and} \quad H_y \propto \frac{1}{f_p}$$

INDICATIVE OF SURFACE AREA AND WETTING CHARACTERISTICS of the PACKING

LET'S PUT THIS ALL TOGETHER...

LIQUID FILM O_2 in WATER AT 25 C

DATA MEASURED with 1 ½ RASCHIG RING, $f_p = 1$

For $G_x = 1500 \frac{lbm}{ft^2 \cdot hr}$, $H_{x_{O_2}} = 0.9$ ft

FIG. 18.21

For O_2 in H_2O at 25 C, $Sc = 381$

THE VALUE of H_x for our conditions will be PROPORTIONAL TO 0.9 ft by the RATIOS of G_x/μ and Sc to those USED TO MEASURE $H_x = 0.9$ ft, USING THE POWERS MENTIONED BEFORE

∴

$$H_x = 0.9\ ft \left[\frac{G_x/\mu}{1500/0.891}\right]^{0.3} \left[\frac{Sc}{381}\right]^{1/2} \frac{1}{f_p}$$

NOTE G_x and μ must be in same units as USED FOR BASE CASE

GAS FILM   Air-Ammonia-WATER SYSTEM

$G_y = 500 \frac{lbm}{ft^2 \cdot hr}$, $G_x = 1500 \frac{lbm}{ft^2 \cdot hr}$, $Sc = 0.66$ @ 25C

At the CONDITIONS ABOVE w/ 1½" RASCHIG RINGS ($f_p = 1$)

$H_y = 1.4$ ft (FIGURE 18.22)

∴

$$H_y = 1.4\ ft \left(\frac{G_y}{500}\right)^{0.3} \left(\frac{1500}{G_x}\right)^{0.4} \left(\frac{Sc}{0.66}\right)^{1/2} \frac{1}{f_p}$$

NOTE: G_y and G_x must be in same units as used for base.

OVERALL TRANSFER

$$H_{O_y} = H_y + \frac{m}{L/V} H_x$$

$$H_{O_x} = H_x + \frac{L/V}{m} H_y$$

NOTE: In the H_x and H_y CORRELATIONS IT IS RECOMMENDED TO USE $\bar{G}_x = \left(G_x\big|_{\text{top column}} + G_x\big|_{\text{bottom of column}} \right) \times \frac{1}{2}$

$$\bar{G}_y = \left(G_y\big|_{\text{top column}} + G_y\big|_{\text{bottom of column}} \right) \times \frac{1}{2}$$

Arithmetic Averages used to get Heights of Transfer units that are representative of entire tower.