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EXPERIMENTAL DETERMINATION OF MASS TRANSFER COEFFICIENTS IN A LABORATORY OF TRANSPORT PHENOMENA

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ABSTRACT

The mass transfer coefficients are a variable present in the mass transfer operations and they are part of many correlations. Most of these coefficients are calculated through correlations, others are obtained through experiments. This article presents a wet wall tower that has been used by the students of Chemical Engineering in the Laboratory of Transport Phenomena in the Faculty of Chemistry at the Universidad Nacional Autónoma de México ,UNAM to get some mass transfer coefficients.

KEYWORDS: *Mass transfer coefficients, Wet wall tower, Transport Phenomena.*

INTRODUCTION

The mass transfer coefficients are a very important variable in the mass transfer operations , since they are inside of many correlations implicitly or explicitly. Therefore knowing its value is essential and when this is not the case they must be obtained experimentally.

THEORETICAL FOUNDATIONS

Coefficients of mass transfer from the wall of a pipe to a fluid in motion can be studied at some wet walls towers. The main reason for the use of this type of equipment is that the area of contact between phases, can be measured with precision. Generally in this type of equipment, the transfer of a substance like a liquid to air is measured. A frequent case is that of the transfer of water from the liquid phase to the gas phase. The amount of water transferred can be measured by the humidity and as since this is a function of the partial pressure of water in air, the transfer equation is given by:

$$Na = kg\ A(\Delta\tilde{p})_{lm} \quad (1)$$

In where Na = flow mass of water in kg mol/h

Kg = individual coefficient of mass transfer from the gas side in $\frac{kg\ mol\ water}{atm\ h\ m^2}$

A = mass transfer surface, m^2 surface.

$(\Delta\tilde{p})_{lm}$= average logarithmic from the force driving in the ends of the column, atm.

$$(\Delta\tilde{p})_{lm} = \frac{(p_1^{water} - p_i^{water}) - (p_2^{water} - p_1^{water})}{ln\frac{p_1^{water} - p_i^{water}}{p_2^{water} - p_i^{water}}} \quad (2)$$

p_1^{water}= partial pressure of the water in the air at the point 1, in atm.

p_i^{water}= partial pressure of the water at the interface in the point i, in atm.

Also:

$$Na = Ca\frac{(Y_2-Y_1)}{A\,V_{H1}\times PM_{water}} \quad (3)$$

Where Ca = volumetric flow of incoming air in m3/h

V_{H1}= input wet volume of air . $\frac{m^3}{kg\ of\ dry\ air}$

And Y_2= outgoing air humidity$\frac{kg\ of\ water}{kg\ of\ dry\ air}$

It should be noted that the mass transfer area is not that of the inner wall of the column, but the interfacial area, this area is calculated by subtracting the thickness of the film of liquid falling from the inside diameter of the column.

From a series of deductions, Bird[1] shows that:

$$La = \frac{\rho\ g\ W\ \delta^3}{3\mu} \quad (4)$$

Where = La volumetric flow of water

ρ = density of the liquid at the average temperature.

g= gravitational constant.

W = the column perimeter = πDI

μ = viscosity; δ film thickness

Therefore the interfacial area is represented by:

A =(DI-2δ) πL (5); L = length of the column; DI = inner diameter.

If the air rate is varied in the experiments, you will see the variation of the coefficient with the rate, if on the other hand the diameter of the column is varied you can also see the effect of this on the mass transfer coefficient.

Gilliland and Sherwood used a column of wet walls to study the vaporization of nine liquid , obtaining the following correlation.

$$\frac{kc\ D}{D_{AB}}\frac{(\Delta P_{air})_{lm}}{P} = 0.023Re^{0.83}Sc^{0.44} \quad (6)$$

Where:

D = diameter; D_{AB} = diffusion coefficient; Re Reynolds number; Sc = Schmidt number .

P = atmospheric pressure. $(\Delta P_{air})_{lm}$ = = logarithmic mean air pressures.

DESCRIPTION OF THE USED EQUIPMENT

The equipment consist of two wet wall towers of 3.03 and 2.04 cm of internal diameter , with a effective length of 101.6 cm. They are built in glass Pyrex and bronze and have two cameras of liquid, one in the upper part to have an uniform spill of liquid and one at the bottom to collect the liquid. The equipment has a tank and a pump of 0.01 CP. The air is supplied by a compressor and is controlled by a pressure control valve. The column also provided with thermocouples installed in different parts of the tower. At the entrance and exit of the air there are a few areas of calm in order to obtain a uniform air flow.

Fig.1.-Wet wall tower

EXPERIMENTAL WORK

To enable the students to obtain experimentally the mass transfer coefficients they must [2]:

1.-Select the rate of air.

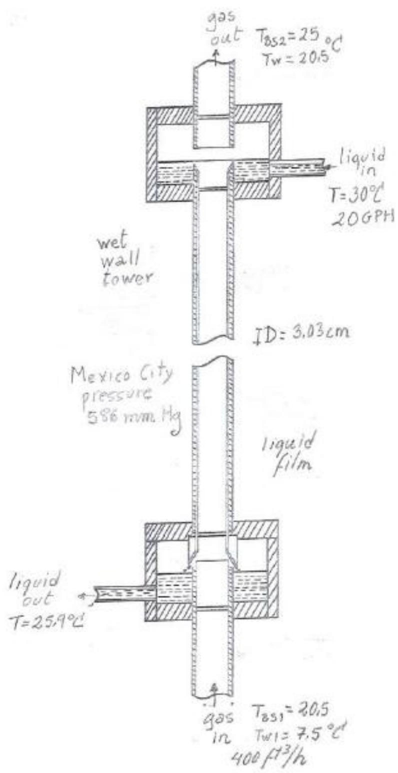
2.- Turn on the water pump

3.- Regulate the flow of liquid until the falling film is uniform.

4.-Take the wet bulb and dry bulb temperatures of the entering and departing air .

5.- Take the time of operation.

EXPERIMENTAL DATA AND CALCULATIONS



In an experiment the student obtained the following results:

From the data the students calculated the humidity of the air using a 586 mm Hg psicrometric chart.

Y_1= 0.002 , Y_2=0.019 kg water vapor/kg dry air.

With the humidity they could calculate de partial pressure of water in the air mixtures. Because

$$Y = \frac{\tilde{p}}{P-\tilde{p}} \times \frac{18}{29}$$

Then $\tilde{p}_1 = 1.88\, mm\, Hg_1$; $\tilde{p}_2 = 17.405\, mm\, Hg$

Water in $20 \frac{gal}{h} \times 3.785 \frac{L}{gal} \times \frac{m^3}{100\, L} = 0.0757 \frac{m^3}{h} = 2.1 \times 10^{-5} \frac{m^3}{s}$

Film wide

W=$\pi\, Di = \pi(0.0303) = 0.09519\, m$

Average temperature of water = 27.95 °C ; $\rho = 996 \frac{kg}{m^3}$;μ=0.86 cps.

From equation (4)

$$2.1 \times 10^{-5} = \frac{996 \times 9.81 \times 0.09519 \times \delta^3}{3 \times 0.836 \times 10^{-3}}$$

$\delta = 3.87X10^{-4}$ m So De=0.0303-2($3.87X10^{-4}$)=0.0295 m

Mass transfer area A=π De L = 3.14 X 0.0295 X 1.01016 = 0.09411 m^2

Air in

$$400 \frac{ft^3}{h} \frac{(0.305)^3 m^3}{ft^3} = 11.35 \frac{m^3}{h}$$

Wet volume of air

$$V_{H1} = \left(\frac{1}{29} + \frac{0.002}{18}\right) \frac{0.02(20.5+273)}{\frac{586}{760}} = 1.079 \frac{m^3}{kg\; dry\; air}$$

Dry air in:

G=$11.35 \frac{m^3}{h} \times \frac{kg\; dry\; air}{1.079\; m^3} = 10.518 \frac{kg}{h}$

Mass flux from equation (3)

$\widetilde{N_A} = \frac{10.518\,(0.019-0.002)}{0.09411 \times 18} = 0.1055 \frac{kg\; mol\; of\; water}{h\; m^2}$

Calculation of the experimental coefficient

$\widetilde{p_i}$= 1.888 mm Hg ; $\widetilde{p_2} = 17.405\, mm\, Hg$; $\widetilde{p_i}$=28.349 mm Hg (water at 28 °C) From equation (2)

$$\Delta P_{ln} = 17.41\, mm\, Hg = 0.0229\, atm$$

Therefore:

$Na = kg\; A(\Delta\tilde{p})_{lm}$=0.1055=kg (0.0229)

The coefficient of mass transfer is : kg=4.6 $\frac{kg\; mol}{h \times m^2 \times atm}$

From Gilliland $\frac{kc\ D}{D_{AB}}\frac{(\Delta P_{air})_{lm}}{P} = 0.023Re^{0.83}Sc^{0.44}$ (6)

Average temperature of air T= 22.75 ;ρ=0.922 $\frac{kg}{m^3}$; μ =0.018 Cps ; De =0.0295

Transversal flow area of air

A=π/4$(0.0295)^2$=6.83 X10^{-4} m^2

Therefore average velocity of gas u $=11.35\frac{m^3}{h}\times\frac{1\ h}{3600\ s}\times\frac{1}{6.83\times10^{-4}m^2} = 4.61\frac{m}{s}$

Reynolds number $Re = \frac{0.0295\times4.61\times0.992}{0.018\times10^{-3}}$=6975

Diffusivity of water y air =0.26x10^{-4} m^2/s

Schmidt number =$\frac{0.018\times10^{-3}}{0.922\times0.26\times10^{-4}} = 0.75$

Therefore $\frac{kc\ D}{D_{AB}} = 31.38$; kc=0.02766$\frac{m}{s}$=99.58$\frac{m}{h} = 99.58\frac{kg\ mol}{\frac{kgmol}{m^3}h\ m^2}$

But $kg = \frac{kc}{RT} = \frac{99.58}{0.082(296)} = 4.1\frac{kg\ mol}{h\ m^2\ atm}$

CONCLUSIONS

The wet wall tower equipment used in the laboratory of Transport Phenomena is simple and easy to operate. The Experimental results obtained by the students area consistent with those that can be obtained through correlations.

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